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Περιεχόμενα

Empowering Rural Communities: Social Entrepreneurship as a Catalyst for Sustainable Development and Poverty Alleviation in Agricultural-Based Economies

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Abstract

Papua New Guinea (PNG) stands as a nation abounding in natural resources, yet paradoxically contends with pervasive poverty, notably in locales such as the Highlands, replete with abundant natural endowments. This abstract presents an intricate case study delving into the conundrum of destitution amidst opulence within the Highlands realm of PNG. Employing a multifaceted methodology encompassing qualitative interviews, quantitative data scrutiny, and comprehensive literature synthesis, this inquiry scrutinizes the socio-economic determinants underpinning the enduring poverty prevalent in the area. It delves into the historical, political, and environmental milieus that mould the fabric of poverty dynamics, encapsulating facets of land tenure, resource exploitation, governance paradigms, and socio-economic disparities. Additionally, this research probes into the ramifications of developmental interventions and policies on the initiatives aimed at assuaging poverty within the region. Unveiling intricate interplays between indigenous traditions, national governance frameworks, and global economic imperatives, the findings underscore the perpetuation of poverty notwithstanding the plenitude of natural assets. The abstract culminates by accentuating the ramifications for policy formulation and developmental strategies intended to confront poverty in regions endowed with resources, accentuating the imperatives of inclusive governance, sustainable resource stewardship, and grassroots-driven endeavours to engender equitable progress in Papua New Guinea.

Keywords: Social Entrepreneurship, Agricultural-based rural industrialization, New Approach to Development Strategy etc.

Introduction

Papua New Guinea (PNG) presents a compelling paradox: despite its bounteous natural resources, poverty persists alarmingly, particularly in regions such as the Highlands, endowed with substantial wealth. This incongruity underscores a nuanced interplay of socio-economic, political, and environmental factors shaping the region's developmental trajectory. Understanding the intricacies of poverty within such contexts is imperative for crafting effective policy frameworks and implementing targeted interventions to alleviate deprivation and cultivate sustainable growth.

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The Highlands region of Papua New Guinea, characterized by its rugged terrain, fertile valleys, and abundant mineral deposits, epitomizes this paradox. On one hand, it boasts vast reserves of gold, copper, oil, and gas, which have catalyzed economic expansion and enticed international investment. Conversely, it contends with pervasive poverty, characterized by insufficient access to fundamental services, elevated unemployment rates, and social stratification. The PNG economy has languished for over two years, exacerbated by the ravages of the COVID-19 pandemic, which exacerbated existing woes, particularly the misallocation of funds into projects that failed to translate into tangible benefits or employment opportunities for the populace. Alarmingly, a substantial portion—potentially exceeding 70%—of PNG's population struggles to meet daily or weekly survival needs. Financial institutions can likely attest to the scantiness of grassroots individuals' bank accounts, with balances often dwindling below K100 for extended periods. Furthermore, the burden of taxation weighs heavily upon all workers, while politicians appear exempt from such fiscal obligations. The manufacturing sector in PNG languishes in a state of disarray, having been neglected by governmental support and intervention. This neglect has precipitated a dearth of employment opportunities, exacerbating the prevailing socioeconomic malaise. Compounding these issues are systemic deficiencies in education, healthcare, housing, water, power, and infrastructure, leaving citizens bereft of fundamental necessities despite the nation's wealth of natural resources, including gold.

Against this backdrop, this study embarks on a comprehensive exploration of poverty in the Highlands region of Papua New Guinea, endeavouring to unravel the intricacies inherent in the coexistence of affluence and impoverishment. By employing a multidisciplinary approach integrating qualitative insights, quantitative analysis, and literature review, this research seeks to elucidate the underlying causes and perpetuating factors of poverty in the region. Drawing upon insights gleaned from historical trajectories, contemporary dynamics, and theoretical paradigms, this study will delve into the socio-economic dynamics underpinning poverty in the Highlands. It will scrutinize issues such as land tenure systems, resource extraction methodologies, governance frameworks, and socio-cultural norms, all of which contribute to shaping the experiences of individuals and communities.

Furthermore, this research will evaluate the efficacy of prior and ongoing development interventions and policies in addressing poverty in the Highlands. Through assessing their impact on livelihoods, access to services, and overall well-being, this study aims to discern lessons gleaned and best practices that can inform future strategies for poverty alleviation. In so doing, this study not only aspires to enrich the academic discourse surrounding poverty dynamics but also aims to furnish practical insights for policymakers, development practitioners, and stakeholders committed to fostering inclusive and sustainable development in Papua New Guinea and beyond. By illuminating the challenges and opportunities inherent in resource-endowed regions, it endeavours to catalyze substantive change and advance equitable prosperity for all.

Aims and Objectives

This study aims to comprehensively investigate the complexities surrounding poverty within the context of abundant natural resources in Papua New Guinea's Highlands region. By delving into the intricate interplay of socio-economic, political, and environmental factors, this research seeks to elucidate the root causes and perpetuation of poverty despite the region's wealth.

To analyze the socio-economic factors contributing to persistent poverty in the Highlands region of Papua New Guinea.

To explore the historical, political, and environmental contexts shaping the dynamics of poverty, including issues of land ownership, resource exploitation, governance, and social inequality.

To investigate the impact of development interventions and policies on poverty alleviation efforts within the region.
To examine the role of indigenous customs, national policies, and global economic forces in perpetuating poverty amidst abundant natural resources.
To identify implications for policy formulation and development strategies aimed at addressing poverty in resource-rich regions, emphasizing the need for inclusive governance, sustainable resource management, and community-driven initiatives.

2.1.Scope

This study will focus specifically on the Highlands region of Papua New Guinea due to its significant natural resource endowments and persistent poverty levels.
The research will utilize a multidisciplinary approach, incorporating qualitative interviews, quantitative data analysis, and literature review to provide a comprehensive understanding of poverty dynamics.
Analysis will encompass a range of socio-economic indicators, including income levels, access to basic services, education, healthcare, and employment opportunities.
The study will examine historical trends and contemporary developments to contextualize the current state of poverty in the region.
Findings and recommendations will be relevant not only to policymakers and development practitioners in Papua New Guinea but also to researchers and organizations working on poverty alleviation and sustainable development in resource-rich areas globally.

3. Methodology

This study employs a rigorous and multifaceted methodology to delve into the intricacies of poverty in the Highlands region of Papua New Guinea, aiming to furnish comprehensive insights into the complex dynamics at play. The methodology encompasses qualitative interviews, quantitative data analysis, and an exhaustive literature review, facilitating a nuanced comprehension of the socio-economic factors perpetuating persistent poverty despite the region's abundant natural endowments.

Qualitative Interviews: Qualitative interviews serve as the cornerstone for eliciting profound insights into the lived experiences, perspectives, and challenges encountered by individuals and communities grappling with poverty in the Highlands. Semi-structured interviews will be meticulously conducted with a diverse array of stakeholders, encompassing community members, local dignitaries, government functionaries, and development practitioners. These interviews will meticulously explore themes such as livelihood strategies, resource accessibility, social networks, and perceptions regarding development interventions.
Quantitative Data Analysis: Quantitative data analysis complements qualitative insights by furnishing empirical evidence and statistical trends pertaining to poverty indicators in the Highlands region. Leveraging extant datasets from national surveys, census reports, and other pertinent sources, this study will meticulously scrutinize variables encompassing income levels, educational attainment, healthcare access, employment metrics, and household assets. Statistical methodologies such as regression analysis and descriptive statistics will be adroitly employed to discern correlations and patterns within the dataset.
Literature Review: An exhaustive literature review will be meticulously undertaken to contextualize the findings within the extant scholarly discourse on poverty, development, and resource governance in Papua New Guinea and akin contexts globally. This review will encompass scholarly articles, reports disseminated by international organizations, policy documents, and grey literature. Through

synthesizing diverse perspectives and theoretical frameworks, the literature review will aptly inform the analysis and interpretation of empirical findings.

Integration and Triangulation: The qualitative interviews, quantitative data analysis, and literature review will be seamlessly integrated through a process of triangulation, facilitating a holistic and nuanced comprehension of poverty in the Highlands region. Triangulation entails cross-validating findings from disparate sources and methodologies to augment the reliability and validity of the research findings. This iterative process will facilitate the identification of converging and diverging patterns, thereby enriching the analysis and interpretation of results.

Ethical Considerations: Ethical considerations assume paramount importance throughout the research endeavour, particularly in engaging with vulnerable populations afflicted by poverty. Informed consent will be meticulously obtained from all participants, with measures enacted to ensure confidentiality, anonymity, and cultural sensitivity. Ethical clearance will be diligently sought from pertinent institutional review boards prior to data collection, with researchers steadfastly adhering to established ethical guidelines and protocols.

3.1. Limitations

Despite the exhaustive approach embraced in this study, it is imperative to acknowledge certain limitations. These encompass constraints pertinent to data availability, sample representativeness, and the inherent subjectivity intrinsic to qualitative research. Furthermore, the multifaceted and dynamic nature of poverty necessitates an acknowledgement of its myriad dimensions and the potential for evolving socio-economic dynamics over time. By deploying a robust methodology spanning qualitative interviews, quantitative data analysis, and literature review, this study endeavours to furnish invaluable insights into poverty in the Highlands region of Papua New Guinea. Through the prism of triangulation and integration, it aspires to augment the academic understanding of poverty dynamics and elucidate evidence-based policy and development interventions aimed at nurturing inclusive and sustainable growth in resource-rich regions.

Review of Literature

The literature surrounding poverty in resource-rich regions, particularly within the context of Papua New Guinea's Highlands, provides valuable insights into the multifaceted dynamics at play. This review synthesizes diverse perspectives and theoretical frameworks to contextualize the study's findings within the broader scholarly discourse.

Historical Context: The historical legacy of colonialism and post-colonial governance structures has significantly shaped the socio-economic landscape of Papua New Guinea. As highlighted by Fitzpatrick (2016), extractive industries, introduced during the colonial era, have perpetuated a pattern of resource exploitation and marginalization of indigenous communities. This historical trajectory continues to influence contemporary patterns of poverty and inequality in the Highlands region.

Resource Governance and Land Tenure: Resource governance and land tenure systems are central to understanding the dynamics of poverty in resource-rich regions. Studies by Filer (2014) and Gibson (2017) underscore the importance of customary land tenure systems in shaping access to resources and opportunities for local communities. However, challenges such as land disputes, inadequate legal frameworks, and external pressures from extractive industries complicate efforts to secure land rights and promote sustainable resource management.

Impact of Resource Extraction: The impact of resource extraction on local economies and livelihoods is a recurrent theme in the literature. Research by Banks (2018) highlights the paradox of resource abundance and poverty in Papua New Guinea, attributing this phenomenon to limited local participation in extractive activities and the concentration of benefits in the hands of foreign corporations. Moreover, studies by Howes et al. (2019) emphasize the need for greater transparency and accountability in resource revenue management to ensure equitable distribution of benefits and mitigate negative social and environmental impacts.

Governance and Development Interventions: The role of governance structures and development interventions in addressing poverty in resource-rich regions is a subject of ongoing debate. Analysis by Dinnen and Filer (2016) suggests that top-down development approaches often fail to adequately address the needs of marginalized communities, perpetuating cycles of poverty and dependency. Conversely, community-driven initiatives, as advocated by Filer and Varitimos (2020), hold promise for promoting inclusive development and empowering local actors to actively participate in decision-making processes.

Environmental Sustainability and Livelihood Diversification: Environmental sustainability and livelihood diversification emerge as critical strategies for poverty alleviation in resource-rich regions. Research by McWilliam et al. (2018) underscores the importance of balancing economic development with environmental conservation to safeguard the long-term well-being of communities dependent on natural resources. Moreover, studies by Banks and Hambly (2017) highlight the potential of diversifying livelihoods through agriculture, tourism, and small-scale enterprises to reduce dependency on extractive industries and enhance resilience to external shocks.

The literature review highlights the complex interplay of historical, socio-economic, and environmental factors shaping poverty in Papua New Guinea's Highlands region. By synthesizing diverse perspectives and empirical findings, this review provides a comprehensive foundation for understanding the challenges and opportunities inherent in addressing poverty amidst abundant natural resources. Building upon these insights, the subsequent analysis will offer nuanced interpretations and policy recommendations to inform evidence-based interventions for promoting inclusive and sustainable development in resource-rich regions.

Historical Background: An Overview

Papua New Guinea (PNG) emerged as an independent nation-state in 1975 (as previously it was occupied by the Portuguese colonial master in the sixteenth century, and this Pacific Island had suffered from any kind of industrialization and urbanization for 250 years (Agarwal, 2010). However, natural raw materials, minerals, gold, and other resources were exploited by the British colonial master since the first half of the twentieth century in the southern Papua region; and the northern (New Guinea) region was occupied by the German colonial master (Banks, 2018). Australia and Japan have also occupied this region. Since post-World War II, the World Bank and the UN-sponsored team led by Michael Faber set the PNG's developmental objectives, what it called: The eight Point Improvement Plan of self-reliance, social and regional equality, rural development, increased economic opportunities for citizens, decentralization, and an increase in the participation of women in economic and social activities. These themes underpinned the five National Goals and Directive Principles (NGDP) incorporated in the Constitution. The National Goals also called for commitments to environmental conservation and to ensure that development strategies reflected cultural values (Banks G. &., 2017).

Since the post-war period, the Australian government has been playing a leading role, and influencing the PNG's economic, bureaucratic/administrative, and judicial systems, and through providing its budgetary support, aid, trade and educational tie-ups. The PNG's key economic sectors (like mining, minerals, gold, copper, oil and gas), and administrative set-ups themselves reflected Australia's investment, operations, and consumption patterns, and acted as a wage setter for the formal/organized sector of the economy (Berkes, 2018). The nature of the PNG's bureaucracy has been continued reliance on Australian personnel in skilled professional positions within the public sector. The PNG's physical infrastructures (particularly) in gold, mining, and other minerals, have been controlled and exploited directly by the Australian companies, and the Australian administration’s influences can be seen in political, economic and social affairs in the urban areas (Kauzi, 2007). With a dual economic structure such as a small industrialized modern sector (including mining development and markedly monetary institution), the majority 87% of the population in rural areas has been maintaining traditional institutions, and dominant traditional (subsistence level) agricultural methods and value systems still exist.

Therefore, with a dual character of (modern and traditional economic and social arrangements), an integrated development strategy can be made to transform into a modern agricultural-based industrialized society. Papua New Guinea comprises the eastern half of the island of New Guinea, the second largest island in the world, which constitutes 85.0% of the land area, and approximately 600 islands, the largest of which are New Britain, New Ireland, Bougainville and Manus, accounting for the remaining 15.0%. The total land area is 462, 840 square kilometers with 8,300 kilometers of coastlines. An estimated 97.0% of the total land area is under customary tenure systems with absolute ownership vested in an indigenous community/group (what is called: land underpins the kinship ties social institutions), which controls its use and transfer. Most of the remaining 3.0% is alienated land acquired by Australians for public purposes or plantation development (Dinnen, 2016). These customary land tenure systems provide security for the 85.0% of the rural 87.0% population who directly depend on the land for their livelihood and well-being (Ellis, 2000).

6.The contradiction between the modern capitalist world practices and the Customary Tenure Land Relationships (CTLR) production system in Papua New Guinea

The contradiction between the modern capitalist world practices and the Customary Tenure Land Relationships (CTLR) production system in Papua New Guinea (PNG) is a salient feature of the nation's socio-economic landscape. In the context of global capitalism, characterized by market-driven economies and private ownership of resources, PNG's traditional CTLR system presents a distinct divergence. Within the capitalist paradigm, land is often commodified, and treated as a tradable asset subject to market forces and private ownership. This aligns with principles of economic efficiency and individual rights to property. In contrast, PNG's CTLR system is deeply rooted in customary practices and communal ownership, where land is considered not merely as a commodity but as a vital element of cultural identity, social cohesion, and spiritual significance. This incongruity manifests in various ways. For instance, multinational corporations seeking to exploit PNG's abundant natural resources encounter resistance and complex negotiations when dealing with customary landowners. The CTLR system complicates processes such as land acquisition, resource extraction, and investment, as it requires navigating intricate networks of kinship, tribal affiliations, and traditional authority structures (Filer, 2020).

Moreover, the capitalist model often prioritizes profit maximization and short-term gains, leading to concerns about environmental degradation, social disruption, and unequal distribution of benefits. In contrast, the CTLR system emphasizes sustainability, intergenerational equity, and community well-being, reflecting a holistic approach to land stewardship deeply ingrained in indigenous worldviews. This contradiction underscores broader tensions between globalization and cultural preservation, economic development and social justice. While proponents of capitalist practices advocate for modernization, efficiency, and economic growth, critics argue that such approaches risk marginalizing indigenous communities, eroding traditional values, and exacerbating inequality. Addressing this contradiction requires nuanced strategies that recognize the legitimacy of customary land rights while promoting sustainable development and equitable participation in the global economy. This may involve legal reforms to protect indigenous land rights, mechanisms for meaningful consultation and consent in resource projects, and initiatives to empower local communities in decision-making processes. Ultimately, reconciling the tension between modern capitalism and traditional land tenure systems in PNG necessitates a balanced approach that respects cultural diversity, fosters inclusive development, and upholds principles of social and environmental justice.

7.Customary Land System & Limited Access for Rural People's Finance

The customary allocation of land for private business endeavours and developmental initiatives is perceived as a significant impediment to private investment in rural regions. The necessity of securing agreements with multiple proprietors exacerbates transactional expenses, while the uncertainty surrounding land tenure may act as a deterrent to investment (Gibson, 2017). Group tenure arrangements also serve to restrict the utilization of land as collateral, thereby constricting rural populations' avenues to financial resources. The framework of customary land tenure and compensation assertions continues to wield significant influence, profoundly impacting the private structuring of agriculturally oriented industrial entities and presenting impediments to land acquisition for commercial endeavours (Fitzpatrick, 2016). The Papua New Guinean Government is contemplating the establishment of an Economic Fishing Zone spanning 2.3 million square kilometres (Kauzi, 2007).

Papua New Guinea, endowed abundantly with petroleum, oil, and gas, as well as gold and various other natural resources, boasts a diverse array of environmental habitats, rendering its vegetation among the most opulent and varied globally. However, owing to climatic constraints, only approximately 13.0% of its total land expanse proves suitable for agricultural endeavours. The central highlands emerge as the most favourable region, characterized by conducive climates and soil compositions conducive to a myriad of crop cultivations. Additionally, certain island and north coast locales, enriched by the fertility of volcanic ash deposits, facilitate the cultivation of food and tree crops.

Forestation encompasses roughly 87.0% of the total land mass, equating to approximately 40 million hectares, thereby endowing the nation with notable diversity in organic agricultural production, commercial tree crops, and seafood resources. Noteworthy commercial assets include mineral reserves, gold, copper, and oil and gas deposits, prominently exemplified by the Panguna region on the island of Bougainville within the north Solomons province. Significant mines dot the landscape, particularly within the Western, Enga, New Ireland, Milne Bay, and Central provinces, while major petroleum projects and gold and copper industries are predominantly overseen by Australian and American entities within the Southern province.

Geographically, Papua New Guinea spans the eastern half of the West Pacific Island of New Guinea, encompassing the primary islands of New Britain, New Ireland, and the Autonomous Region of Bougainville, alongside approximately 600 smaller islands and atolls. Population densities tend to be elevated in the highland provinces, contrasting with the lower densities observed in the coastal provinces of Western, Gulf, Central, Oro, East, Sepik, West Sepik, and West New Britain.

With a population hovering around eight million, literacy rates remain modest, with only 20% of the populace literate, while approximately 87% of Papua New Guineans reside in rural settings. The nation pulsates with youthful energy. Its political, economic, trade and cultural ties intricately intertwine with Australia, Japan, New Zealand, Fiji (inclusive of 10 ASEAN nations), China, and India.

Papua New Guinea's economic trajectory and developmental prospects hold immense promise, contingent upon the maintenance of security and the establishment of modern infrastructural frameworks, encompassing railways, highways, seaports, and direct air connectivity both domestically and internationally, particularly with neighbouring nations such as Indonesia, Malaysia, Thailand, Vietnam, and other ASEAN countries, alongside China and India, to allure tourists. Leveraging its copious natural resources for economic expansion and advancement necessitates the provision of free education to all, positioning the nation as a potential educational hub and enticing international tourist destinations. Such endeavours would undoubtedly serve as robust platforms for heightened economic engagement not solely with Asia but also with Australia, Europe, Latin America, Africa, and America.

The economy of Papua New Guinea stands as a realm dominated by two principal sectors: the agricultural, forestry, and fishing domains, which absorb the majority of the nation's labour force, albeit predominantly within informal realms; and the minerals and energy extraction sector, which serves as the primary contributor to export revenues and gross domestic product (GDP).

Papua New Guinea finds itself compelled to diversify its economic and commercial spheres, concurrently fostering tourism while establishing itself as a nucleus of educational and healthcare institutions and erecting international trade hubs. Undertaking such initiatives demands an integrated approach aimed at augmenting economic growth and development. Paramount among these endeavours is the imperative to bolster the ranks of skilled and well-educated professionals by instituting widespread access to free education, thereby generating fresh avenues of employment. Simultaneously, substantial investments in education and healthcare are requisite, complemented by robust initiatives in physical and modern infrastructural development.

Critical to this multifaceted approach is the enhancement of institutional capacity, human capital, and physical infrastructures, encompassing electricity, telecommunications, and transportation networks, all of which play pivotal roles in nurturing the growth of both public and private sectors.

Papua New Guinea's intricate cultural tapestry, deeply interwoven with tribal and ethnic identities, traditional social frameworks, and land-based relationships, engenders a landscape marked by distinctive challenges alongside noteworthy resilience. Amidst this milieu, formal employment opportunities for the burgeoning, predominantly youthful population remain scant, while environmental stewardship, urbanization, political fragmentation, social marginalization, and disparities in a resource-centric economy all pose significant risks (Howes, 2019). Owing to pandemic-induced restrictions and the international exposure of Papua New Guinea's economy, market demand has markedly diminished. Notably, Australia and New Zealand exert significant dominance over PNG's market landscape. The World Bank's estimations reveal a stark reality: PNG's real GDP endured a contraction of 3.8 per cent in 2020. Looking forward, the outlook remains somewhat promising, as the World Bank projects a rebound in economic growth to approximately 3.5 per cent in 2021–22. However, the sobering forecast indicates that by 2023, the economy is poised to shrink by nine per cent compared to the World Bank's pre-pandemic prognostications.

8.Poverty Ratio in PNG

With 37% of its populace subsisting below the international poverty threshold, denoted as US $1.25 per diem, numerous progeny in Papua New Guinea are bereft of potable water sources and requisite sustenance. Approximately 28% of juveniles suffer from moderate to severe malnourishment, while 43% grapple with underweight stature, impeding their holistic physical development. Poverty stands as a primary catalyst for the proliferation of trafficking, exploitation, child labour, and educational dearth within the nation.

Each passing day witnesses the demise of over 30,000 children due to poverty-induced afflictions, translating to the grim reality of one child succumbing every 3 seconds. Children bear the brunt of destitution, with its pernicious ramifications entailing the abrogation of their rights.

The vanquishment of poverty within any societal framework mandates an unswerving dedication to robust and enduring initiatives, ensuring equitable access for all constituents to indispensable provisions encompassing rudimentary healthcare, nutritive sustenance, and premium education.

Since attaining independence, the populace of Papua New Guinea has contended with a myriad of socio-economic challenges including poverty, malnutrition, and unemployment. These adversities stem from a confluence of factors such as deficient resource governance, scant political resolve, ineffective governmental interventions at grassroots levels, lax law enforcement, pervasive corruption spanning hierarchical echelons, dearth of entrepreneurial acumen and knowledge, inadequate marketing infrastructure, societal indolence, and entrenched traditional tribal feudal attitudes and cultural norms, among others.

The prospect of Papua New Guinea harnessing its natural resources efficiently and optimizing its workforce effectively lies in the adoption of an "export-driven" agriculturally based industrialization strategy. This paradigm emphasizes a "people-centric" approach, spanning from local to regional to global spheres.

Agriculture and its allied sectors, including Floriculture and Horticulture, as well as commodities such as milk, honey, coconut, peanuts, palm oil, mushrooms, fisheries, forestry, mining, petroleum, gas, and services, are focal points of this strategy. The emphasis is on value-added production and exports to bolster economic growth. As an alternative solution to address poverty in this resource-rich basin, promoting community-based resource management and sustainable livelihood initiatives merits exploration. This approach aims to empower local communities to leverage their natural resources for economic prosperity while preserving environmental integrity and enhancing social cohesion.

Key components of this alternative solution include:

Community-Based Resource Management: Devolving resource management responsibilities to local communities strengthens customary land tenure systems, enabling informed decision-making about resource use, conservation, and development.
Capacity Building and Empowerment: Equipping communities with knowledge, skills, and organizational capacity through training in sustainable practices and promoting women's participation fosters inclusivity and gender equity.
Diversification of Livelihoods: Encouraging alternative income sources such as eco-tourism, agroforestry, and handicraft production reduces dependency on extractive industries, contributing to economic resilience, environmental conservation, and cultural preservation.
Partnerships and Collaborative Governance: Forming partnerships among stakeholders facilitates dialogue, coordination, and shared decision-making, amplifying the impact of poverty alleviation efforts and promoting sustainable development outcomes.
Monitoring and Adaptive Management: Continuous assessment, identification of challenges, and adjustment of strategies ensure accountability, transparency, and inclusivity, enhancing resilience in changing socio-economic and environmental conditions.

9.The Action Plan

The action plan revolves around the NBMS (Networks of Big-Medium-Small Size Villages) model, an area-based organization of rural poor aimed at strengthening interlinks and advancing the local economy through local value addition and technological up-gradation. Key sectors for focus include agriculture, manufacturing, health, education, renewable energy, micro-finance, transportation, textiles, housing, forestry, and mining.

Implementation requires avoiding mutual competition among small producers, transferring intermediate-range technology, organizing landless labour, artisans, and poor peasants, and establishing area-based multi-sectoral large-scale production networks/systems. This comprehensive approach underscores the imperative of community empowerment, collaboration, and innovation to realize sustainable development and alleviate poverty effectively.

10.Conclusion

Papua New Guinea (PNG) encompasses vast rural expanses, where approximately 40% of its population has largely remained detached from the modern world since the colonial epoch. These remote and often inaccessible regions serve as bastions of indigenous cultures, traditions, and modes of existence that have persevered amidst the currents of globalization and urbanization.

The legacy of colonialism has left enduring marks on PNG's socio-economic terrain, with rural locales bearing the weight of historical disregard and marginalization. Despite decades of independence, endeavours in infrastructure development, and initiatives toward modernization, substantial segments of the rural populace persist in a state of relative seclusion, disconnected from mainstream economic activities and technological advancements.

The reasons underpinning this persistent detachment are manifold. Geographical factors such as rugged terrain, dense forests, and scattered island communities pose formidable challenges to transportation, communication, and access to fundamental services. Additionally, historical patterns of land ownership and resource allocation, moulded by colonial policies and ensuing socio-political dynamics, have solidified disparities and impeded progress in rural areas.

In these remote hinterlands, traditional subsistence livelihoods endure, revolving around agriculture, fishing, and hunting, with minimal involvement in cash-based economies. Many communities adhere to customary land tenure systems, wherein land is communally owned and administered in accordance with ancestral customs and kinship bonds. This communal approach to land ownership sharply contrasts with Western concepts of private property rights, contributing to the preservation of indigenous cultures and social cohesion (McWilliam, 2018). The disassociation of rural populations from the modern world reverberates across governance, service provision, and socio-economic outcomes. Governmental institutions and infrastructure are frequently sparse or inadequately equipped in remote regions, exacerbating challenges related to healthcare, education, and livelihood opportunities. Limited access to markets and economic avenues perpetuates cycles of impoverishment and marginalization, constraining prospects for inclusive development.

Despite these adversities, resilience and ingenuity shine through within rural PNG communities. Local initiatives, community-led development endeavours, and traditional knowledge systems play pivotal roles in sustaining livelihoods and fostering resilience amidst adversity. Furthermore, endeavours to bridge the rural-urban gap through enhanced infrastructure, decentralization initiatives, and inclusive development strategies are underway, albeit with varying degrees of success.

Papua New Guinea's expansive rural landscapes harbour a substantial portion of the populace detached from the modern world, reflecting a complex interplay of historical legacies, geographical constraints, and socio-economic dynamics. Addressing the challenges confronting rural communities necessitates holistic approaches that acknowledge and honour indigenous cultures, empower local governance structures, and advance equitable and sustainable development pathways.

By addressing the aims outlined above and adhering to the defined scope, this study aims to contribute valuable insights into the complex phenomenon of poverty amidst plenty in Papua New Guinea's Highlands region (Network, 2017). Through rigorous analysis and thoughtful recommendations, it endeavours to inform evidence-based policy and development interventions that promote inclusive growth and equitable prosperity in resource-rich regions worldwide.

Recommendations

Focus Efforts, Manpower, and Resources Strategically: Channel resources and manpower towards endeavours where the projected returns are optimized, ensuring efficient allocation of efforts and resources.
Adapt Public Service Standards to Local Contexts: Eγθ

Coal's Last Breath: mining Health Impacts in England's Transition

-Aayushi Sharma[1], Laia Maynou Pujolras[2], Jordi J. Teixidó[3]

Abstract

This study used a natural experiment to determine how closure of coal plants affect the air pollution and in-turn the health outcomes (physical and mental health) in England. The introduction of Carbon Tax policy in the United Kingdom in 2013, precipitated the closure of multiple coal plants, highlighting the imperative for further investigation into its implications. The study used a Staggered Difference-in-Difference with the Callaway & Sant'Anna estimator along with an event study model, to incorporate differential treatment timing. The results of this study suggest that coal plant closures improve air quality. Regarding health outcomes, it reduces hospital admissions among respiratory patients, and asthma (among adults), and decreases the prevalence of asthma. Furthermore, it reduces mortality among the most deprived under the age of 75 years and mortality for mental and behaviour diseases. These findings suggest that the closure of the coal plant improves the air quality, and thus aid in enhancing the health outcomes. This finding is crucial for the development of informed and affective environmental policy.

Keywords: Coal-fired plants; Emissions; Physical health; Mental health

1. Introduction

The UK is the eighth-largest contributor to the present-day global warming, mainly due to its historical high consumption of coal in the energy sector. The consumption of coal in the UK reached its highest point in the year 1956 at 221 million tonnes (Evans, 2023). The Clean Air Act was rolled to curb the "Great Smog" of London, as a result of this, by 1970's the coal consumption dropped to 120 million tonnes. By the end of 2000's, it further dropped to 60 million tonnes. As of 2022, the coal consumption in the UK is 6.2 million tonnes[4] (Evans, Analysis: UK emissions fall 3.4% in 2022 as coal use drops to lowest level since 1757, 2023).

The UK introduced the Carbon tax in 2013 concerning its obligatory reduction in carbon emission targets under the Climate Change Act of 2008, while European Union Emission Trading System (EU ETS) imposed a lower price (Leroutier, 2022). This policy led to the closure of many plants emitting heavily, and thus leading to a lower carbon emission (Global Energy Monitor; Leroutier, 2022). Beyond carbon emissions and its related climate impact, changes in local pollution have also been documented as a result. It has been researched that

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[4] The current operating capacity of the Coal-fired power plant in the UK is 4140 MW and the current operating annual CO2 emissions is 21 million tonnes (Global Energy Monitor).

the closure of two boilers, in the coal plants led to a decrease in concentrations of PM2.5 at the local and regional levels (Shon, Kang, Park, & Bae, 2020).

This paper analyses the impact of coal plant closures in the local authorities of England, and its neighbouring local authorities on health outcomes. The objective of this research is to causally identify the link between the closure of coal plants and its potentially improvement of health outcomes among the people in England. The link between coal plants pollution and its health impacts is well documented in the literature (Guttikunda & Jawahar, 2014; Munawer, 2018). Munawer (2018) found that emissions from coal-based power plants, including COx, NOx, SOx, particulate matter (PM) and other heavy metals, are associated with deteriorating health outcomes. When these emissions mix with rainwater, they cause acid rain, which not only leads to health issues, like skin cancer, nose irritations, asthma, headache, destabilisation of heartbeats but also impacts the food web (Munawer, 2018). Additionally, chemical reactions between nitrogen dioxide and PM 2.5 leads to cardiac arrhythmias in adults, chronic obstructive pulmonary disease (COPD), asthma, and increase in mortality among infants (Munawer, 2018). These factors have contributed to an estimated 80000 to 115000 premature deaths and 20.5 million asthma cases in India, costing the government approximately USD 3.2 to 4.6 billion (Guttikunda & Jawahar , 2014).

However, identifying any positive effect that should emerge when the coal plant closes –i.e. whether the negative health impact remains long after or vanishes—is an empirical question not studied well. This link is important because the introduction of Carbon Tax policy, 2013 led to the closure of many coal plants in England. Therefore, establishing a causal link between the outcome of climate policy (coal plant closures) and public health outcomes can be a key to further boost climate policies and its public acceptance. Furthermore, the findings of this study hold potential for broader applicability and external validity.

To the best of our knowledge, there exists a notable gap in the literature regarding the examination of the effects of coal plant closures on health outcomes in England. This study aims to fill this void, through state-of-the-art econometric techniques. This research will put a light on the coal power plant closure on health effects of the people in England from 2000 to 2020. Notably, it will encompass an investigation into mental health outcomes alongside physical health impacts. The data has been divided into 3 parts; health data collected from Nomis (Official Census and Labour Market Statistics of the UK), and Fingertips (Office for Health Improvement and Disparities); emissions data from UK-AIR (Air Information Resource); and coal-plant closure data from Global Energy Monitor. Due to nuanced variations arising from timings of closure of coal plants, or what is commonly referred to as differential time treatment, we have incorporated recent advancements in difference-in-differences methodology, particularly focusing on differential treatment timing. This approach, akin to staggered difference-in-differences analysis as elucidated by Callaway and Sant'ana, allows for a more precise examination of the effects.

The results of this study finds that the closure of coal plants, significantly improves air quality, as nitrogen dioxide decreases by 4.429 micrograms, on average (or a reduction of 15.2%). Moreover, coal plant closures led to a significant reduction in the hospital admissions among respiratory and asthma patients (above the age of 19), as on average, it decreased by 4.1% and 10.7% respectively. It is consistent to the research conducted in the US revealed that the asthma attacks decreased (Casey, et al., 2020) and the respiratory health among the children

(Komisarow & Pakhtigian, 2021) as the exposure to coal power plant emissions lowered, due to the closure of coal plants. This paper is different from the previous one as it is focused specifically in England's coal plants and health outcomes, unlike these which were based in the US.

Our findings also show that, mortality of people under 75 (most deprived) has significantly reduced by 3.56%, on average due to the closure of coal plants. Furthermore, on average, the prevalence of asthma rates also decreased significantly by 7.4%. Lastly, mortality due to mental and behavioural diseases also declined by 5.45%, on average in the local authorities which closed the coal plants and its neighbour than which does not. This study shows that the closure of the coal plants leads to improvement in the air quality, and thus in the health outcomes of the people.

There is a pressing need to comprehend how the closure of coal power plants impacts carbon emissions and subsequently influences the health outcomes of individuals residing in areas previously affected by coal-related pollution. The outcomes derived from this research endeavour are anticipated to inform evidence-based policymaking in the domain of public health and environmental regulation.

The paper is as follows: section 2 explains a detailed review of the previous work on coal plants, pollution, and its health impact with gaps in the literature is mentioned. Section 3 mentions the data collection and the methodology used. Section 4 describes the results of our analyses. Finally, section 5 concludes our paper.

2. Coal plants, pollution, and health impacts

The industrialisation led to the expansion of coal power plants in the Britain, which provided an unprecedented rate of growth and left some negative effects behind. The coal-fired power plants, a crucial source of energy in industrialization period, are responsible for the air pollution (Kopas, et al., 2020). It releases toxins and harmful air pollutants in the form of fine and ultrafine particles, like PM2.5, mercury, sulphur dioxide, carbon monoxide and other greenhouse gases (Finkelman, Wolfe, & Hendryx, 2021; Fuller, et al., 2022). People who are exposed to ambient air pollution, may suffer from respiratory issues because ultrafine particles, like PM2.5 can enter deeply in the lungs and do severe harm to the alveolar wall (Xing, Xu, Shi, & Lian, 2016). There are studies related to PM10 pollutant which is significantly related to the morbidity and mortality (Anderson, Thundiyil, & Stolbach, 2012; Chen, et al., 2012), with its impact varying with socio-demographic factors (Chen, et al., 2012).

Industrialisation, increased urbanisation, growth in the population, and combustion of fossil fuels has led to a rise in 66% deaths due to modern pollution in the last couple of decades (Fuller, et al., 2022). According to data by the Global Burden of Diseases, Injuries, and Risk Factors Study (GBD), 2015, evaluated that 16% of the deaths (or 9 million deaths) worldwide has been attributed to the pollution and it has been similar since 2015 (Fuller, et al., 2022). Studies have shown that pollution have an adverse impact on the health as well as mortality, with impacting children and older population more severely (Hospido, Sanz, & Villanueva, 2023).

A study of the impact of outdoor air pollution on the mortality in China revealed that levels of air pollution and mortality related to cardiopulmonary diseases and lung cancer are significantly related (Caoa, et al., 2011). Various studies have indicated the negative impact of air pollution on the premature mortality, and it is estimated that it could increase by two times by 2050 at the global level if emissions remain at the same level (Lelieveld, Evans, Fnais, Giannadaki, & Pozzer, 2015). Moreover, a study in Colorado found that proposed decommissioning of two coal-fired power plants led to 2 less premature deaths, fall in hospitalisations, and other morbidities, due to reduction in PM2.5 emissions (Martenies, Akherati, Jathar, & Magzamen, 2019).

Moreover, emerging evidence suggested that the air pollution affects the brain aging (Block & Calderón-Garcidueñas, 2009; Zhang, Chen, & Zhang, 2018), as ultra-fine particulate matter enters the brain (Block & Calderón-Garcidueñas, 2009), and leads to psychotic illnesses like schizophrenia (Antonsen, et al., 2020), a disorder which affect thinking and behaviour. It implies that the increased levels of pollution worsen the mental health, leading to depression, anxiety, suicides, and other mental health issues (Lawrance, Thompson, Fontana, & Jennings, 2021). In addition to this, studies indicated that ambient air pollution, especially PM emissions, lead to changes in metabolism and higher stress (Li, et al., 2017), disproportionally higher among older men in specific cold months (Mehta, et al., 2015). On the other hand, short-run study on clean indoor air leads to reduction in stress hormones (Li, et al., 2017). A study on neurobehavior problems in children due to the impact of living in vicinity (within 10 miles) of the coal power plants finds that the proximity to coal plants is significantly related to the neurobehavioral problems like social problems, affective problems, and anxiety problems (Zhang, et al., 2021).

All in all, specialized literature is plenty of evidence showing both that pollution has detrimental effects on health and that coal plants are a source of local pollution. The extent to which these effects vanish whenever coal plants stop functioning permanently remains an empirical question.

3. Methodology and Dataset

3.1.Identification Strategy

The paper will exploit casual inference techniques to find out the relationship between coal plant closures and its impact on the health outcomes in the English local authorities.

First of all, a treatment group and a control group have to be identified. The treatment variable defines the control group as zero when the plant is operating and the treated group as one when all the units are closed of a particular plant[5], and their neighbouring local authorities (by border). The control group correspond to local authorities where the coal plants have not been closed yet, and its neighbouring local authorities (by border). The assumption here is that a coal plant pollution does not only affect the hosting local authority but also bordering local authorities. This empirical decision is therefore conservative one. Figure 1 depicts the coal plants closure in the year 2000 versus the closure in the year 2022. In the year 2000, none of the coal plants were closed but by the year 2022 all except 1 were closed.

[5] Most of the coal power plants have more than one unit of the same plant. Moreover, in some local authorities, there are more than one coal power plant.

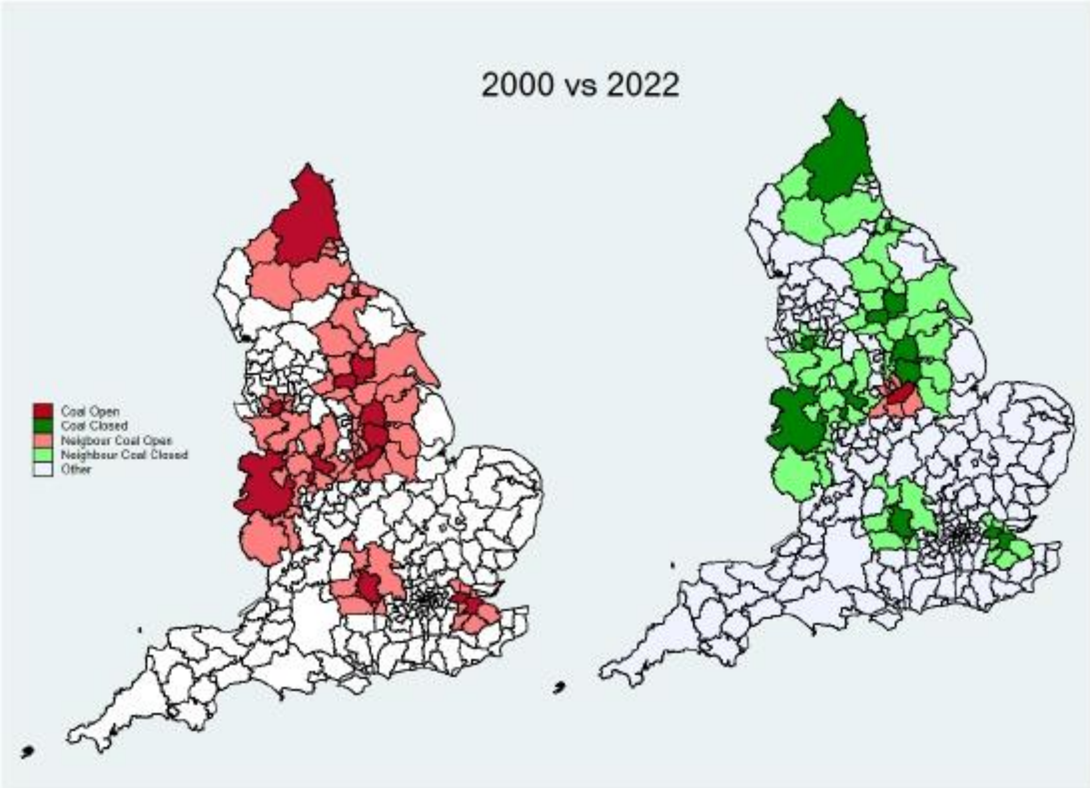

Figure1. Closing of coal plants in the local authorities in England in the year 2000 v/s 2022. Data source: Global Energy Monitor

There were some neighbouring local authorities, which were sharing border with the local authority which closed the coal plant and which did not. By simple logic, this research has considered it to be a part of the local authority which did not close the coal plant (or the control group). This is due to the reason that the local authority where the plant is open is still emitting pollution, meaning there will be still some pollution from coal-fired power plants in the neighbouring local authorities.

Figure 2 shows the closure of coal plants from 2000 to 2022. The figure is depicting that all units of the coal plants are closed. In the year 2003, only 2 coal plants were closed out of 17 operating coal power plants taken for our study. The High Marnham power station (2003), the Drakelow power station (2003), and then the Wilton Cogen power station (2007), these coal plants were closed in the early 2000s. The Longannet Power Plant, the Ferrybridge C Power Plant, and the Rugeley Power Plant; the three largest coal plants in the UK were shut down in the year 2016 (Evans, 2016). The Eggborough Power Plant in 2018 (EP Power Europe) and Fiddlers Ferry Power Plant in 2020 (SSE Thermal) were closed. The dependence of energy generation has been changed from coal to other sources like wind energy, solar energy, hydro energy, nuclear energy, and gas (Evans, 2023). By the year 2022, 16 coal power plants have been closed, and as of 2023 only one coal-fired power plant is operating in England, which is Ratcliffe power station. This similitude in treatment implies that coal plants tend to close at different time, easing thus our identification strategy. Therefore, our identification strategy, Staggered Difference-in-Difference by Callaway & Sant'Anna (2020) is relevant here, which captures the differential treatment timings.

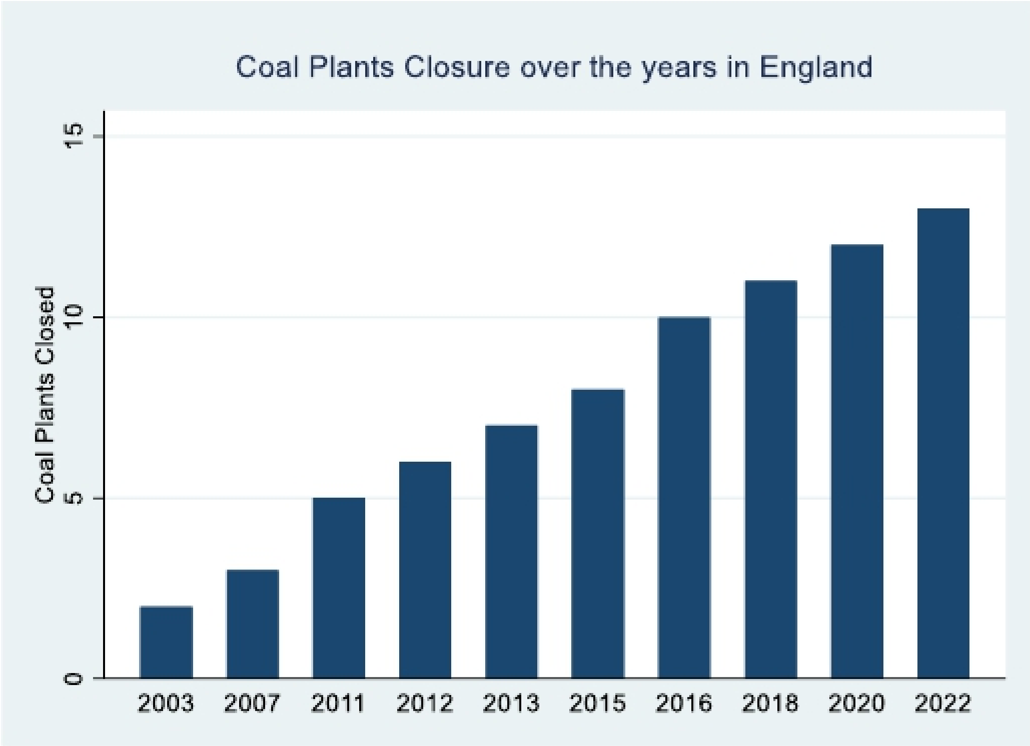

Figure 2. Coal Plants Closure in England over the years. Data Source: Global Energy Monitor

This research will exploit the exogenous variation from the coal plant closures through a staggered difference-in-difference approach. The staggered difference-in-difference will allow to study the units (local authorities) entering the treatment group (closure of coal plant) at different points in time, which would not be estimated by the canonical difference-in-difference technique. The methodology developed by Callaway & Sant'Anna (2020), and is used for estimating the model with multiple time periods, will be used here.

The components of staggered difference in difference are

$$ATT\ (g,t) = \mathbb{E}\ [Y_{i,t}(g) - Y_{i,t}\ (g')/G_i = g] \quad (1)$$

where, g = group, t = time period, Y= Variable of Health Outcome

In the cases where the local authorities do not have coal plants, it would be a never treated case, and denoted by $g' = \infty$ meaning that

The cases in which the local authorities have coal plants but have different closure periods and not yet closed will be a not yet treated case, denoted by $g' > t$.

Here, not yet treated cases, will be applied, so that treatment and control groups are more similar also in terms of unobservables.

The estimated model would be:

$$H_{i,t} = \delta_t + \alpha_g + \beta_1\, DID + \beta_3 X + \varepsilon_{i,t} \quad (2)$$

Here, $H_{i,t}$ is the health outcome, δ_t is the time fixed effect, α_g is the group fixed effect, DiD = Treatment X Post Treatment Period, which implies, coal plant in the local authority (and its neighbouring) and it is closed. β_1 *is the parameter of interest*, X = Covariates including income deprivation, population, share of 65 people.

The main assumptions of the canonical Difference-in-Differences model are parallel trends assumption, no anticipation, and Stable unit treatment value assumption (SUTVA). The parallel trend assumption posits that prior to the implementation of a treatment, both the treatment group and the control group should exhibit similar trends. This suggests that any differences observed between the two groups after the treatment can be attributed to the treatment itself rather than pre-existing disparities. In the context of an event study, adherence to the parallel trend assumption entails that estimates preceding the treatment year are statistically insignificant or demonstrate negligible effects, reaffirming the absence of differential effects prior to the treatment.

No anticipation assumption refers that treatment path is not known a priori. Lastly, SUTVA assumption means that the control group should not be affected by the treatment. Since, we estimate our model by Staggered Difference-in Difference by Callaway and Sant'ana, besides of these above assumptions, we also need to have conditional parallel trends assumptions on a "Never-Treated" or a "Not-Yet-Treated" group (Callaway & Sant'Anna, 2020). It implies this assumption holds after controlling for covariates. Since, our treatment is closure of coal plants in different years, we have used a "Not-Yet-Treated" group. Lastly, there should be a positive proportion of population starts from period g (Callaway & Sant'Anna, 2020).

Further, we use event study model to estimate the length of exposure of treatment effect of closure of coal plants on the emissions, and the health outcomes.

$$H_{i,t} = Closure_{i,t-j} \sum_{j\in(-m,..0,..,n)} \gamma_j + \alpha_i + \delta_t + \beta X_{i,t} + \varepsilon_{i,t} \quad (3)$$

Here, $H_{i,t}$ is the health variable, which is our outcome variable. Closure is the coal plant closure in the local authority and its neighbouring. $\sum_{j\in(-m,..0,..,n)} \gamma_j$ is the time-period when the closure is happening. α_i and δ_t are the panel fixed effects. $X_{i,t}$ is the control variables, and $\varepsilon_{i,t}$ is the error term.

Besides of plausibility of parallel trends, the event study estimates are useful to capture the long-term effects of the coal plant closures on the level of emissions and health outcomes, key for our research question. Once a coal plant stops emitting some health outcomes may take longer than other in reacting. Some health outcomes like mortality do not change rapidly in few years. Exposition can have longer impact.

3.2. Data

We compiled a panel dataset of all the English local authorities from 2000 to 2022. A local authority in the England oversees the council services. They are government bodies responsible for managing public services, like education, waste management, housing, local taxation, and facilities within specific geographic areas, such as cities, towns, and counties (Government of the UK, 2016).

As of 2021, there are 317 local authorities in England, which consists of county councils (21), district councils (164), unitary authorities (62 and the Isles of Sicily), metropolitan districts (36), and London boroughs (32 and the City of London) (Government of the UK, 2016). Out of 317 local authorities, 14 local authorities have or previously had a coal power plant. So, we have taken those 14 local authorities and their neighbouring local authorities were 64. Therefore, we have taken 78 local authorities for our analysis. This will determine our treated and control groups. Treated local authorities will be those with closed coal plant during the period of analysis. Control groups are those local authorities with open coal plant.

The dataset comprises data from four different data sources at the local authority level from coal plants in England detailing its closures, the health outcomes in these local authorities, and emissions from different pollutants.

The data on the closure of coal power plant in England has been collected from the Global Energy Monitor, a non-governmental organisation from San Francisco, which shares information and data on clean energy and fossil fuels at the global level. There are 30 coal power plants in the UK, out of which 20 are in England, 2 are in Wales, 2 are in Northern Ireland, 6 are in Scotland. Out of 20, 17 coal power plants are either operating or retired, and 3 were cancelled. Since, our analysis is focusing on England's coal plants closure, we have incorporated 17 coal power plants in the 14 local authorities in England (Global Energy Monitor, 2023). Figure 1 shows the map of the local authorities having a coal plant, which are either operating or retired over the period in England. They have been mapped to their respective local authority from their location. The dataset contains the number of units of each coal plants (up to 6 units per plant), the local authority to which they belong, the start and the retired year.

The health data of England has been collected from the Nomis (Official Census and Labour Market Statistics of the UK), and Fingertips (Office for Health Improvement and Disparities) for the period 2000 to 2020. This includes emergency hospital admissions for asthma for children and adults, emergency hospital admissions for respiratory issues, and emergency admissions for children with lower tract infections. There is data on asthma prevalence, which is measured by the patients with asthma, excluding those who have not been prescribed drugs in the past twelve months over the practice list size for patients, and it is measured in percentages (Fingertips). And on chronic obstructive pulmonary disease prevalence (or COPD prevalence), which is measured in patients with COPD as recorded on practice disease register over total practice list size, it is measured in percentages (Fingertips). Some variables related to mortality are also collected, mortality due to mental and behavioural disorders, mortality due to diseases of respiratory system, mortality due to asthma, mortality under 75 most deprived and least deprived, mortality under 75, suicide rate among males, and suicide rates among females.

Finally for emissions data, we collected emissions data from UK-AIR (Air Information Resource), using the R package 'openair.' The variables related to emissions include Nitrogen Dioxide (NO2), Nitric Oxide (NO), and PM10.

After collecting all the data; coal plant closures, health, and the emissions data, it was merged at the local authority level and a panel data is formed from the year 2000 to 2022. One limitation of this study is the presence of missing data for some years for health variables which led to unbalanced panel data. This may introduce potential biases or limitations in the analysis, as the absence of data could impact the accuracy and reliability of the findings.

Table 1 shows the main descriptive statistics of the important variables studied in this research, catering to only those local authorities having a coal plant or is a neighbour. A panel for 8257 observations from 78 local authorities from the year 2000-2022 is constructed.

Table 1, shows that the mean nitric oxide, nitrogen dioxide, and PM10 are 31.83 µg m-3, 37.077 µg m-3, and 21.25 µg m-3 respectively, in the 78 local authorities for the year 2000-2022. The average population of England for the year 2001-2020 is 171218. On average the emergency admissions for respiratory diseases, children with lower tract infections, asthma (under 19 years), and asthma (aged 19 years and above) are 1344.15, 379.60, 166.33, and 81.57 respectively for the year 2013-2020. The mean of mortality due to respiratory and mortality over 75 years are 426.96 deaths and 2268.54 deaths respectively, for the year 2013-2021. Prevalence of asthma and COPD is 6.1% and 1.82%, on average for the period 2009 to 2020, in England. On average, the unemployment rate is 5.6% in England for the period 2004 to 2022. The share of 65 and above people in England are 15%, on average, for the period 2001 to 2020.

Table 1. Descriptive statistics for the local authorities having a coal plant and its neighbour local authorities

Variable	Year	Observations	Mean	Std. dev.	Min	Max
Active Coal Plant nearby	2000-2022	184	.102	.303	0	1
Closed a Coal Plant	2000-2022	1,610	.897	.303	0	1
Emissions						
Nitric Oxide (NO)	2000-2022	979	31.832	24.621	1.185	167.108
Nitrogen Dioxide (NO2)	2013-2022	979	37.077	16.190	8.059	123.094
Particulate Matter 10 (PM10)	2007-2022	852	21.252	5.113	10.271	40.188
Population	2001-2020	6,180	171218.1	115549.9	2140	1141816
Health Outcomes						
Emergency Hospital Admissions for Respiratory Diseases	2013-2020	2,498	1344.157	380.632	511.07	2915.92
Emergency Admissions for Children with lower tract infections	2013-2020	2,509	379.603	181.097	19.7	1058
Hospital admissions for asthma (under 19 years)	2013-2020	2,496	166.339	73.317	17.47	537.97
Emergency hospital admissions for asthma in adults (aged 19 years and over)	2013-2020	2,498	81.574	25.943	28.27	242.72
Mortality Due to Respiratory Diseases	2013-2021	1,368	426.966	364.962	0	2278
Under 75 Mortality	2001-2016	5,186	364.665	76.876	201.038	705.769
Under 75 Mortality Least Deprived	2002-2014	4,212	263.793	47.772	125.479	494.618
Under 75 Mortality Most Deprived	2002-2014	4,212	516.481	125.125	219.939	995.414
Mortality due to Asthma	2006-2020	4,225	2.305	.725	0.673	9.282
Mortality Over 75 years	2013-2021	1,368	2268.545	2035.518	5	12136
COPD Prevalence	2009-2020	3,836	1.832	.510	0.690	3.817
Asthma Prevalence (all ages)	2009-2020	3,524	6.107	0.684	3.428	8.262
Mortality Due to Diseases of Mental and Behavioural	2013-2021	1,354	283.397	262.111	0	1618
Suicide Rate Male	2001-2019	5,518	15.709	4.246	5.310	38.628
Suicide Rate Female	2001-2019	2,531	5.837	2.030	1.722	16.100

IMD Average (Income Deprivation)	2000-2020	6,828	19.763	9.211	4.132	61.341
Unemployment Rate	2004-2022	5,209	5.641	2.600	0.9	22.3
Share of age-65	2001-2020	2,560	0.155	0.038	0.060	0.294

4. Results

4.1. Coal Plant closures and Emissions

We first estimate the impact of coal plant closures on the emissions. We have included Nitrogen Dioxide, Nitric Oxide, and PM10 for emissions. Given data constraints, we chose to use a control group consisting of local authorities without coal plants for this case. We will thoroughly address potential concerns through comprehensive robustness checks.

The covariates included in this model are population, deprivation score (measured by IMD Average), and share of 65 people. These variables could be having some relationship with the outcome variable (to address to endogeneity problem) and to have conditional parallel trends, we have included these covariates in the study.

First, in table 2, we estimated the closure of coal plants on nitrogen dioxide (NO2) which, is inversely related and is significant. The overall ATT shows that the levels of nitrogen dioxide have reduced by 4.429 micrograms, on average, in each cubic metre of air (μg m-3) in the focused local authority and its neighbouring compared to the local authorities and its neighbouring which did not have the coal plants. Then, we analysed the levels of nitric oxide and coal plant closures. However, the ATT for all groups across all periods is not significant. Lastly, we estimate closures of coal plants on the levels of PM10 thereafter, which is negatively related, but not significant.

Figure 4 depicts the potential parallel trends assumption. Figure 4 displays the event study approach at the yearly level. In the figure 4, nitrogen dioxide starts to fall after the 0 period (or period after the coal plants closure), then it starts to increase in the 5^{th} period. Nitric Oxides also decrease initially till 5^{th} period and then it starts to increase. Particulate Matter (PM10) follows a similar pattern, as it starts to fall till 3^{rd} period then it starts to increase.

Table 2. Emissions and coal-fired power plants closure

	Nitrogen Dioxide (NO2)	**Nitric Oxide (NO)**	**PM10**
Differences in Differences Model			
Closures X Post	-4.429*** (2.132)	-2.235 (2.889)	-1.252 (0.986)
Event Study Model			
Year -13	-3.785** (1.643)	-5.327** (2.171)	0.390 (0.398)
Year -12			0.397 (0.345)
Year -11	-1.113 (1.030)	-4.945*** (1.447)	0.366 (0.612)
Year -10	-2.333 (3.864)	3.619 (6.900)	-1.193* (0.617)
Year -9	3.915 (2.682)	-3.843 (3.560)	-0.572 (0.542)

Year -8	0.328 (1.305)	-1.947 (1.412)	-0.213 (0.707)
Year -7	1.454 (5.945)	-3.288 (4.019)	-0.505 (0.956)
Year -6	-5.953 (3.848)	-0.918 (4.241)	-1.141 (1.598)
Year -5	1.809 (2.200)	-0.634 (3.591)	-0.328 (0.758)
Year -4	1.419 (3.001)	-0.773 (2.533)	0.547 (0.549)
Year -3	-0.679 (2.536)	1.727 (4.960)	1.714** (0.795)
Year -2	-1.403 (1.916)	-0.151 (2.722)	-0.652 (1.286)
Year -1	2.173 (1.649)	2.464 (3.185)	0.734 (1.061)
Year 0	0.359 (3.093)	5.500* (3.201)	-0.260 (0.916)
Year 1	-4.760*** (1.460)	-6.385*** (2.391)	-0.854 (3.083)
Year 2	-5.478*** (1.240)	-5.363*** (1.500)	-3.333 (2.945)
Year 3	-10.547*** (2.434)	-11.668*** (1.281)	-2.662** (1.056)
Year 4	-12.056*** (2.454)	-7.008 (6.769)	-2.042 (1.626)
Year 5	-5.679*** (1.361)	-9.853*** (2.652)	-0.235 (0.351)
Year 6	-5.614*** (2.026)	-4.927 (3.335)	0.101 (0.524)
Year 7	-0.479 (2.700)	4.620 (4.104)	-2.804*** (0.550)
Observations	333	410	374
Controls	Yes	Yes	Yes

Note; This table displays result of staggered difference-in-difference model and event study. The sample is defined as emissions in the local authority and coal plant closures (for the period 2000-2022) in England. Parentheses contain the se. Significance Levels: * = 10%, ** = 5%, *** = 1%

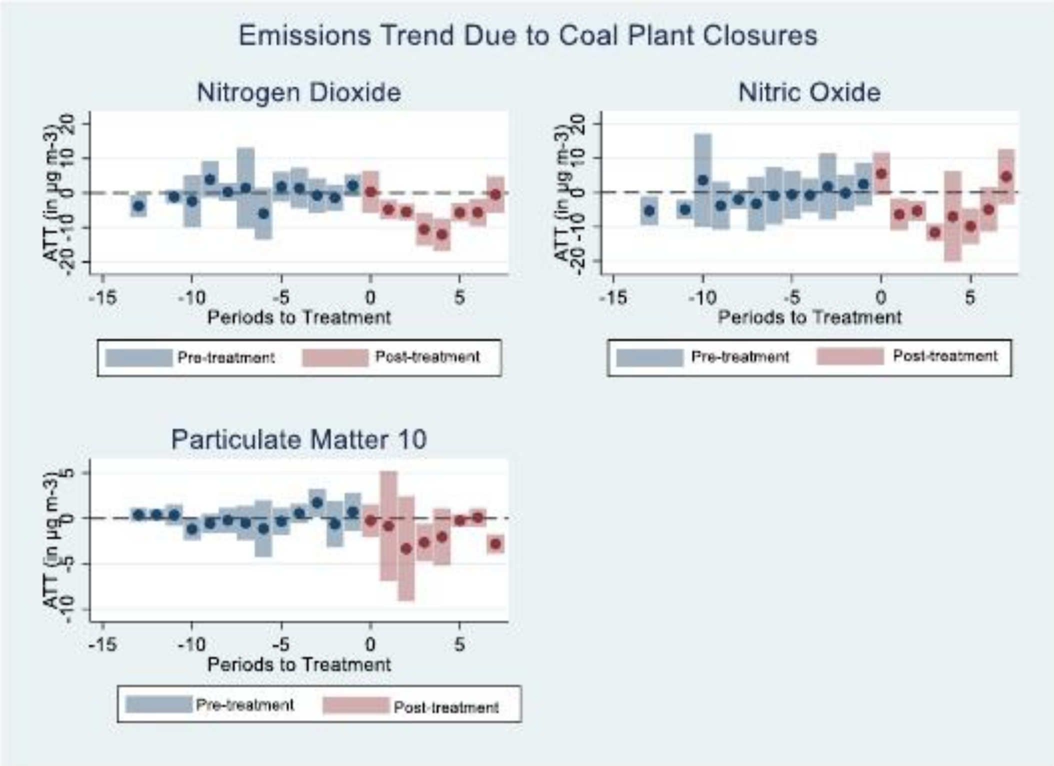

Figure 1. Event study of emisisons due to closure of coal-fired power plants

4.2. Coal Plant Closures and Health Outcomes

4.2.1 Hospital Admissions

The first health outcome analysed is emergency hospital admissions related to respiratory complications, as a measure of short-term health impact. For this, we have taken emergency hospital admissions for respiratory diseases, emergency admissions for children with lower tract infections, emergency hospital admissions for asthma (aged 19 years and older), and emergency hospital admissions for asthma (aged under 19), all in logarithms. The covariates used in the regression are are population and deprivation score (IMD scores).

Table 3 reports these results, first, with the overall ATT and then, by year-effect. For these variables we have less years, we have 8 periods before the treatment and 5 periods after the treatment.

Figure 5 depicts the potential parallel trends assumption. It illustrates the hospital admissions for respiratory diseases and for asthma (aged 19 and above) started to fall and has a decreasing trend after the treatment (closure of the coal plants) has taken place. Moreover, hospital admissions for children with lower tract infections has first decreased then it increased till 4^{th} period and it again decreased in the 5^{th} period. However, the figure 5 shows that hospital admission for asthma (aged under 19) has an increasing trend.

The results for emergency hospital admissions for respiratory diseases indicate a negative and a significant effect when the coal plant closes in the local authorities and its neighbouring. It implies that there has been a reduction in emergency hospital admissions for respiratory diseases by 4.12%, on average. Moreover, there has been a fall of 10.79% (on average) for the emergency hospital admissions for asthma among adults in the local authorities closing the coal plants and its neighbouring, compared to those local authorities have not closed the coal plants (and its neighbour). Further, emergency admissions for children with lower tract infections is significant in the 5^{th} period after the coal closures, implying that due to closures of coal plants in those local authorities and its neighbouring encountered,

Table 3. Hospital Admissions and Coal Plants Closure

	Emergency Hospital Admissions for Respiratory Diseases	Emergency Admissions for Children with lower tract infections)	Hospital Admissions for Asthma (aged 19 years and over)	Hospital Admissions for Asthma (aged under 19)
Difference-in-Difference Model				
Closures X Post	-0.041**	-0.046	-0.107***	0.044
	(0.016)	(0.056)	(0.032)	(0.057)
Event Study				
Year -8	-0.036	0.144	-0.049	0.009
	(0.037)	(0.106)	(0.095)	(0.048)
Year -7	-0.013	-0.151	0.144*	-0.105
	(0.032)	(0.192)	(0.076)	(0.135)
Year -6	0.022	0.074	0.018	-0.057
	(0.026)	(0.062)	(0.048)	(0.056)
Year -5	-0.031	-0.102	-0.115***	0.072
	(0.024)	(0.093)	(0.040)	(0.061)
Year -4	0.074*	-0.018	0.112*	-0.131**
	(0.040)	(0.065)	(0.065)	(0.051)
Year -3	-0.090**	-0.011	-0.151***	-0.006
	(0.041)	(0.088)	(0.049)	(0.045)
Year -2	0.025	-0.0003	0.089**	-0.035
	(0.021)	(0.058)	(0.041)	(0.055)
Year -1	0.003	0.095**	0.017	0.011
	(0.016)	(0.048)	(0.038)	(0.041)
Year 0	-0.020	-0.028	-0.095***	0.030
	(0.021)	(0.051)	(0.033)	(0.050)
Year 1	-0.031**	-0.030	-0.138***	0.040
	(0.014)	(0.064)	(0.045)	(0.053)
Year 2	-0.061	-0.124	-0.099*	-0.051
	(0.038)	(0.125)	(0.050)	(0.109)
Year 3	-0.058**	-0.061	-0.141**	0.076
	(0.023)	(0.083)	(0.055)	(0.1003)
Year 4	-0.035	0.138	-0.079	0.095
	(0.022)	(0.096)	(0.051)	(0.101)
Year 5	-0.092***	-0.288***	-0.074	0.233***
	(0.035)	(0.111)	(0.074)	(0.090)
Obs.	336	333	336	336
Controls	Yes	Yes	Yes	Yes

Note: This table displays result of staggered difference-in-difference model and event study. The sample is defined as hospital admissions in the local authority for the period 2013-2020 and coal plant closure from 2000-2022 in England. Parentheses contain the se. Significance Levels: * = 10%, ** = 5%, *** = 1%

on average, 28.8% less patients of lower tract infections among children than those local authorities which did not close the coal plants (and its neighbour). The variable hospital admissions for asthma among children is not significant.

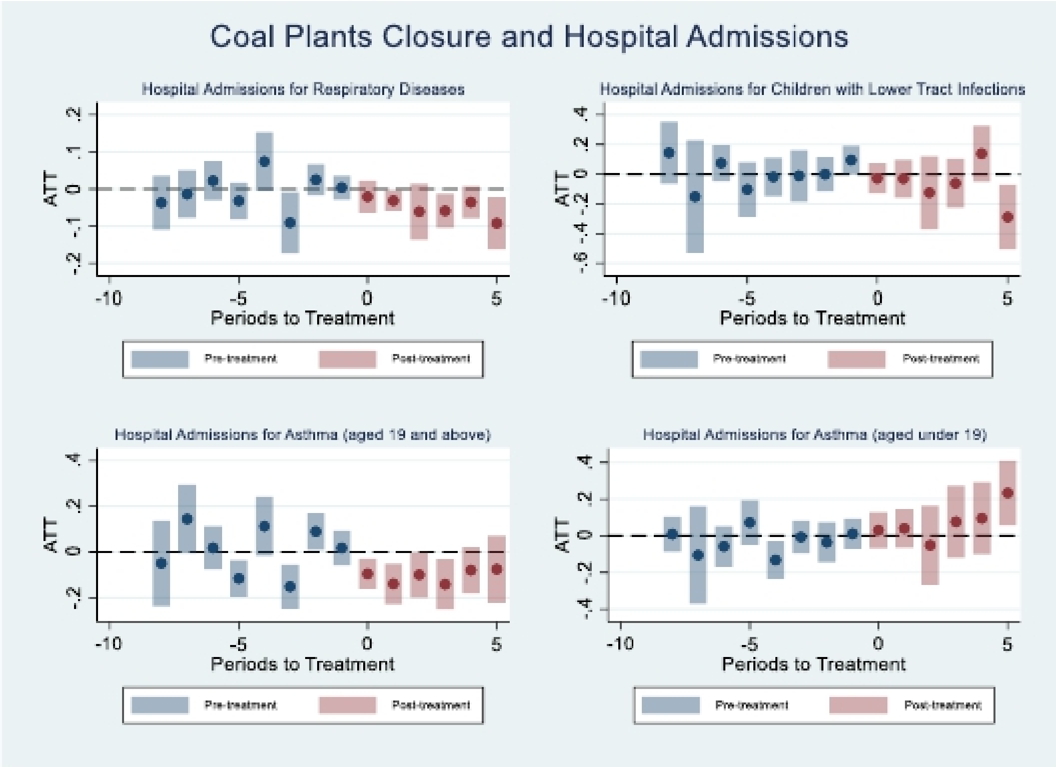

Figure 2. Event study of hospital admissions due to closure of coal-fired power plants

4.2.2. Coal Plant Closures and Mortality

We are interested in finding out the long-term phenomenon which is mortality, as it takes some time to prevent mortality. To measure the impact of closure of coal plants on mortality, we have used Mortality under 75, mortality under 75 for most deprived, mortality under 75 for least deprived, mortality due to asthma, mortality due to respiratory diseases, all in logarithms. The covariates used in the regression are population and deprivation score (IMD score), except for mortality under 75 for most deprived and least deprived, where only population as the covariate has been used (because it automatically controls for the deprivation score), and no covariate has been taken for mortality over 75.

Table 4 present the results of mortality due to different causes, with each variable encompassing varying durations for pre-treatment and post-treatment periods. Specifically, mortality among people under 75 years of age includes 20 years before the treatment and 13 years after the treatment. Mortality among the most deprived and least deprived under 75 years of age includes 19 years before the treatment and 11 years after the treatment. Mortality due to asthma includes 15 years before the treatment and 13 years after the treatment. Mortality due to respiratory diseases includes 8 years before the treatment and 5 years after the treatment. Lastly, mortality among individuals above 75 years of age includes 8 years before the treatment and 6 years after the treatment.

Our findings show that mortality for people aged under 75 who are most deprived has reduced. Closure of coal plants lead to, on average, 3.56% less deaths for under 75 most deprived people in the local authorities which has closed the coal plants and their neighbouring local authorities, compared to local authorities and its neighbour where the coal plant has not been closed. Mortality for under 75 people who are least deprived, does not have any impact. It could be the most deprived people are more prone to air pollution, and might be living near the coal-fired plants.

Mortality due to asthma and respiratory diseases are significant only after certain time has passed. Since, it is a long-term event, mortality due to Asthma has become negative and significant after the 10th period and there is on average a 30% fall in the mortality after the coal plant closures. Furthermore, mortality due to respiratory diseases has become negative in the 4th period, it is around 0.6% after the coal plant closures, however it is not significant.

Mortality for the people over the age of 75 is not significant, however, it is negative when coal plant closes, it implies that the mortality is due to aging or natural factors among them. It remains the same throughout.

Figure 6 depicts the potential parallel trends assumption. The figure illustrates that mortality under 75 is not significantly negative after the closure of the coal plants. Mortality under 75 among the most deprived people starts to decline after the 4th period after the closure of coal power plants and mortality due to asthma starts to decline significantly after the 10th period after the closure of coal plants. Mortality under 75 for least deprived did not decline significantly after the closure of the coal plants. Mortality due to respiratory diseases decreases after 4th year, however it is not significant. Mortality aged over 75 starts to decline after the 4th period, however it is not significant.

Table 4. Mortality and Coal Plants Closure

	Under 75 Mortality	Under 75 Most Deprived	Under 75 Least Deprived	Mortality due to Asthma	Mortality Due to Respiratory Diseases	Mortality Over 75 years
Differences in Differences Model						
Closures X Post	0.004 (0.008)	-0.035** (0.016)	0.022 (0.017)	0.024 (0.044)	0.0002 (0.025)	-0.007 (0.013)
Event Study						
Year -20	0.021 (0.026)					
Year -19	-0.003 (0.019)	-0.059*** (0.019)	-0.018 (0.019)			
Year -18	-0.0003 (0.009)	0.001 (0.025)	-0.008 (0.021)			
Year -17	-0.006 (0.018)	0.018 (0.016)	-0.030 (0.018)			
Year -16	0.012 (0.005)	0.036** (0.014)	0.046*** (0.011)			
Year -15	0.002 (0.007)	-0.005 (0.011)	0.0003 (0.018)	0.142*** (0.049)		
Year -14	0.001 (0.007)	-0.011 (0.011)	-0.003 (0.012)	0.330*** (0.084)		
Year -13	-0.001 (0.005)	-0.007 (0.007)	-0.002 (0.011)	-0.114 (0.134)		
Year -12	0.001 (0.005)	0.009 (0.009)	0.021* (0.011)	0.047 (0.070)		
Year -11	-0.010** (0.004)	0.008 (0.007)	-0.016 (0.011)	-0.026 (0.092)		
Year -10	0.002 (0.005)	0.002 (0.007)	-0.004 (0.011)	-0.019 (0.084)		

Year -9	0.001 (0.003)	0.016* (0.009)	-0.007 (0.010)	-0.018 (0.084)		
Year -8	0.010 (0.004)	-0.002 (0.005)	0.002 (0.010)	-0.051 (0.066)	-0.035 (0.031)	-0.023 (0.031)
Year -7	-0.009** (0.004)	0.002 (0.007)	-0.004 (0.009)	0.001 (0.089)	-0.028 (0.041)	0.043* (0.025)
Year -6	-0.004 (0.003)	-0.004 (0.006)	-0.002 (0.009)	0.034 (0.066)	-0.021 (0.025)	0.017 (0.016)
Year -5	-0.005 (0.003)	-0.007 (0.007)	0.002 (0.008)	0.023 (0.043)	0.019 (0.019)	-0.006 (0.013)
Year -4	0.005 (0.004)	-0.005 (0.006)	0.018* (0.011)	-0.009 (0.041)	0.042* (0.022)	0.015 (0.014)
Year -3	0.001 (0.003)	0.004 (0.008)	-0.016 (0.011)	-0.003 (0.040)	-0.056* (0.033)	-0.003 (0.019)
Year -2	0.001 (0.004)	-0.004 (0.008)	-0.0003 (0.011)	0.004 (0.045)	0.019 (0.024)	0.020 (0.015)
Year -1	-0.003 (0.003)	-0.007 (0.007)	-0.021* (0.012)	-0.077* (0.043)	0.032 (0.022)	-0.010 (0.018)
Year 0	0.002 (0.003)	-0.018** (0.008)	0.004 (0.010)	0.029 (0.044)	-0.001 (0.022)	-0.003 (0.015)
Year 1	0.003 (0.007)	-0.017 (0.015)	0.037** (0.015)	0.007 (0.049)	0.006 (0.025)	-0.007 (0.009)
Year 2	0.007 (0.010)	-0.004 (0.022)	0.054*** (0.019)	0.010 (0.066)	0.006 (0.026)	-0.014 (0.016)
Year 3	0.002 (0.010)	-0.021 (0.021)	0.068*** (0.021)	0.092 (0.072)	0.033 (0.038)	-0.011 (0.015)
Year 4	0.018* (0.010)	-0.059** (0.024)	0.009 (0.025)	0.235** (0.114)	-0.006 (0.051)	0.008 (0.032)
Year 5	0.022* (0.013)	-0.053* (0.031)	0.007 (0.026)	0.012 (0.071)	-0.079 (0.066)	-0.006 (0.028)
Year 6	-0.001 (0.017)	-0.051** (0.023)	0.040 (0.030)	-0.0204 (0.054)		-0.024 (0.038)
Year 7	0.0001 (0.019)	-0.044 (0.032)	0.034 (0.044)	-0.014 (0.074)		
Year 8	-0.005 (0.021)	-0.096** (0.041)	-0.033 (0.047)	0.030 (0.105)		
Year 9	0.003 (0.023)	-0.083 (0.051)	-0.057 (0.052)	0.117 (0.135)		
Year 10	-0.017 (0.023)	-0.086* (0.048)	-0.029 (0.055)	-0.300** (0.132)		
Year 11	0.001 (0.021)	-0.071 (0.044)	0.001 (0.059)	-0.392* (0.210)		
Year 12	-0.017 (0.020)			-0.532*** (0.126)		
Year 13	-0.008 (0.023)			-0.264** (0.134)		

Obs.	1,207	988	988	802	893	207
Controls	Yes	Yes	Yes	Yes	Yes	Yes

Note: This table displays result of staggered difference-in-difference model and event study. The sample is defined as mortality for the period 2013-2020 and the coal plant closure for the period 2000-2022 in the local authority in England. Parentheses contain the se. Significance Levels: * = 10%, ** = 5%, *** = 1%

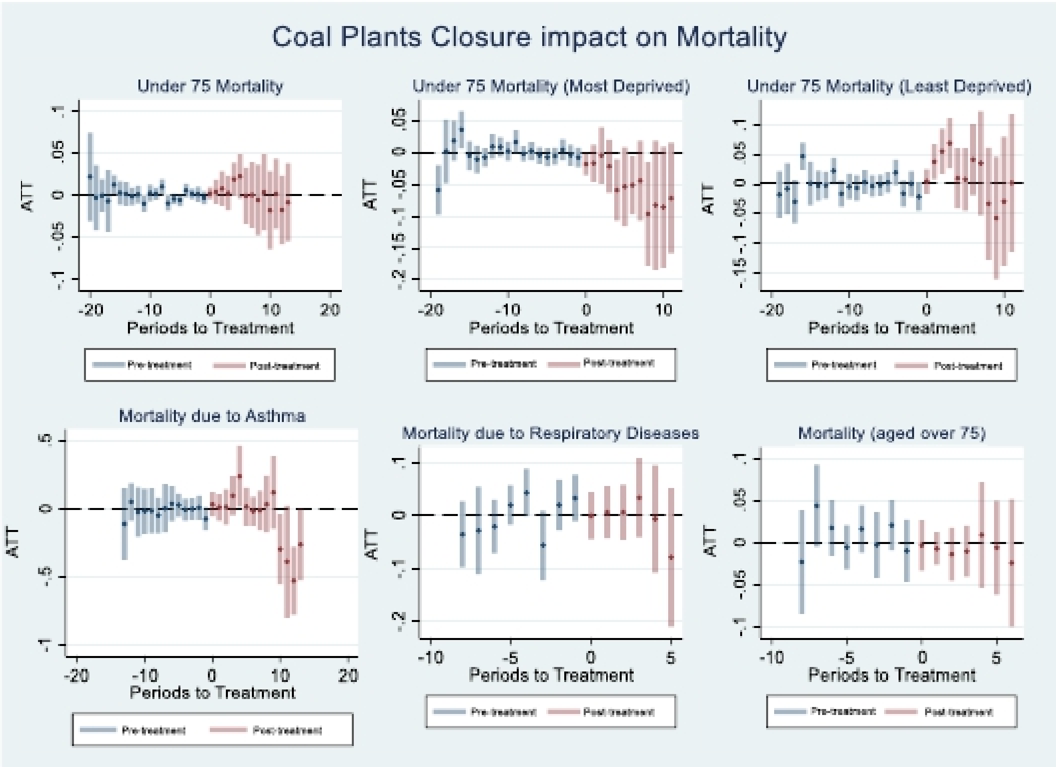

Figure 3. Event study of mortality due to closure of coal-fired power plants

4.2.3. Coal Plant Closure and Prevalence of Asthma and COPD

Next, prevalence of asthma and chronic obstructive pulmonary disease (COPD) are estimated, to find out how it is related to coal plants closure. The covariates used for prevalence of asthma and COPD are population and deprivation scores.

Table 5 shows that the prevalence of asthma is significant at 10% level of significance. It implies that after the coal plants are closed, the local authorities which closed the coal plants and its neighbour experience, on average, a fall of 0.07% in asthma prevalence rates.

Prevalence of COPD is not significant, on ATT for all groups and time periods. Figure 7 depicts the potential parallel trends assumption. It shows that the COPD prevalence does not change significantly. However, prevalence for asthma decreased in the 4th period and it remains negative afterwards.

Table 5. Disease Prevalence and Coal Plants Closure

	COPD Prevalence	**Asthma Prevalence (all ages)**
Differences in Differences Model		
Closures X Post	-0.006 (0.024)	-0.074* (0.038)

Event Study		
Year -12	0.022 (0.029)	0.050 (0.039)
Year -11	0.019 (0.037)	0.051 (0.098)
Year -10	0.036 (0.025)	-0.013 (0.052)
Year -9	0.013 (0.016)	0.036 (0.051)
Year -8	-0.007 (0.008)	-0.004 (0.019)
Year -7	-0.001 (0.008)	0.020 (0.024)
Year -6	-0.005 (0.010)	0.012 (0.026)
Year -5	0.001 (0.007)	0.025* (0.014)
Year -4	0.028 (0.027)	0.048 (0.025)
Year -3	-0.017 (0.024)	0.014 (0.014)
Year -2	-0.008 (0.015)	-0.003 (0.027)
Year -1	-0.013 (0.019)	0.018 (0.016)
Year 0	-0.003 (0.017)	-0.026* (0.015)
Year 1	-0.009 (0.018)	-0.028 (0.027)
Year 2	-0.037 (0.043)	-0.017 (0.036)
Year 3	0.011 (0.027)	-0.007 (0.044)
Year 4	-0.032 (0.044)	-0.112* (0.057)
Year 5	-0.032 (0.044)	-0.251*** (0.064)
Year 6	0.001 (0.043)	-0.229 (0.079)
Year 7	0.028 (0.057)	-0.073 (0.101)
Year 8	0.078 (0.055)	-0.082 (0.138)
Year 9	0.008 (0.085)	
Obs.	766	702

Controls		Yes	Yes

Note: This table displays result of staggered difference-in-difference model and event study. The sample is defined as prevalence of diseases for the period 2009-2020 and the coal plant closure from 2000-2022 in the local authority in England. Parentheses contain the se. Significance Levels: * = 10%, ** = 5%, *** = 1%

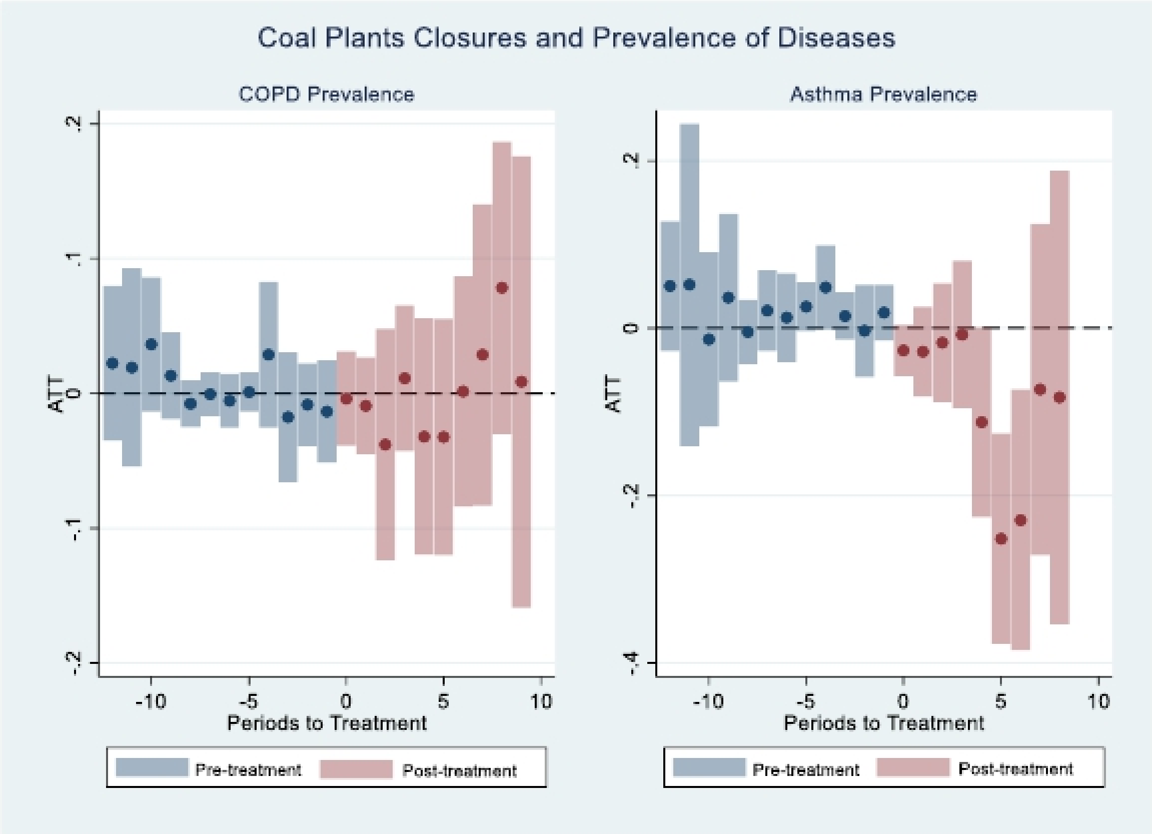

Figure 4. Event study of prevalence of diseases due to closure of coal-fired power plants

4.3. Coal Plant Closures on Mental Health

To analyse the impact of coal plant closures on the mental health, we use mortality due to behavioural and mental health issues, suicide rate male, and suicide rate female, in logarithms. The covariates associated with mental health are deprivation rate and the share of 65 people.

The share of people aged 65 and above is used as control because it might be affecting the mortality due to mental illnesses, which might not be related to the coal plant closures. And deprivation rate might be impacting the mental health indirectly, so taking it as a control would lead to a more reliable result.

Table 6 reveals that, mortality due to diseases of behavioural and mental health reduced by 5.4% in the local authorities and in their neighbouring where the coal plants are closed compared where it is not. There is a negative relationship which has been seen with the suicide rates of males and females with the coal plant closures, however, it is not significant.

Figure 8 depicts the potential parallel trends assumption. It shows that the mortality due to mental and behaviour diseases starts to decrease after the treatment has occurred. Suicide rate among males and females does not exhibit any change after the treatment.

Table 6. Mental Health and Coal Plants Closure

	Mortality Due to Diseases of Mental and Behavioural	Suicide Rate Male	Suicide Rate Female
Differences in Differences Model			
Closures X Post	-0.054** (0.021)	-0.069 (0.057)	-0.011 (0.100)
Event Study			
Year -18		-0.411** (0.205)	-0.752*** (0.183)
Year -17		-0.193** (0.094)	0.373** (0.164)
Year -16		0.083 (0.055)	-0.045 (0.096)
Year -15		0.310 (0.227)	-0.178* (0.092)
Year -14		0.005 (0.044)	0.032 (0.104)
Year -13		-0.139 (0.098)	0.129** (0.063)
Year -12		0.012 (0.089)	-0.036 (0.085)
Year -11		-0.071 (0.071)	-0.068 (0.059)
Year -10		-0.017 (0.060)	-0.121** (0.057)
Year -9		-0.010 (0.056)	0.068 (0.072)
Year -8		0.043 (0.054)	-0.085 (0.086)
Year -7		0.076 (0.051)	-0.288** (0.146)
Year -6	0.201 (0.156)	-0.015 (0.026)	-0.237 (0.14)
Year -5	-0.086 (0.090)	0.009 (0.026)	-0.142* (0.080)
Year -4	-0.036 (0.023)	-0.097* (0.050)	0.199*** (0.055)
Year -3	-0.010 (0.030)	0.042 (0.036)	-0.119* (0.067)
Year -2	-0.012 (0.040)	-0.028 (0.035)	0.105** (0.046)
Year -1	0.124 (0.081)	0.073* (0.040)	0.030 (0.077)
Year 0	-0.048 (0.047)	-0.045 (0.029)	0.082 (0.062)

Year 1	-0.025 (0.022)	-0.084** (0.041)	0.016 (0.101)
Year 2	-0.064** (0.032)	-0.036 (0.068)	0.002 (0.177)
Year 3	-0.062 (0.041)	-0.005 (0.080)	0.036 (0.183)
Year 4	-0.031 (0.044)	-0.066 (0.086)	-0.105 (0.159)
Year 5	-0.180*** (0.027)	-0.012 (0.163)	-0.178 (0.292)
Year 6		-0.145 (0.151)	-0.228* (0.123)
Year 7		-0.121 (0.124)	-0.189 (0.211)
Year 8		-0.300*** (0.116)	-0.174 (0.214)
Year 9		-0.223 (0.192)	0 (omitted)
Year 10		-0.176 (0.110)	
Year 11		0.173* (0.100)	
Year 12		0.085 (0.083)	0 (omitted)
Obs.	184	637	457
Controls	Yes	Yes	Yes

Note: this table displays result of staggered difference-in-difference model and event study. The sample is defined as mental health for the period 2001-2019 and for the coal plant closures from 2000-2022 in the local authority in England. Parentheses contain the se. Significance Levels: * = 10%, ** = 5%, *** = 1%

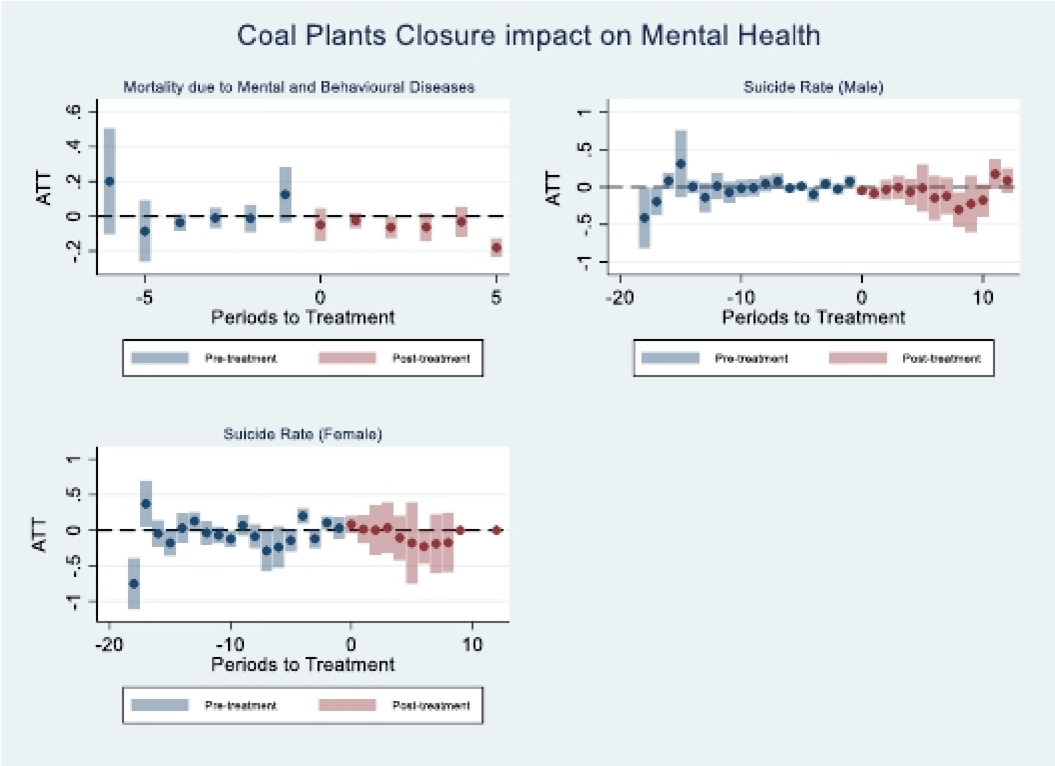

Figure 5. Event study of mental health due to closure of coal-fired power plants

5. Discussion

The primary objective of this paper is to investigate the causal relationship between coal-fired power plants closure on the health outcomes in England. Our period of analysis is from 2000 to 2022, when major coal-fired power plants were closing. And one of the main policies during our period of analysis is the Carbon Tax Policy (2013), which was introduced in the United Kingdom. Emissions from coal-fired power plants like PM10, nitric oxides, and nitrogen dioxide, directly impacts the cardiovascular and respiratory morbidity and mortality of the population as it leads to oxidative stress and inflammation (Anderson, Thundiyil, & Stolbach, 2012). Therefore, it is crucial to conduct research analysing the impact of coal plant closures on health outcomes through the mechanism, emissions that they release. Our analysis focusses only in England, as it has the maximum coal-fired power plants and the rest 3 countries in the UK do not have enough coal power plants, that we could do the causal inference.

We have found some evidence from our estimation analysis and it is consistent with the previous literature that coal-fired plants have a direct impact on emissions like nitrogen dioxide, nitric oxides, and PM10. The results from emissions show that the overall ATT for the levels of nitrogen dioxide have reduced by 4.429 micrograms, on average, in each cubic metre of air (µg m-3) in the focused local authority and its neighbouring compared to the local authorities and its neighbouring which did not have the coal plants. This is consistent with the studies that coal plant closures lead to a reduction in emissions (Shon, Kang, Park, & Bae 2020; Russell, Belle, & Liu 2017).

While nitric oxide decreased for 3 periods after the closures and then it again increased. Report on Greenhouse Gas Emissions (2022) revealed that the there has been change in the proportion of greenhouse gas emissions from power stations, which were highest 10 years ago to domestic transport sector, which became highest since 2014 (National Statistics, 2024). The main source of nitrous oxide are coal, domestic transportation, and agriculture. Moreover, emissions from domestic transportation increased between the years 2013 and 2017; and emissions from agriculture sector stayed at the similar level from 2000's (National Statistics, 2024). All these factors could have contributed to an initial decline followed by an increase in nitric oxide levels.

Moreover, PM10 decreased in the 3rd period after the closure of the coal plant then it again increased. A report by National Statistics (2024), revealed that a decrease in emissions from power sector has been offset by a rise in emissions from burning of wood in domestic settings and solid fuel burning in the industry (particularly the burning of biomass based-fuels). Biomass based-fuels proportion contributed PM2.5 emissions have increased from less than 1% before 2009 to 6% in 2022 (National statistics, 2024). This could have offset the decrease of emissions from coal plants closure.

This research further finds that the hospital admissions for respiratory and hospital admissions for asthma (among above 19) have declined by 4.1% and 10.7% respectively, which is consistent with the previous studies (Martenies, Akherati, Jathar, & Magzamen, 2019).

Furthermore, the results also show that mortality for people aged under 75 who are most deprived has reduced. Closure of coal plants lead to, on average, 3.56% less deaths for under 75 most deprived people in the local authorities which has closed the coal plants and their neighbouring local authorities, compared to local authorities and its neighbour where the coal plant has not been closed. It could be the reason that the most deprived people are more prone to air pollution, and might be living near the coal-fired plants. Due to the closure of the coal plants their environmental conditions improved as a result; their mortality decreased.

The results of this study should that there is no causal relationship between the closure of coal-fired power plants and the prevalence of COPD, which is consistent with the study by Amster, Haim, Dubnov, & Broday (2014). They found that exposure to coal-fired power plants does not have any association with the prevalence of COPD and asthma. An important contribution of our paper to theirs is the revelation that the prevalence of asthma declined by 7.4% after the closure of the coal plants.

The 5.4% reduction in deaths from mental and behavioural disorders fills a research gap pointed out by Martenies, Akherati, Jathar, and Magzamen (2019), who noted the limitation of not analysing neurocognitive effects. However, the suicide rate among males and females are not significant. The factors affecting suicide rate could be due to two reasons in this context. Firstly, there is a negative relationship between emissions and mental health implying, a reduction in emissions would improve mental health (Lawrance, Thompson, Fontana, & Jennings, 2021). Moreover, as the coal plants are closed in the local authority, there would have been more cases of unemployment. The studies indicated that there is a negative effect of unemployment on the mental health, unemployment leads to poor mental health (Murphy & Athanasou, 1999).

These important findings show us that the closure of coal-fired power plants indeed improve the health outcomes of the people living close to them. The limitations this paper include limited data units, which is available for only some years for some of the health variables. Furthermore, migration could serve as a valuable control variable in this context. However, it is worth noting that migration data is only accessible at the census level, meaning it is collected every 10 years. Consequently, there is a decade-long gap between available data points.

Additionally, this study did not encompass the financial benefits resulting from improved health outcomes, nor did it delve into the economic repercussions of coal plant closures on the income of employees working in coal power generation units. These aspects lie beyond the scope of our paper.

6. Conclusion

The study evaluates the effect of coal plants closures on the health outcomes of the people living in England. The study analysed the local authorities where the coal plant has been closed and its neighbouring local authorities and the health status of the people with the people living in the local authorities in which the coal plant has not been closed and its neighbouring local authority. We have used the emission as the mechanism through which we find the relationship between coal plant closures and its impact on the health outcomes. The study has implemented Staggered Difference-in-Difference approach to acknowledge the difference in treatment timings.

The main results shows that the emissions have been reduced over the years, as coal plants got closed. The significant drop has been seen in the emissions of nitrogen dioxide, which is around 15.2% due to the closure of the coal-fired power plants. The health outcomes also improved, as hospital admissions for respiratory declined, on average, by 4.1% and hospital admission for asthma (aged 19 above), on average, declined by 10.7%, in the local authorities where they closed the coal plant and its neighbouring local authorities. The mortality rate among under 75 most deprived decreased, on average, by 3.5% in those local authorities over the years. Furthermore, mortality due mental diseases also fell by 5.4%, on average, in the local authorities and its neighbour which have closed the coal plants. Lastly, the prevalence of asthma decreased by 7.4%, on average, in the local authorities which close the coal-fired power plants and its neighbouring.

The research suggests a positive impact on the overall health outcomes of the people in the main local authority and it's neighbouring over the years due to the coal plant closures. Further study on longitudinal data would be needed to find out the relevant impact of coal plants closure on mortality. Moreover, with the longitudinal data, it is possible to include the migration data, which is available at census level.

This research could be an important tool for the government in decision-making of weighing the pros and cons of having a coal plants. Our study did not estimate the impact of coal-fired power plants on the income of the workers employed in this sector, however, it focused on the related health outcomes on the people. Further, health is the most important aspect of life, if people are healthy, then they are considered efficient. They would be more efficient in terms of working; they would not need to visit the healthcare centres frequently which saves their time and money. As a result, it would be better for everyone in the country. More healthy people help in generating more efficient outcome, which was not in our scope of research.

Non-renewable energy sources like coal present pressing challenges to global health, encompassing both physical and mental well-being, which the world economy must address in the coming years. The significance of this research lies in its ability to offer valuable insights for policy decisions and public health interventions. Through an exploration of the impact of coal plant closures on health outcomes, including reduced air pollution and enhanced respiratory health, this study has the potential to inform policymakers striving to advance public health and environmental sustainability goals. Furthermore, by delving into the economic and social consequences of such closures, it enables the development of strategies to alleviate negative effects on affected communities. Ultimately, this research contributes to evidence-based decision-making aimed at improving public health and environmental well-being, thereby underscoring its relevance in the realms of environmental policy and public health advocacy.

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Appendix

I. Causal relationship between unemployment and the closure of coal-fired power plants in England

We need to check if unemployment has a causal relationship with the coal plant closures. We analyse the unemployment on the coal plant closures. We have included population and IMD score as a covariate in this analysis. We get this result.

Table 7 shows that the unemployment gets significant from the 10th period till 12th period after the closure of the coal-fired power plants. However, the overall ATT is not significant for all the periods, on average.

Figure 8 shows the potential parallel trends in unemployment due to the closure of coal-fired power plants. The unemployment starts to increase from the 10th period then it peaked in the 11th period, then it starts to fall. It remained positive and significant in the 12th period as well, however, in the 13th period, it becomes negative.

Table 7. Mental Health and Coal Plants Closure

	Unemployment
Differences in Differences Model	
Closures X Post	0.038 (0.341)
Event Study	
Year -17	0.576 (0.574)
Year -16	0.363 (0.931)
Year -15	0.659416 (0.605)
Year -14	-0.741434 (1.048)
Year -13	0.2100609 (0.570)
Year -12	-0.047884 (1.074)
Year -11	-0.727703 (0.555)
Year -10	-0.270075 (0.635)
Year -9	0.9315118** (0.417)
Year -8	0.1626377 (0.348)
Year -7	-0.035999 (0.592)

Year -6	0.3162919 (0.515)
Year -5	-0.084417 (0.405)
Year -4	-0.516488 (0.362)
Year -3	-0.437874 (0.375)
Year -2	-0.047343 (0.336)
Year -1	0.9245242** (0.389)
Year 0	-0.252866 (0.415)
Year 1	0.028886 (0.391)
Year 2	-0.46708 (0.422)
Year 3	0.1218414 (0.332)
Year 4	0.2088317 (0.443)
Year 5	0.995703 (0.802)
Year 6	-0.527923 (0.566)
Year 7	-0.366645 (0.656)
Year 8	-0.07379 (0.929)
Year 9	0.5325032 (0.947)
Year 10	1.315615** (0.640)
Year 11	2.953612*** (1.118)
Year 12	1.886802*** (0.710)
Year 13	-0.464132 (1.013)
Obs.	1054
Controls	Yes

Notes. This table displays result of staggered difference-in-difference model and event study. The sample is defined as unemployment for the period 2004-2022 and for the coal plant closures from 2000-2022 in the local authority in England. Parentheses contain the se. Significance Levels: * = 10%, ** = 5%, *** = 1%

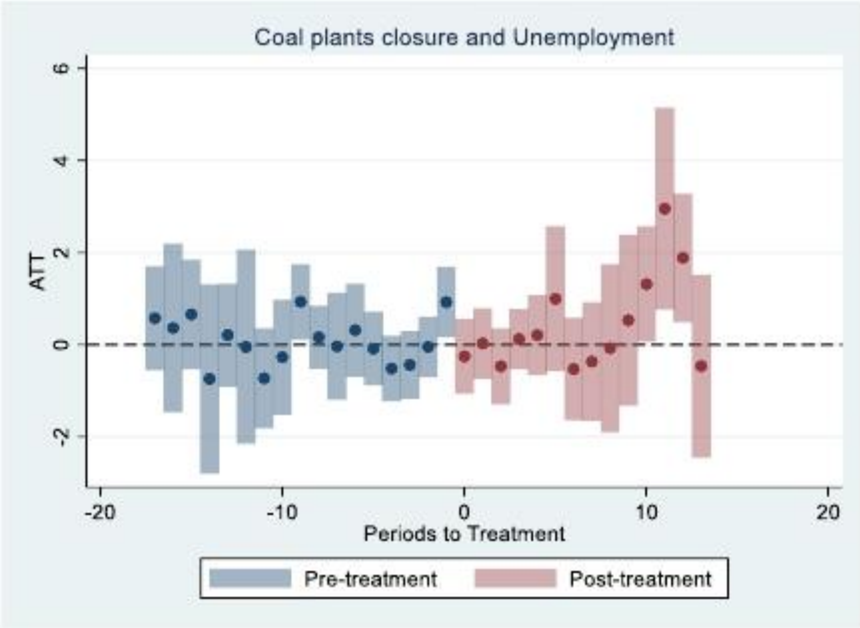

Figure 6. Potential Parallel Trends in unemployment

II. These emission results are in logarithms.

	Nitrogen Dioxide (NO2)	**Nitric Oxide (NO)**	**PM10**
Differences in Differences Model			
Closures X Post	-0.152*** (0.054)	-0.088 (0.192)	-0.038 (0.438)
Event Study Model			
Year -13	-0.084* (0.046)	-0.017 (0.074)	0.031 (0.021)
Year -12			0.018 (0.015)
Year -11	-0.029 (0.030)	-0.265** (0.087)	0.022 (0.033)
Year -10	-0.031 (0.072)	0.250 (0.217)	-0.059* (0.030)
Year -9	0.094* (0.055)	-0.236 (0.167)	-0.023 (0.021)
Year -8	0.004 (0.047)	-0.116* (0.060)	0.001 (0.020)
Year -7	-0.005 (0.191)	-0.280 (0.228)	-0.046 (0.037)
Year -6	-0.109 (0.102)	0.101 (0.190)	-0.058 (0.066)
Year -5	0.069 (0.058)	0.031 (0.091)	-0.010 (0.035)
Year -4	0.049 (0.078)	0.054 (0.074)	0.015 (0.035)

Year -3	-0.040 (0.063)	-0.019 (0.084)	0.072 (0.049)
Year -2	-0.048 (0.042)	-0.094 (0.075)	-0.034 (0.066)
Year -1	0.061 (0.043)	0.099 (0.094)	0.028 (0.047)
Year 0	-0.027 (0.076)	0.109 (0.080)	0.0004 (0.053)
Year 1	-0.110** (0.047)	-0.129 (0.129)	-0.035 (0.133)
Year 2	-0.135*** (0.039)	-0.085 (0.081)	-0.131 (0.148)
Year 3	-0.311*** (0.092)	-0.321*** (0.081)	-0.091 (0.059)
Year 4	-0.365*** (0.062)	-0.255* (0.136)	-0.061 (0.075)
Year 5	-0.186*** (0.024)	-0.400*** (0.052)	0.019** (0.008)
Year 6	-0.228*** (0.031)	-0.309*** (0.068)	0.033*** (0.012)
Year 7	-0.169*** (0.039)	0.122** (0.058)	-0.105*** (0.016)
Obs.	410	410	374
Controls	Yes	Yes	Yes

Notes. This table displays result of staggered difference-in-difference model and event study. The sample is defined as emissions in the local authority and coal plant closure from 2000-2022 in England. Parentheses contain the p-value. Significance Levels: * = 10%, ** = 5%, *** = 1%

III. This includes the results for Control 2: All the local Authorities included irrespective of having a coal plant or not.

1. Hospital Admissions

Table 7. Hospital Admissions (control2)

	Log(Emergency Hospital Admissions for Respiratory Diseases)_ YC1_All	log(Emergency Admissions for Children with lower tract infections_YC1_All)	Log(Hospital Admissions for Asthma) (aged 19 years and over)_YC1_All	Log(Hospital Admissions for Asthma) (aged under 19)_YC1_All
Difference-in-Difference Model				
Closures X Post	-0.038*** (0.012)	-0.064 (0.042)	-0.074* (0.031)	0.044 (0.043)
Event Study				
Year -8	-0.013099 (0.0253449)	0.0340801 (0.0509884)	-0.0429573 (0.0556719)	0.0908005** (0.0361001)
Year -7	-0.0117598 (0.0278922)	-0.0591804 (0.1411807)	0.1243739 (0.0795393)	-0.1289544 (0.0926188)

Year -6	0.008205 (0.0112852)	0.0834916* (0.0437206)	0.0609106** (0.0292693)	0.028003 (0.0348506)
Year -5	-0.0074152 (0.0112127)	-0.0877633 (0.0604025)	-0.0219352 (0.032706)	0.0456676 (0.0361256)
Year -4	-0.0128612 (0.0099194)	-0.0435478 (0.0492223)	0.0142787 (0.045875)	-0.1588*** (0.043565)
Year -3	0.001143 (0.018456)	0.013868 (0.0340152)	-0.0615586* (0.0351929)	0.0145339 (0.0395125)
Year -2	0.0073579 (0.0172274)	-0.0085806 (0.038024)	0.0697426** (0.0348634)	-0.0287416 (0.0402403)
Year -1	0.017407 (0.0116232)	0.0713098* (0.0382686)	0.0461265 (0.0286925)	-0.013746 (0.0346974)
Year 0	-0.0254875 (0.0130897)	-0.0209127 (0.0396623)	-0.0705366*** (0.0269486)	0.0435643 (0.0364365)
Year 1	-0.0277626* (0.0145467)	-0.0468185 (0.0575074)	-0.0920562* (0.0477126)	0.0577187 (0.0422561)
Year 2	-0.0600844*** (0.0209591)	-0.1418456** (0.0591607)	-0.0872853** (0.0429965)	-0.0376582 (0.0793473)
Year 3	-0.0639464*** (0.0206059)	-0.0942127 (0.0788877)	-0.1336733*** (0.047917)	0.0182081 (0.0761865)
Year 4	-0.0130238 (0.0174266)	0.1265268 (0.0798876)	-0.0513825 (0.0522912)	0.1013096 (0.0803028)
Year 5	-0.0730579*** (0.023962)	-0.4167601*** (0.0673656)	0.0887614 (0.0826496)	0.1850164*** (0.0508023)
Obs.	2,123	2,100	2,123	2,122
Controls	Yes	Yes	Yes	Yes

Notes: This table displays result of staggered difference-in-difference model and event study. The sample is defined as hospital admissions in the local authority for the period 2013-2020 and coal plant closure from 2000-2022 in England. Parentheses contain the p-value. Significance Levels: * = 10%, ** = 5%, *** = 1%

2. Mortality

Table 8. Mortality (control2)

	l(Under 75 Mortality) YC1_All	Under 75 Most Deprived (with pop as covariate) YC1_All	Under 75 Least Deprived (with pop as covariate) YC1_All	Log (Mortality due to Asthma) YC1_All	Mortality Due to Respiratory Diseases YC1_All	Mortality Over 75 years YC1_All
Differences in Differences Model						
Closures X Post	-0.0082394 (0.0085337)	-24.3006*** (8.420592)	1.628688 (4.945315)	0.082995** (0.0378458)	5.84747 (12.73326)	-22.82875 (36.07144)
Event Study						
Year -20	0.0173049 (0.0131714)					

Year -19	-0.0218373** (0.0105387)	-37.0695*** (9.276531)	-1.363121 (5.747931)			
Year -18	-0.0068214 (0.0065338)	-11.10936 (9.355794)	-1.294364 (8.435937)			
Year -17	0.001989 (0.0060102)	-0.7697263 (9.123552)	-5.972813 (4.409421)			
Year -16	0.0079617 (0.0053417)	12.25721*** (4.317784)	7.43316** (3.248185)			
Year -15	-0.0018724 (0.0048122)	-5.10187 (4.570212)	-5.799491 (4.325721)	0.1038606 (0.0639404)		
Year -14	-0.000719 (0.004177)	-1.663013 (6.461924)	-0.7688024 (3.336677)	0.2180543*** (0.0319445)		
Year -13	0.0000163 (0.0036387)	-4.374816 (3.829981)	0.6752391 (3.017983)	-0.1358644 (0.0945772)		
Year -12	0.0024916 (0.0039461)	3.242585 (3.940093)	1.600352 (2.961856)	0.0021402 (0.0555684)		
Year -11	-0.0056609 (0.0035346)	-1.797862 (3.95316)	-6.08901** (2.85825)	0.0574397 (0.072742)		
Year -10	0.0023235 (0.003682)	3.111859 (3.485671)	-3.020148 (2.701099)	-0.0245674 (0.0513288)		
Year -9	0.0027103 (0.0034222)	3.645172 (3.680561)	1.973191 (2.189796)	0.044198 (0.0604079)		
Year -8	0.0026797 (0.0032939)	1.865357 (3.206553)	0.1915735 (2.530556)	-0.0693691 (0.0407578)	-15.6830*** (4.987302)	-20.52542 (35.02539)
Year -7	-0.0073365** (0.0034998)	2.240393 (3.335245)	-0.9030412 (2.16475)	0.0617397 (0.0504412)	5.517335 (13.06632)	-45.9491** (23.22522)
Year -6	-0.003384 (0.0029435)	1.166795 (2.942403)	-2.848005 (1.901245)	-0.0078891 (0.0387239)	-14.32246 (10.86676)	2.409266 (18.01078)
Year -5	-0.0010432 (0.0026936)	-3.558003 (3.52518)	1.279891 (2.011056)	0.0404175 (0.0255675)	13.17756 (9.317124)	-54.7633** (23.30975
Year -4	0.0060682* (0.0031933)	-2.383874 (3.305248)	3.941545 (2.556598)	-0.04485* (0.0233293)	10.66738 (9.223735)	10.33822 (29.8655)
Year -3	-0.0000441 (0.0026817)	2.765033 (3.760271)	-3.282357 (2.647319)	-0.0060661 (0.03413)	-16.03319 (10.68294)	13.32222 (31.59422)
Year -2	0.0007279 (0.0037675)	-0.9752341 (3.654285)	-0.7045858 (2.295381)	0.0568936 (0.0378081)	5.200663 (8.174642)	-23.83192 (21.81487)
Year -1	-0.0025083 (0.0040844)	-2.730378 (3.531299)	-5.44495** (2.650412)	-0.1150603*** (0.0344063)	4.49513 (9.361184)	8.948427 (19.03501)
Year 0	-0.0002209 (0.0037494)	-10.20149** (4.55799)	1.225108 (2.50306)	0.0651374* (0.0386248)	2.512814 (12.66429)	-33.20883 (27.46488)
Year 1	-0.0038374 (0.0073457)	-9.036948 (7.133794)	7.412298 (3.240193)	0.0204818 (0.039689)	14.43807 (15.38216)	-37.82925 (30.06306)
Year 2	-0.0024378 (0.0093065)	-3.125412 (10.89656)	8.861494* (4.764169)	0.0854814** (0.0408163)	8.051915 (11.09015)	-2.188454 (36.90559)
Year 3	-0.0035061 (0.0087444)	-14.97426 (10.1986)	10.95732** (5.232579	0.1018236*** (0.0366183)	19.36653 (15.75231)	-12.35836 (38.86352)

Year 4	0.0095954 (0.0093138)	-46.3914*** (11.8293)	-2.785211 (7.541102)	0.121603** (0.0517532)	0.7778002 (23.51092)	30.3974 (46.71459)
Year 5	0.0092519 (0.0137879)	-45.2353*** (13.52128)	-0.5232307 (7.460553)	0.1415061*** (0.0444227	-26.21206 (26.86487)	-30.38333 (90.06567)
Year 6	-0.025531 (0.0176546)	-40.1821*** (12.05591)	1.957002 (8.159666)	0.1834766*** (0.0573135)		-77.98333 (121.2199)
Year 7	-0.0188391 (0.020453)	-33.78241** (16.21655)	3.870032 (10.9014)	0.155603** (0.0616347)		
Year 8	-0.019455 (0.019871)	-55.4867*** (18.43476)	-14.26804 (10.5098)	0.1673611 (0.1026352)		
Year 9	-0.0194926 (0.0239696)	-53.6959*** (19.37308)	-18.85468* (11.11537)	0.0544069 (0.0870418)		
Year 10	-0.058522** (0.0236002)	-57.3115*** (17.42597)	-16.16176 (12.38575)	-0.1911352 (0.1326841)		
Year 11	-0.0447006 (0.0207728)	-50.0310*** (17.77402)	-11.1361 (14.41416)	-0.2893884 (0.2461871)		
Year 12	-0.045647*** (0.0167121)			-0.2726171*** (0.0752923		
Year 13	-0.0317366** (0.0149195)			-0.2998847*** (0.0543154)		
Obs.	4,721	3,887	3,887	3,863	898	1,260
Controls	Yes	Yes	Yes	Yes	Yes	Yes

Notes. This table displays result of staggered difference-in-difference model and event study. The sample is defined as mortality for the period 2013-2020 and the coal plant closure for the period 2000-2022 in the local authority in England. Parentheses contain the se. Significance Levels: * = 10%, ** = 5%, *** = 1%

3. Disease Prevalence

Table 9. Disease Prevalence

	COPD Prevalence YC1_ALL	Asthma Prevalence (all ages) YC1_ALL
Differences in Differences Model		
Closures X Post	0.0195162 (0.0192142)	-0.0540238* (0.0307176)
Event Study		
Year 12	0.0289215 (0.0266929)	0.03239 (0.0459859)
Year 11	0.0215913 (0.0180438)	0.0172276 (0.0654495)
Year 10	0.0121546 (0.0207443)	0.0019037 (0.0482117)
Year 9	0.0032514 (0.0108501)	-0.0022916 (0.031714)

Year 8	-0.0068548 (0.0047436)	-0.0000818 (0.0162627)
Year 7	0.0046715 (0.0082093)	-0.015959 (0.0214808)
Year 6	-0.003976 (0.0091313)	0.0181301 (0.0248439)
Year 5	0.0037564 (0.0077234)	0.0192585 (0.0148581)
Year 4	0.029512 (0.0283413)	0.0572938*** (0.0157992)
Year 3	-0.0128847 (0.0205905)	-0.0036307 (0.0111366)
Year 2	0.0024246 (0.0054348)	-0.0170458 (0.0118631)
Year 1	0.015517 (0.0125384)	0.0304021** (0.0151162)
Year 0	-0.0068714 (0.0149094)	-0.0285873** (0.0132558)
Year 1	0.0086244 (0.0165312)	0.0011472 (0.0212352)
Year 2	0.0129522 (0.0201456)	0.0052605 (0.0306898)
Year 3	0.0265692 (0.0233045)	0.0339929 (0.0365046)
Year 4	0.0099755 (0.033258)	-0.0576756 (0.0512628)
Year 5	0.0013745 (0.0301058)	-0.2235047*** (0.0522229)
Year 6	0.0150868 (0.0341812)	-0.2099752*** (0.063461)
Year 7	0.0568858 (0.0441417)	-0.0928531 (0.0831306)
Year 8	0.1137582*** (0.0404409)	-0.1383744 (0.1255809)
Year 9	0.0765349 (0.0618564)	
Obs.	3,435	3,144
Controls	Yes	Yes

Notes. This table displays result of staggered difference-in-difference model and event study. The sample is defined as prevalence of diseases for the period 2009-2020 and the coal plant closure from 2000-2022 in the local authority in England. Parentheses contain the se. Significance Levels: * = 10%, ** = 5%, *** = 1%

4. Mental Health

Table 10. Mental Health

	Mortality Due to Diseases of Mental and Behavioural YC1_ALL	Log(Suicide Rate Male) YC1_ALL	Log(Suicide Rate Female) YC1_ALL
Differences in Differences Model			
Closures X Post	-1.713427 (4.536697)	-0.04889 (0.039002)	0.045182 (0.082286)
Event Study			
Year -20		-0.0654*** (0.0318101)	0.256123*** (0.0318101)
Year -19		0.154748*** (0.0267383)	-0.17064*** (0.0267383)
Year -18		-0.02809 (0.040714)	-0.04168 (0.079567)
Year -17		0.061844 (0.04266)	-0.04148 (0.069371)
Year -16		0.053918* (0.0320191)	0.062209 (0.05373)
Year -15		0.038419 (0.036926)	-0.04277 (0.041646)
Year -14		-0.01559 (0.033191)	0.117847* (0.0646834)
Year -13		0.001392 (0.027353)	0.02365 (0.066056)
Year -12		0.018079 (0.031672)	0.007404 (0.044782)
Year -11		0.007667 (0.029371)	0.020989 (0.047077)
Year -10		-0.03097 (0.033251)	-0.04067 (0.045436)
Year -9		0.037125 (0.030221)	0.075029 (0.057497)
Year -8	-6.54392 (15.32777)	-0.01164 (0.022899)	0.031584 (0.044241)
Year -7	-0.9020199 (7.375724)	0.052108** (0.0260583)	0.05971 (0.053746)
Year -6	-3.131446 (6.706624)	-0.05217** (0.0238365)	-0.00699 (0.050516)
Year -5	9.022464** (4.340394)	0.007344 (0.027225)	0.019285 (0.041798)
Year -4	-0.6219845 (6.226665)	-0.07592*** (0.0288497)	0.070421* (0.0373377)

Year -3	10.85957 (8.060079)	0.050165 (0.031721)	0.014 (0.041572)
Year -2	4.816517 (5.363124)	-0.01402 (0.029558)	0.025074 (0.02748)
Year -1	3.672716 (4.916108)	0.059848*** (0.0225954)	-0.03334 (0.041396)
Year 0	2.619226 (8.606192)	-0.03251 (0.032081)	0.062736 (0.050749)
Year 1	2.050444 (8.151607)	-0.05587 (0.036353)	0.09913 (0.096177)
Year 2	-8.240946 (8.049459)	-0.02683 (0.044295)	0.147944 (0.150505)
Year 3	-1.32557 (7.586363)	-0.06042 (0.060094)	0.093776 (0.163582)
Year 4	0.0860734 (6.604517)	-0.0355 (0.058455)	-0.03765 (0.120896)
Year 5	-21.09234* (10.99739)	-0.05568 (0.081558)	-0.1672*** (0.0513381)
Year 6		-0.07043 (0.092588)	-0.13364 (0.120387)
Year 7		-0.0571 (0.096664)	0.048706 (0.147036)
Year 8		-0.20637** (0.0983968)	0.020762 (0.156508)
Year 9		-0.12166 (0.147686)	-0.30421*** (0.0889066)
Year 10		-0.06563 (0.097074)	
Year 11		0.16832*** (0.0624142	
Year 12		0.108493 (0.067373)	-0.35938*** (0.0767026)
Obs.	898	2,254	1,695
Controls	Yes	Yes	Yes

Notes. This table displays result of staggered difference-in-difference model and event study. The sample is defined as mental health for the period 2001-2019 and for the coal plant closures from 2000-2022 in the local authority in England. Parentheses contain the se. Significance levels * = 10%, ** = 5%, *** = 1%

Empowerment and Nutrition: Analyzing Women's Food Consumption through Socio-Economic Lenses using NFHS 5 data

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Abstract: *The food security of women is contingent upon their economic status, education levels, health, and their position within the family and society and these factors are closely linked to a woman's own nutritional status. In this paper we try to analyze how the consumption of certain food items by women is affected by various socio economics factors using the NFHS 5 dataset. It has been found that mobility, decision making power, financial autonomy, higher education, wealthier household and employment have a positive impact on the consumption of food items.*

Introduction

A situation of food security arises when "all the people, at all the times, have physical availability and economic access to adequate, safe and healthy food to fulfill their food preferences and dietary needs for an active and healthy life" (FAO, 1996).
Food security encompasses the consumption of high-quality food containing sufficient calories, along with essential micro and macro nutrients. Despite the rapid economic growth in India, the enhancement of nutritional well-being among both children and adults has shown only marginal improvements. Although the National Food Security Mission has boosted the production of pulses and cereals, agricultural yield has diversified into fruits, vegetables, and dairy, indicating improvements in the overall quality of diets. Despite significant investments in the agricultural sector, the increase in production has not swiftly and comprehensively translated into improved nutritional statuses for children and adults (Narayan 2015).

Nutritional health is a characteristic of an individual and not the household. The dietary quality and the average nutrient intake of any household is the most significant determinant in the welfare of its members, nutritional welfare is experienced individually. The household is the most dominant institution to affect the nutritional well being of the individuals. Therefore it is crucial to recognize how individual members are allocated resources within the household (Villa et al 2011). Food distribution within households exhibits a bias favoring adult males both in terms of quantity and priority. Some families display preferential spending on economically productive members, often adult men. Mother's income is positively related to their own calorie intake. Qualitative studies reveal a belief among the respondents that adult males are given priority, particularly in matters of nutrition and delicacies. Typically, the household's manager or earner, handling both household lands and non-agricultural income, is a man unless an adult male is absent. Elderly individuals receive favored and nutritious food as recognition for past economic contributions. Discrimination against women is influenced by individual body mass and energy spending, with those engaged in energy-intensive activities receiving a higher food allocation. Certain household work by women is often perceived as less energy-intensive than men's fieldwork. Individuals with a perceived higher status in the family are favored in allocating high-status or special foods. (Abdullah 1983, Palriwala 1993, Harris-Fry 2017, Rathnayake and Weerahewa 2002, Haddad et al 1996).

A woman's societal status is influenced by gender norms, personal attributes, and achievements. Perceptions of women within their social environment also contribute to shaping their status. The food security of women is contingent upon their economic status, education levels, health, and their position within the family and society. Women with lower status experience limited control over family resources, lower self-esteem, and restricted access to health services, among other challenges. These factors are closely linked to a woman's own nutritional status (Ramachandran 2004). Historically, as women's status within the family increased with age and the birth of children, particularly sons, they were allocated more nutritious food. However, with the rise of urbanization and modernization, the influence of status on food allocation has diminished (Gittelsohn 1991).

The NFHS 5 has collected data on the frequency of the consumption of seven food categories: **milk, pulses, green leafy vegetables, fruits, eggs, fish and chicken**. The data was collected on how often these foods are consumed by men and women: Daily, weekly, occasionally or never. Around 47 % of women consumed leafy vegetables daily and 38 % consumed them on a weekly basis. Almost 45 % women consumed pulses daily as well as weekly. Milk and curd are being consumed by around 45 % women on a daily basis and weekly by 23 %. Coming to fruits, around 54 % women did not consume fruits even once a week. About one third of women consumed non vegetarian foods like chicken, fish, meat and eggs on a weekly basis. This pattern of food consumption has remained more or less similar since the last NFHS survey in 2005-06. Since the last survey an increase in the daily consumption of milk and curd and a decrease in the daily consumption green leafy vegetables in both men and women has been seen.(NFHS 5: India)

Power Dynamics and Autonomy in Gendered Household Roles: Reviewing the Literature

Gender relations encompass the tangible power dynamics between men and women within both domestic and socio-economic spheres, as outlined by Hodgson and McCurdy in 2001. The concept of gender refers to socially constructed roles and responsibilities accepted by society for each gender. For instance, societal norms often designate women as primarily responsible for child-rearing and domestic duties due to their ability to bear children. These gender-defined roles extend to resource entitlements within households, influencing social, political, and behavioral outcomes (Marshal 1994).

In family settings, men and women assume distinct roles related to procuring, cooking, and distributing food. It is crucial to optimize their contributions by ensuring equitable access and control over resources, promoting food security. Research by Sharon in 2013 highlights that women, especially in developing nations, often have less control over resources compared to men. Nonetheless, studies reveal that when women have control over resources, the overall health and nutrition levels, particularly of women and children, significantly improve.

Women's autonomy manifests in three key domains: the freedom of movement, control over finances, and decision-making power, as identified by Bloom et al in 2001. Notably, studies indicate that when women possess decision-making authority, they tend to allocate food resources in a manner that maximizes nutritional outcomes for the entire household. The influence of women's control extends to production, purchasing, or income, shaping favorable food distribution outcomes for women (Haddad et al 1998, Nazli and Hamid 1999). Conversely, women with limited social mobility exhibit lower food allocations, as observed by Carloni in 1981. Educated women generally have access to resources because they are more likely to earn and thus are able to participate in decision making and thus have a high status and a greater bargaining power in the family. However some women despite being educated do not yield a bargaining power due to other reasons. (Chen &Li 2009)

The bargaining power of individuals within a household hinges on their "fallback position," representing the options available in the event of cooperation failure. Determinants of this fallback position encompass factors like parental wealth, non-wage income, and legal frameworks governing marriage and family. Resource ownership, particularly productive assets such as land, plays a pivotal role in determining bargaining power. Women possessing more productive resources tend to have a stronger fallback position, directly correlating with enhanced bargaining power (Agarwal 1997, Sen 1990).

Research findings suggest that household income has minimal influence on the nutritional status of females; however, an increase in female income significantly enhances nutritional outcomes for both men and women, as indicated by Messer in 1997. Women's employment not only amplifies their contribution to family income but also elevates their social standing, reducing reliance on males for sustenance. This economic independence grants them greater influence in household matters, thereby bolstering their bargaining power. Additionally, women with higher status and education are less likely to discriminate against their daughters, attributed to their increased knowledge and control over resources. In the context of marital dynamics, exogamous women, separated from their natal families after marriage, may experience reduced status and control over resources, potentially leading to preferences for sons and insufficient support for daughters. Conversely, endogamous women, residing in proximity to their natal place, enjoy superior social and familial status. It is agreed that higher education level in women is associated with her and her family’s well being. Education increases women’s knowledge to make effective choices, their independence and control over resources. (Bose, 2011)

The presence of female decision-makers in households is linked to improved nutritional outcomes, resulting from optimized food allocation. However, despite potential benefits, disparities in food allocation towards women may persist due to the overarching responsibility to ensure everyone in the household is adequately fed, as discussed by Harris-Fry et al. in 2017. Despite limited social mobility, women might encounter fewer inequalities in this context, given the historical precedent of women traditionally having more control over food allocation within the household (Harris-Fry et al., 2017).

A large family size can often affect the food consumption especially for the women. Familial hierarchy and larger size of a household has significant impact on food intake by women. It has been found a higher calorie intake for women in larger households (Rathnayake and Weerahewa 2002). Contrarily, another study showed a higher calorie intake by males in large household sizes (Chaudry R 1983).

Methods

Data Source

We used the data from the nationwide National Family Health Survey, round 5, conducted in 2019-20. It is conducted by the Ministry Of Health and Family Welfare, coordinated by the International Institute of Population Sciences, Mumbai. NFHS 5 was conducted in two phases for approximately 636,699 households, with a sample of 724,115 women and 101,839 men who were eligible for interviewing. 4 survey questionnaires were used; household, woman, man, biomarker. For our analysis only the women's and men's questionnaire has been used. It collected information from all eligible men and women aged 15-49 about a variety of topics; on women's characteristics, fertility, marriage, nutrition, reproductive health, domestic violence, sexual behavior, HIV/AIDS and childcare (NFHS 5: India)

The NFHS 5 collected data on the frequency of the consumption of seven food categories: **milk, pulses, leafy vegetables, fruits, eggs, fish and chicken**. The data was collected on how often these foods are consumed by men and women: Daily, weekly, occasionally or never. In the analysis the consumption of food on a daily and weekly basis is combined and the consumption of food occasionally and never is clubbed together. We assign a value of 1 if the respondent consumes the food item on a daily or weekly basis, otherwise value 0 is assigned. The dependent variables used in this study thus becomes dichotomous; coded as 1 and 0 implying that logistic regression would be an appropriate method. We ran seven regression models, one for each food item.

We used NFHS 5 data to see the impact of women's empowerment on their food consumption. NFHS 5 includes information on the frequency of various food items for both men and women. According to table 1, urban women consume more of these food items at least once in a week than rural women. It can be seen in the table below that women who completed more years of schooling have better consumption than women with no or less schooling especially in consumption of milk and fruits. It shows that women with higher education tend to lead a healthy eating behavior. The consumption of milk/curd, fruits and fish is higher among higher caste women compared to lower caste women. Among other food category the difference is negligible. The consumption of milk/curd, pulses and fruits is higher among rich class. Thus, deficiency in diet is found among women with less or no schooling, residing in rural areas and belonging to lower caste and poorer household. (NFHS 5: India)

Table 1: Percentage of women age 15-49 consuming specific foods at least once a week by background characteristics, India: 2019-21

Background characteristic	Milk or curd	Pulses or beans	Dark green, leafy vegetables	Fruits	Eggs	Fish	Chicken or meat	Number of women
Age								
15-19	69.8	91.9	89.4	47.0	43.1	32.8	33.7	122,544
20-29	72.6	93.1	91.3	51.9	46.0	35.7	36.8	236,584
30-39	72.4	93.3	91.1	49.7	46.0	36.8	36.7	197,936
40-49	73.3	93.0	90.7	48.4	44.2	36.5	35.4	167,051
Residence								
Urban	78.8	94.2	91.3	64.5	51.9	38.9	42.4	235,279
Rural	69.1	92.3	90.6	42.5	41.8	34.2	32.8	488,836
Schooling								
No schooling	66.0	92.1	90.1	34.3	41.2	31.9	33.9	163,492
<5 years complete	62.9	91.7	91.3	38.6	51.7	45.7	41.3	37,549
5-7 years complete	69.4	92.8	90.7	44.1	46.1	36.7	37.4	96,806
8-9 years complete	68.4	92.7	91.0	46.7	44.4	37.0	34.5	129,094
10-11 years complete	76.3	93.1	90.5	56.3	47.9	37.5	38.4	109,777
12 or more years complete	81.3	94.0	91.4	66.4	45.4	34.6	35.3	187,396
Religion								
Hindu	72.9	93.3	91.2	48.9	41.5	32.4	32.0	589,164
Muslim	68.2	91.9	89.5	51.4	65.6	54.4	58.1	97,595
Christian	69.6	86.9	81.8	58.8	70.9	63.2	61.6	16,995
Sikh	83.8	91.0	93.5	60.0	13.4	4.2	7.0	11,404
Buddhist/Neo-Buddhist	67.5	89.1	91.3	52.2	59.6	42.0	54.8	4,571
Jain	92.2	98.6	95.2	78.7	6.7	2.6	3.3	1,632
Other	38.9	90.6	91.4	36.4	46.8	41.9	39.4	2,754
Caste/Tribe								
Scheduled caste	68.7	92.2	90.6	44.4	48.4	37.4	37.7	158,483

Scheduled tribe	54.9	90.3	91.0	37.4	46.4	36.0	37.1	67,263
Other backward class	76.5	93.6	90.2	50.3	42.7	32.4	33.7	310,783
Other	74.9	93.5	91.9	57.9	45.7	39.6	37.5	182,474
Don't know	57.9	91.3	91.1	44.0	50.5	43.9	41.6	5,112
Wealth quintile								
Lowest	52.6	91.3	91.1	26.8	41.4	38.5	31.5	133,973
Second	65.9	92.2	90.7	37.9	45.0	37.2	35.3	144,813
Middle	74.5	92.7	90.1	48.3	48.4	36.7	39.1	148,616
Fourth	80.1	93.6	90.2	59.4	48.0	36.2	39.4	150,680
Highest	86.2	94.7	91.9	73.7	42.2	30.2	33.7	146,032
Total	72.2	92.9	90.8	49.7	45.1	35.7	35.9	724,115

Source: NFHS 5

The frequency of consumption of these food items by women is presented in table 2. Amongst these categories, the consumption of milk, pulses, and green vegetables is higher. Approx 49 percent women consume milk/curd daily, 23 percent women consume weekly and 22 percent consume occasionally but there are 6 percent women who never consume milk/curd. Half of the women consume pulses/ beans on a daily basis and an additional 43 percent consume on a weekly basis. The consumption of fruits among women is inadequate. Only 12 percent women consume fruits daily and 48 percent consume occasionally. Very few women consume eggs, fish, and chicken/meat daily. Mostly women never consume these non-vegetarian food items.

Table 2: Frequency of consumption by women

Percent distribution of women age 15-49 by frequency of consumption of specific foods, India, 2019-21						
Frequency of consumption						
Type of food	**Daily**	**Weekly**	**Occasionally**	**Never**	**Total**	**Number**
Milk or curd	48.8	23.5	21.9	5.8	100	724,115
Pulses or beans	49.6	43.3	6.7	0.4	100	724,115
Dark green, leafy vegetables	52	38.8	8.9	0.3	100	724,115
Fruits	12.5	37.1	48.7	1.6	100	724,115
Eggs	5.2	39.9	26.9	28	100	724,115
Fish	5.1	30.6	29.9	34.4	100	724,115
Chicken, meat	1.4	34.5	32.6	31.5	100	724,115

Source: NFHS 5

Explanatory variables

1. Bargaining power: Several studies have used a wide range of indicators as proxy to measure women's bargaining power. In line with the previous studies, we employ the following indicators to measure women's bargaining power:

1.1 Mobility: To capture this we included three questions; usually allowed to go to market, allowed to go to health care, and allowed to go to places outside this village provided by NFHS. We used principal component analysis to construct a mobility index.

1.2 Decision making: We again used principal component analysis using three questions (who usually make decides on respondent's health, on large household purchases and her visits to family and friends) to construct a decision making index.

1.3 Financial autonomy: Coded as 1 if respondent has money that she alone decide on how to use, otherwise 0.

2. Educational attainment: Four dummies have been used in this study: No education coded as 0, primary education coded as 1, secondary education coded as 2 and higher education coded as 3.

3. Employment: Status of respondent is coded as 1 if employed and 0 if unemployed, in the paper.

4. Wealth Index: A composite index based on 33 assets ranging from a pressure cooker to a tractor and housing characteristic such as type of toiled facility, drinking water source, type of windows etc. It was constructed by NFHS itself, coded as 1 for "poorest", 2 for "poorer" ,3 for "middle", 4 for "richer" and 5 for "richest".

5. Family size: We divided family size into two category and coded as 1=small if family members are less than and equals to 5 and 2= large if family members are greater than 5.

6. Area: We used the codes as 1 if it is an urban area and 2 in case of rural area.

7. Caste: Coded as 1 in case of schedule caste, 2 if schedule tribe and 3 if respondent belongs to general category as control variables.

Analysis

The regression results are presented in tables 3 and 4. We ran seven different logit regressions to examine the effect of all explanatory variables on all the seven food items.

Table 3: Regression results for vegetarian food items:

VARIABLES	Milk	Pulses	Leafy Vegetables	Fruits
Mobility	0.155***	0.171***	0.250***	0.142***

Decision Making	-0.129***	0.0793**	0.157***	-0.0414**
Have own money to spend	0.0379*	0.244***	0.248***	0.106***
Age Category	0.140**	0.250***	0.0713	-0.0774
Education				
Primary	-0.196***	-0.0822*	0.0782	0.149***
Secondary	-0.127***	-0.0764*	0.0884**	0.374***
Higher	0.161***	0.0951	0.247***	0.829***
Wealth				
Poorer	0.528***	0.0308	-0.0137	0.359***
Middle	0.925***	0.110**	-0.0641	0.683***
Richer	1.277***	0.159***	-0.0962*	0.949***
Richest	1.709***	0.426***	0.0235	1.370***
Caste				
Scheduled Tribe	-0.495***	-0.760***	0.013	0.122***
OBC	0.194***	0.0691	-0.0118	0.0610**
None of them	0.188***	0.0772	0.223***	0.183***
Don't know	-0.521***	-0.114	-0.0435	-0.257**
Family Size of household	0.029	0.196***	0.183***	- 0.0819***
Employment status of women	0.0109	-0.117***	-0.155***	-0.0176
Area of residence	0.263***	0.0999**	-0.011	-0.214***
Constant	-0.535***	1.737***	1.762***	-0.746***
Observations	54,816	54,816	54,816	54,816
Level of significance: *** p<0.01, ** p<0.05, * p<0.1				

Table 4: Regression results for Non Vegetarian Food Items:

VARIABLES	Eggs	Fish	Chicken
Mobility	-0.0424	- 0.0876***	-0.0507*
Decision Making	-0.0537***	0.0930***	- 0.0697***
Have own money to spend	-0.0975***	- 0.0589***	-0.104***
Age Category	-0.138**	-0.065	-0.196***
Education			
Primary	0.128***	0.289***	0.0447
Secondary	0.285***	0.476***	0.212***
Higher	0.304***	0.523***	0.136***
Wealth			

Poorer	0.123***	-0.0958***	0.176***
Middle	0.175***	-0.252***	0.235***
Richer	0.0595*	-0.395***	0.197***
Richest	-0.362***	-0.911***	-0.274***
Caste			
Scheduled Tribe	0.279***	0.331***	0.456***
OBC	-0.118***	-0.0603**	-0.0886***
None of them	-0.351***	-0.186***	-0.275***
Don’t know	-0.102	0.0425	-0.0338
Family Size of household	-0.313***	-0.290***	-0.312***
Employment status of women	0.0991***	-0.0782***	0.0623***
Area of residence	-0.572***	-0.547***	-0.551***
Constant	0.833***	0.384***	0.520***
Observations	54,816	54,816	54,816
Level of significance: *** p<0.01, ** p<0.05, * p<0.1			

Mobility or the freedom of movement is positively related to the consumption of milk, pulses, leafy vegetables and fruits, indicating if women have greater freedom of movement then she is more likely to increase her well being by incorporating a variety of nutritional food into her diet. The results are also significant at 1 % level of significance. But in case of non vegetarian food items, mobility is not positively associated.

Women’s **decision making** power, measured by their involvement in taking decisions regarding their health, household purchases, visits to family etc is positively related to the intake of pulses, leafy vegetables and fish, suggesting greater decision making helps with increased nourishment.

Financial autonomy is significantly more likely to increase the frequency of the consumption of milk, pulses, vegetables and fruits but less likely to have non vegetarian food items. Financial independence gives women some power to reallocate resources towards her own well being. These results show that women with great autonomy can improve their nutrition intake.

As compared to no education, women with **higher education** are significantly more likely to have high nutritional food. Results are positive and significant for milk, leafy vegetables, fruits, eggs, fish and chicken, meaning better education can help women change the practices that contribute to poor health. Better education not only positively affects them but also ensures the family’s well being by promoting a balanced diet.

Women who are **employed** are positively related to their consumption of egg, chicken and milk. Results are significant only for egg and chicken. On the other hand, employed women are significantly less likely to consume pulses and leafy vegetables.

Women belong to Scheduled Tribe are significantly more likely to consume eggs, fish and chicken but less likely to consume dairy products and pulses. Results are significant at 1% level of significance. Women belonging to OBC or General caste are more likely to consume milk and fruits but less likely to consume meat and eggs. These results are also significant.

Women of **wealthier** households are more likely to have a higher consumption of milk, fruits and pulses. As compared to higher level of household wealth, women of poorer and middle income households are significantly more likely to consume eggs and chicken.

Women belonging to **larger families** are significantly less likely to consume fruits, meat and eggs and more likely to consume pulses and leafy vegetables. Results are significant at 1% level of significance.

Women residing in **rural** areas are negatively associated with the consumption of eggs, chicken, fish, leafy vegetables and fruits and positively associated with milk and pulses. Results are significant for all food items except leafy vegetables.

A well balanced diet is of utmost importance to achieve a healthy life and should be a priority for everyone irrespective of their gender. In India, men and boys are given priority on food in terms of both quantity and quality. It is one of the basic human right but still mostly women and girls suffer from malnutrition because of such discrimination. To achieve the sustainable development goal of zero hunger (Goal 2: Zero hunger), we need to empower women so that they can claim their rights and improve health and nutrition for themselves as well as for their families because women are the ones who make most of the food related decisions in their families.

While female autonomy indicators like mobility and financial control enhance vegetarian food consumption, they do not significantly drive the consumption of non-vegetarian foods. Cultural, religious, and socio-economic factors continue to dominate dietary choices in India, underscoring the deep-rooted nature of vegetarianism in the country. In many households, women are traditionally responsible for maintaining dietary practices, including vegetarianism. This role is often seen as part of their duty to uphold family and cultural values. . Despite increased autonomy in other areas, such as decision-making and mobility, women might still conform to established dietary norms to fulfill societal expectations and maintain harmony within the household. While men might have the flexibility to eat non-vegetarian food outside the home without significant moral repercussions, women are expected to uphold these traditions within the household. Meat consumption is often associated with masculinity and strength, reinforcing gender stereotypes. This association further entrenches the gender gap in dietary practices, making it challenging for changes in female autonomy to translate into significant dietary shifts. Thus strong cultural, religious, and gendered foundations of vegetarianism in India explain why female autonomy does not substantially affect non-vegetarian food consumption (Johnston et al 2021, Natrajan & Jacob 2018)

As is visible from the results of this paper that empowerment of women will lead to better health outcomes within households due to an improvement in the consumption if nutritious foods. Women with greater autonomy and bargaining power within the family are more likely to allocate resources towards healthier food options, hence enhancing the overall well being of the family.

Conclusion

In a developing country like India the distribution of limited food among all the family members is a tough decision. Despite having enormous economic growth, India is ranks 111th out of 125 countries in the Global Hunger Index. A woman is the prime distributor of food in household, yet she ends up not receiving adequate nutrition due to the prevailing social and cultural practices. A woman's status is determined by societal gender norms, personal attributes and achievements.

The study reveals that women's food consumption is affected by various socio economic factors. Within the social environment, how others perceive a woman also shapes her status. Women's food security depends on their economics status, along with their education levels and their social status in their family and in the society. Women with low status have less control on the family's resources, low self esteem and little access to health services, among other things. These factors are closely connected to a woman's own nutritional status.

The results from this study contribute to the existing literature on food consumption patterns and gender dynamics in India. By signifying a strong positive correlation between women's autonomy (here measured by mobility, decision-making power and financial independence) and the consumption of vegetarian food items, this study aligns with previous findings highlighting the importance of women's control over resources in improving household nutrition. Conversely, the limited impact of these indicators on the consumption of non-vegetarian food items emphasizes the influence of cultural norms and traditional dietary practices. This research reinforces the importance of promoting women's education and financial independence to enhance their bargaining power within households and thus strengthening household dietary diversity.

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Asymmetric Impact of Uncertainty measures: EPU, VIX, EVX and OVX on Commodity Prices

Abstract

Commodity price fluctuations are the main drivers of economic development, impacting many areas of the economy. This study takes a comprehensive approach, analyzing the effect of shocks that arise with uncertainty, such as stock market uncertainty (VIX), economic policy uncertainty (EPU), exchange rate uncertainty (EXV), and oil volatility on the volatility of commodities prices (OVX). The study applies the nonlinear Autoregressive-distributed Lag (NARDL) approach, a robust methodology that captures both the long and short-run nonlinearities through positive and negative partial sum decomposition of the explanatory variables. The findings of the study show that EPU positively affects commodity prices, whereas VIX inversely affects them. OVX positively affects commodity prices, while EXV does not impact commodity prices in the short run. However, in the long run, EPU has a negative impact on commodity prices. Similarly, VIX and EXV negatively affect commodity prices in the long run. In the long run, positive (negative) changes in oil volatility

increase (decrease) commodity prices. These findings hold significant implications for policymakers and stockholders, equipping them with valuable insights to hedge their assets and portfolios during uncertain periods.

Keywords: Uncertainty, Commodity prices, NARDL model

Introduction

Markets of commodities are the oldest markets, and these markets originated several centuries ago, around 4500 BC. The rationale for the traditional roots of the primary commodity market is that these markets were fundamental markets within which import and export of manufactured products (like food, sugar, gold, etc.). The prices of such commodities are mainly influenced by the supply and demand laws (for commodities). As time passes, commodities markets become more sophisticated. They are being subjugated by the traditional market participants in commodity consumers and producers (Triantafyllóu, 2020). Because of the speedy financialization of the commodity market, commodities became the more prominent asset class for the financial market participants as opposed to bonds, stocks, and derivatives due to increased risk and volatility. Several researchers (Erb & Harvéy, 2006; Gortón & Róuwenhorst, 2006; Źhang & Guesmĩ, 2017) discovered that the rapid inpouring of significant investment funds into the commodity market with a negative association between the stock exchange index and commodity market.

Accordingly (Triantafyllóu., 2018), markets of commodities are comparatively immune to abrupt variations within the stock market's economic policy uncertainties. What matters to the investors in the commodity market is their capability to forecast the abrupt volatility within the financial and macroeconomic sectors. Volatility in commodities plays a significant role in the dynamics of worldwide economic activity (Aharón., 2018; Ṟehman & Vó., 2021; Ḃahloul and Gupta., 2018). Commodity price fluctuations tend to be the main drivers of economic development, affecting many areas of the economy. Various studies indicate that the prices of commodities may serve as a vital predictor of the economy's future direction, as they are continually auctioned with efficient information in structured markets (Códy & Mĩlls, 1991; Mḁrquis & Cunnĩngham, 1990). Wḁugh. (1944) shows that customers favor price volatility more than price stability. On the opposite side, Oi., Ẃ (1961) suggests that concerning producers' price stability is more suitable. Mḁssell., (1969) supports the net outcome of the commodity prices stability for both the consumer and the producer using the projected value of change in surplus as a measure of gain, and the net gain is obtained from the stable commodities prices.

In the last few years, the correlation between commodities prices and uncertainty shocks has captured the focus, and it is indicated that uncertainty affects the volatility of commodity prices (Bakḁs & Triantḁfyllou, 2020; Lu & Yĩn, 2018; Bóuri et al., 2023). The investment decision of the speculative trader is influenced by uncertainty shocks on the prices of commodities. When an unpredictable event occurs, this causes a reduction in consumers' consumption activity, leading to a change in the prices of commodities. Hence, it is crucial to examine the impact of uncertainty on commodities. The effect of single uncertainty on commodity markets is examined by (-Karḁbulut, & Dóker, ƻ020; Razḁ eŧ al., ƻ018; Źhang & Ẃu, 2015; Tiḁn & Li., 2019; Bḁkas & Triantafyllóu, ƻ020; Ꞩu et aĺ., ƻ018). Triantafyllóu (ƻ020) found the negative effect of pandemic uncertainty on commodity prices. (Kḁrabulut eŧ aĺ., ƻ020) applies wavelet coherence analysis to determine the effect of world trade uncertainty (WTU) on commodity prices. Results show that WTU strongly impacted prices between 2009-2010 and 2015-2016. (Razḁ et al, ƻ018) find EPU significantly impacts gold prices using non-parametric causality in quantile analysis. Few studies determined the effect of several measures of uncertainty on commodities (Triantafyllóu, ƻ018; Hao & Tao, 2020b; Ḡozgor & Sheng, ƻ018). Such as (Bakḁs and Triantafyllóu ƻ018) use monetary and financial uncertainties on commodities and found that unobservable macroeconomic shocks have an impact on the volatility of commodities more than obvious macroeconomic shocks. Qin et al. (ƻ020) found an association between oil prices and uncertainty (such as EPU, Monetary, Fiscal EPU, and Trade EPU) using the Wavelet approach and provides a significant impact of EPU on oil prices. Furthermore, MEPU (monetary EPU) impacted the oil prices more than the FEPU (fiscal EPU) before Trump became president. In line with (Bakḁs & Triantafyllóu, 2018), an increase in macroeconomic uncertainty increases uncertainty in aggregate supply and demand, and hence, prices of commodities are linked with these aggregate demand and supply; therefore, volatility increases with the increase in macroeconomic uncertainty. But left to explore EPU, stock market volatility, oil price and exchange rate uncertainty with commodity prices, which this study analyzes in a non linear manner.

Uncertainty shocks, e.g., financial crisis-October 2008 (started with the crash of the subprime mortgage market in the USA). The Ȅuropean debt crisis (EDC) held in August 2011(the crisis that started with the collapse of financial institutions, high debt of government and increasingly growing bond yield spreads in the securities of government in many European countries), COVID-19 pandemic (coronavirus pandemic triggered by the severe sentiment syndrome, first detected in Wuhan, China in December 2019) have a specific effect on the demand of the commodities (Huang et al.., 2021). As emphasized, most of the current literature concentrates on the single factors dimension (Su et al., 2018), while commodity financialization shows the significance of news factors and has a multidimensional nature of the problem. From the experience of GFC 2007-09 and the EDC 2011, commodities are considered a safe investment. During the GFC of 2008-2009, the response of production and price level to the commodity price shocks intensify with the volatility in the world's stock market across countries (Kḁng et al., 2020b). The three dimensions discussed above are not necessarily isolated from each other, but they are ultimately connected in a complex structure. Empirical results may be considered biased without the involvement of all these three dimensions (Hu et al., 2020). To address this issue, we include all three dimensions and attempt to examine how large macroeconomic factors lead to commodity price volatility. This study addresses three questions: What is the impact of uncertainty (EPU, VIX, OVX, EXV) on the price volatility of commodities? What is the impact of positive and negative uncertainty shocks on commodity prices? Weather nonlinear relationship exists between uncertainty (EPU, VIX, OVX, EXV) and commodity prices?

Firstly, this research offers a wealth of insights into the impact of uncertainty shocks on the prices of commodities by using various uncertainty measures (EPU, VIX, OVX, EXV). Secondly, we examine uncertainty shocks' positive and negative impact on multiple commodities prices. This may give an idea of how widespread uncertainty affects the prices of commodities. Thirdly, this study employs the Nonlinear-Auto-Regressive Distributive lag (NARDL) model. It considers both the long and the short-run asymmetric behavior, permitting the testing of hidden co-integration. Although some of the previous literature (Bḁkas & Triantafyllóu, 2020) use vector autoregressive (VAR), Granger causality (Nichólas et al., 2021; Kḁrabulut et aĺ., 2020) and other models (ARDL, GARCH, CoVAR) but these models are not reliable for this study because the probability of direction of causal connections shifts with time. The recent economic situation is complex, and these methods cannot determine the long- and short-term nonlinearities through the positive and negative partial sum decomposition of the explanatory variables; therefore, NARDL is an appropriate model. In addition, the NARDL method accounts for asymmetry and co-integration dynamics among the input series. Fourth, it has practical implications for investors to diversify their portfolios and for policymakers to establish a policy to lessen the negative effect of uncertainty on commodities markets. Findings of the study highlight uncertainties significantly affect commodity prices in short run and in long run however the intensity vary over the period. Stock market uncertainty (VIX) inversely affect commodities while EPU and OVX positively influence. In the short run EXV do not cause commodity price. In the long run increase in uncertainty (EPU, VIX, EXV) negatively react to commodities prices whereas OVX positively influence commodity prices. The results provide investors an insight about future investments and risk management against uncertainty.

Literature Review

In the dynamics of global economic activity, the impact of the crisis 2019, 2015, 2015, and GFC 2008 has hit the markets of commodities. In post-crisis, worldwide commodity markets experienced drastic fluctuations, with a risk of contagion across different commodity prices. Commodity price fluctuations have been monitored carefully by policymakers and experts as one of the prime gauges in policy-making and corporate decision-making (Zhaó et al., 2020). Global commodity prices for energy products fall sharply as a result of the pandemic-driven global recession (Khalid et al., 2020; Ẃu eł al., 2023).

Concerning commodity relationships, Coşkun (2018) investigates shock propagation and stock market volatility spillover in commodity markets. (Aydoğan., 2017) examines the influence of oil price volatility on the stock market in net oil "import and export" countries. For economists, assessing the uncertainty and analyzing the effect on the market's dynamic behavior is difficult since there is no objective to measure. Uncertainty is the conditional volatility of an unforeseeable disorder based on proxies in the literature. The typical indicators are the implied volatility (VIX) of stock market returns, the cross-sectional distribution of company earnings, and the stock market returns (Joëts et al., 2017). The principle of uncertainty can be outlined by the ideas of Ķnight., (1921), who distinguished a known probability distribution (risk) set of future events from unknown probabilities (uncertainty) events.

Recent studies by Ludvigsón. (2021) demonstrate that uncertainty fluctuates with time, and these fluctuations are exogenous to the business cycle (Nicholas Blóom, 2009, 2014; Jurado et al., 2015). These studies show that a rise in uncertainty has daunting aggregate economic implications and recommend multiple mechanisms. Uncertainty dampens the actual activity and the real options (Gábor-Tóth & Georgarakos, 2019). Investors lack clarity about future markets and policy development when facing policy uncertainty, forcing them to be more careful about their investment decisions and postpone investment until the situation is specific. This lowers the level of investment, with a negative impact on economic growth (Chén & Li., 2020). However, in financialization, investors are more susceptible to non-conventional shocks, e.g., sentiments, political uncertainties, and unpredictable consequences in the commodity market. For instance, market resistance and investor sentiments triggered drastic fluctuations in commodity prices when investors invest in the commodity futures, leading to deviations among coin fundamentals and prices of commodities (Mastérs, 2008; Tạng & Xióng, 2012). A thriving research direction takes financialization and various factors into commodity pricing models (Ji et al., 2019). Researchers focus on figuring out the fundamental mechanism of how commodities prices can be influenced by the following factors and effectively quantifying the results. From the viewpoint of demand-supply and macroeconomic fundamentals, the prices of commodities are studied (Ortéga., 2014), uncertainty, geopolitical risk (Antonakakis., 2017; Balcilar Gupta., 2016; Joëts et al., 2017), and commodity financialization (Tạng & Xióng., 2012). The association between uncertainty shocks and commodity volatility is confirmed by (Qĩn et aĺ., 2020b; Ṣu eŧ aĺ., 2018). Qin & Taó. (2020a) studied the association between the crude oil market and EPU, complementing the significant position of oil prices based on fundamentals. Similarly, Su et al. (2018) found both a negative and positive association of EPU with oil prices, indicating that EPU of the US economy significantly influences oil prices. Indeed, uncertainty distresses the prices of commodities through financial mode by impacting the investment-related choices of the speculative buyers with commodity price volatility (Ƕuạng et aĺ., 2021).

Uncertainty across various channels affects the economy (Reenen., 2007), the prices of stocks (Pastor & Veronesi, 2012), and the returns of the market (Brógaard & Détzel, 2015), influence price volatility (Bahloul et al., 2018). Despite the extensive literature (Bérger & Uddĩn, 2016; Reboredo & Uddĩn, 2016) on commodity price drivers, few studies find the link between EPU on prices of commodities and stock volatility (Ḃahloul eŧ al., 2018). One of the key barriers to business operations in emerging economies is frequent and abrupt economic policy changes. The EPU index (Baker., 2016) is appropriate and convenient for quantifying its effect on economic indicators (Sharmạ & Paramati, 2021). Economic policy combines monetary, regulatory, and fiscal policy, guided by banks and government. Economic policy plays a significant role in shaping financial markets and needs recurrent adjustment if there is some change in the economic situation (Ảdjei & Ảdjei, 2017). The decision-making process of customers and investors is affected by economic uncertainty. Investors are unsure about investing in the economy with uncertain conditions (Ṟaza et al., 2018) because they tend to keep capital to shield themselves from any losses that arise in the future (Gozgór & Ongan, 2017). Several measures established EPU predictors, gold being the most important among them. Gold has been accepted, processed, and deemed resistant to physical decay and can be used as a source for exchange (Jones & Sạckley, 2016). The results of EPU on metals (gold) varied over time and were positive from 2006 to 2008 and from 2013 to 2017 (Gaó et al., 2019). SackĺEy., (2016) recommends that along with the traditional variables, the haven status of gold causes its price to increase at times of uncertainty and concludes that gold prices increase with the rise in EPU and edge as safe heaven. (Wang, & Yaróvaya., 2017; Van & Hellér., 2016).

In the same way, -Ḃalcilar et al. (2016) found a significant impact of uncertainty on gold returns for quarterly data. (Ḃouoiyour & Wóhar., 2018) determined a powerful and positive association between gold returns and the uncertainty index. Gold offers excellent security against extreme volatility. It is a safe haven for storing value and has never fallen below zero in its entire history. (Li and Lucéy (2017) observed that precious metals' positive and durable factor is a haven against EPU. Similarly (Huynh, 2020) found that producing precious metals is interconnected, affecting demand and supply. During the 2007-2008 financial crisis, precious metals (platinum, gold, palladium, and silver) suffered significant price falls. Traditionally, due to general and cultural perceptions, silver and gold have an intrinsic value; these are hedge and safe metals (Péng., 2019). Meantime, silver and gold are regarded as replacements for currency. The values of gold and silver were stable for eras up to the second half of the 20th century (Officer, 2018), and these metals are characterized by high volatility (Gupta., 2019).

Economic development depends heavily on economic policy, and unstable policy retards the development process (Raza et al., 2018). To overcome this issue, Yang and Dérbali (2019) examined which assets can help mitigate global uncertainty. Gold is a commodity for risk aversion, has long been used as a hedge, and acts as safe security in economic turmoil. EPU makes it harder for investors to determine the potential investment environment and lowers the public trust index, negatively affecting economic growth (Nyamela & Gupta., 2020). EPU can influence the real economy's consumption, exports, GDP, expenditures, exchange rate, crude oil, and real estate prices, evident by (Chén & Wang., 2019; Gan & Nadeem., 2020; Lĩu & Lĩu., 2018).

Natural gas and crude oil are primary energy sources for the world's economy. In order to allow hedging against the risks, energy commodities may act as substitutes for bonds and stocks (Batten & Lucey., 2017). Uncertainty in oil and gas prices significantly affects a country's industrial production and economic development. Since the coronavirus pandemic, global commodity prices have fallen. In the first half of 2020, the COVID-19 pandemic wreaked havoc on the world economy, making it difficult for the commodities and financial markets to operate stably. The pandemic's massive impact on a global scale has resulted in a surge in literature. (Alhammadi., 2020; Gubareva., 2021; Źhang., 2020b). The epidemic of COVID-19 is posing significant challenges to the world's economy. Many industries and organizations have suffered due to contingency measures, and commodity prices have declined with a significant shift in macroeconomic conditions (Gubarevḁ., 2021). Covid-19 significantly affects global commodity markets (Goodell., 2020; Sharif., 2020). Commodity dynamics in the bear market and its early recovery from COVID-19 offer a distinct opportunity to examine the economic effects of the crisis on the prices of critical resources, which is vital for the global financial system and the economy's overall stability. Commodity price instability of energy, agriculture, livestock, precious metals, and non-precious metals are studied by (Gubarevḁ & Ali, 2021; Mikutowski., 2019).

An essential determinant of EPU and economic performance is volatility in oil prices (Bloóm., 2017). Oil is an essential source of energy in the world and an investment product with key economic characteristics. As oil redistributes income among the net oil exporting and the importing countries, high oil prices negatively impact aggregate demand (Lĩu., 2019). The negative effect of the EPU on revenues is caused by endogenous EPU responses (X. Chén eƚ al., 2̶020; Ķang eƚ al., 2017). It is evident that negative and positive impacts on sector returns through energy price uncertainty (Phan et al., 2015). There are different justifications for such impacts: risk-return trade-off, inflationary volatility, and the opportunity to hedge spot and futures contracts (Shahzḁd et al., 2020). Uncertainties linked to economic and government policies have been highly appreciated by policymakers since the GFC of 2008 has been rediscovered in theory (Antónakakis et al., 2018). It is significant to analyze the action of agricultural commodity prices and volatility, a key component of household consumption. They also have food protection, primarily affecting the poor population (Sóytas et al., 2018). Volatility in prices could deter investment and decrease financial stability. For example, food price uncertainty was judged to be responsible for the political turmoil faced by several nations. For the economic difficulty among poor people and child starvation in developing economies (Irwĩn., 2018).

Bakḁs et al. (2020) argue that the ongoing coronavirus pandemic causes a dramatic rise in uncertainty that dramatically impacts the economy. Increasing uncertainty due to the pandemic usually correlates with declining demand and economic activity disruption. Recent studies investigate the impact of a pandemic on markets and the economy (Bloom & Bakér., 2020; Źhou et al., 2020). The crises have significant effects on commodities. Price uncertainty of energy and agriculture commodity prices has become a significant issue among academics and policymakers. Literature highlights the connection between shocks in oil and agriculture commodity prices. Any oil price change can impact the entire economy (Akhtér et al., 2021).

Crude oil has long been regarded as the world's valuable raw material and vital energy source. It is crucial for socio-economic growth and stability. Food fuel interconnections have been of intense importance since the global financial crisis (Pal & Mĩtra., 2018). Natural resources: Oil and precious metals are essential variables exposed to macroeconomic conditions. Oil is used in many sectors, including the manufacturing of products and transportation. Gold has a storage value and is significant in forming central bank monetary policy. Over the long-term horizons, precious metals and oil prices are positively correlated, which can be clarified on two fronts. Firstly, precious metals and oil are denominated in US dollars, and as the US dollar value rises. The dollar-based asset value declines as investors perceive these assets to be expensive in a way that oil and precious metals are dependent. Secondly, raising oil prices lifts the production cost, which in turn increases the inflation rate (Mensĩ & Ķang., 2021) since gold is a haven against the inflationary periods (Shahzạd eƚ al., 2019; Ẉang et al., ƻ011). With the rise of inflation, the demand of investors for gold rises, which causes gold prices to rise. Overall, the price of crude oil acts as a leading indicator for price levels of various commodities, and a rise in oil prices negatively influences various industries and slows economic development (Mensĩ et al., 2021). Shahzạd et al. (ƻ018) found the effect of oil price shocks on metals and found the aggregate demand shocks had a severe spillover impact on all metals, apart from gold prices. Źhang et al. (ƻ018) studied the association between oil, platinum, and gold and found that sudden oil shocks and price jumps had various effects on platinum and gold. Chén et al. (ƻ019) found a positive time-varying association between precious metals and crude oil traded in China, which was reversed during the financial crisis. The interrelated nature of oil, agriculture, commodities, and metal price fluctuations through the transmission of shocks in price have a grim consequence for investors and policymakers (Maĩtra et al., ƻ020). They realize the asymmetric shocks for negative and positive price shocks (Åhti., ƻ009; Nazlioglu., ƻ011). The volatility in oil prices affects commodity prices (Ahmadĩ et al., ƻ016; Luó et al., ƻ018). There is an evident volatility spillover among commodity markets and oil (Guhathakurta eƚ al., ƻ020). (Nazlioglu and Soytas, 2011, 2012) found that oil prices positively influence agricultural commodities, such as soybeans and corn. The price dependence of oil with soybean, wheat, and corn rose after 2011 using the copula-based method found by Reboredo (ƻ012).

Shahzạd et al. (2018) used delta CoVaR and conditional VAR models and discovered the energy price spillover risk to the agro-commodity market. In line with the earlier research, Shahzạd et al. (ƻ018) found asymmetric volatility spillover among the markets of agro commodity and oil. Luó et al. (2018) found asymmetric volatility spillover among the USA and China agro-commodity by using the DCCGARCH model. The results depict negative volatility and a higher level of market interdependence than positive volatility. Yahya et al. (2020) examined volatility spillover through a network approach and found that oil and agriculture commodities have asymmetric bidirectional knowledge flow, and oil is still a net receiver after 2006. Rafiq & Blóch. (2016) revealed the long-run positive impact of oil price increases on the prices for twenty commodities while the negative short-run effect on thirteen commodities. When endogeneity is considered, oil prices have little effect on beverage and cereal prices, but they have a significant effect on metal prices. Few studies examine the effect of various uncertainty measures on commodity markets (Triantafyllóu et al., 2018; Ḃalcilar et al., 2016; Ḃilgin et al., 2018; Qĩn et al., 2020b). Balcilar et al. (2016) investigate how equity market and policy uncertainty affect the volatility and gold returns using nonparametric causality in the quantiles test. For daily and monthly data, causality exists using multiple uncertainties to volatility and gold returns. Causality weakens with quarterly data, which is only essential for a few uncertainty measures and gold volatility. Triantafyllóu et al. (2018) employ the VAR model to analyze the impact of shocks in uncertainty on the volatility of commodities prices for the USA. The volatility in commodity prices is influenced by unobservable macroeconomic shocks rather than by noticeable disruptions to the macroeconomy. The findings indicate that unobservable economic uncertainty indicators consistently impact commodity price volatility (Juradó et al., 2015). Further results show that the positive shock in unobservable macroeconomic and financial uncertainty increases the volatility of the large commodity market and the prices of individual commodities over time. B.ĩlgin et al. (2018) examine the asymmetric effect of four uncertainty measures on commodities using the NARDL model.

The findings support increased EPU increase in gold prices. Gold prices are less likely to decline when the economic conditions get better. Qin et al., (2020b) applied the wavelet approach to analyze the association between oil prices and measures of uncertainty. The findings approve of both the negative and positive effects of EPU on oil prices, indicating that policy instability in the US economy will impact oil prices. The finding supports the equilibrium model, implying that EPU has a particular impact on oil prices. Fluctuations in the commodity market are linked to the dynamics of supply demand and the change in macroeconomic conditions (Gupta et al., 2018).

Data and Methods

Data

This study employs monthly data from 2001 to 2020. USA is the world's largest commodity producer and second-largest commodity consumer. The data is collected from Thomson Reuters. Three main commodities, agriculture, metals, and energy are selected for analysis as dependent variable. This study uses four measures of uncertainty: EPU, VIX, OVX, and EXV as independent variables, while the dependent variable is the commodity prices. The study examines the asymmetric impact of uncertainties (EPU, VIX, OVX, and EVX) on commodity prices, a topic of great relevance in the current economic climate. Eight commodities are classified into three major categories: energy, precious metals (gold and silver), and agriculture (wheat, corn, soybean, sugar and rice), providing a comprehensive overview of the market.

Method

Considering the objectives of the study, a linear model has two deficiencies. First, this model ignores the asymmetric impacts of uncertainty. Second, other inherent nonlinearities may be found in our data, and this model can impose unreasonable constraints that may lead to unfair conclusions (Trachanąs et al., 2012). A suitable nonlinear model is required to examine the positive and negative impact of uncertainties on commodities. This is where the NARDL method comes in. While previous studies have used it to study the asymmetric effect of various factors, its application to the asymmetric impact of uncertainties on commodity prices is a novel approach. It can determine nonlinearities in the short and long run through the positive-negative partial sum decomposition of the explanatory variables, providing a more comprehensive understanding of the market dynamics.

The decision to use the NARDL method in this paper is based on four key reasons: a) NARDL captures both long-run and short-run asymmetric co-integration, providing a comprehensive view of the market dynamics. b) It allows us to determine responses to both negative and positive changes in each explanatory variable, helping to build the line of asymmetry. c) This method is capable of handling several data series of integration order and is used to evaluate both nonlinear and linear co-integration, ensuring the robustness of our findings. d) To study both nonlinearity and non-stationarity combinations, we employ an unrestricted error correction model, further enhancing the reliability of our results.

We consider long-run asymmetric regressions as follows in equation 1:

$$CP_t = \beta^{+}UV_t^{+} + \beta^{-}UV_t^{-} + \mu_t \tag{1}$$

Where β^{+} and $\beta^{-}$are the related long-run asymmetric parameters, μ_t is an i.i.d. process which has finite variance and mean is zero, and UV_t is decompose in the equation 2.

$$UV_t = UV_0 + UV_t^+ + UV_t^- \quad (2)$$

With UV_0 is the initial value of uncertainty and UV_t^+ and UV_t^- representing the partial sums of positive and negative changes in uncertainty (EPU, VXO, MU, ERU), followed in equation 3 and
4:

$$UV_t^+ = \sum_{j=1}^{t} \Delta UV_t^+ = \sum_{j=1}^{t} \max(\Delta UV_t, 0) \quad (3)$$

$$UV_t^- = \sum_{j=1}^{t} \Delta UV_t^- = \sum_{j=1}^{t} \min(\Delta UV_t, 0) \quad (4)$$

The following equations 3 and 4 can be rewritten in terms of EPU as in equation 5 and 6:

$$EPU_t^+ = \sum_{j=1}^{t} \Delta EPU_t^+ = \sum_{j=1}^{t} \max(\Delta EPU_t, 0) \quad (5)$$

$$EPU_t^- = \sum_{j=1}^{t} \Delta EPU_t^- = \sum_{j=1}^{t} \min(\Delta EPU_t, 0) \quad (6)$$

NARDL model derived from eq (1) can be rewritten as equation 7:

$$CP_t = \sum_{i=1}^{j} \varphi_i \Delta CP_{t-i} + \sum_{i=0}^{k} (\theta_i^+ \Delta UV_{t-i}^+ + \theta_i^- \Delta UV_{t-i}^-) + {}_t \quad (7)$$

Where φ_i is the autoregressive parameter, φ_{i^+} and φ_{i^-} are the asymmetric distributed lags, and ${}_t$ is a zero-mean, homoscedastic $i.i.d.$ process. The asymmetric error correction model (AECM) follows equation 8:

$$\Delta CP_t = \rho CP_{t-1} + \theta^+ UV_{t-1}^+ + \theta^- UV_{t-1}^- + \sum_{i=1}^{j} \gamma_i \Delta CP_{t-i} + \sum_{i=0}^{k} (\delta_i^+ \Delta UV_{t-i}^+ + \delta_i^- \Delta UV_{t-i}^-) +$$

t (8)

Where $\theta^+ = -\rho\beta^+$ and $\theta^- = -\rho\beta^-$.

In terms of all uncertainty measures AECM equation is written as follows in equation 9:

$$\Delta CPt = \alpha + \alpha 1CPt{-}1 + \beta 1EPUt{+}{-}1 + \beta 2EPUt{-}{-}1 + \beta 3VIXt{+}{-}1 + \beta 4VIXt{-}{-}1 + \beta 5OVXt{+}{-}1 + \beta 6OVXt{-}{-}1 + \beta 7EXVt^{+}{-}1 + \beta 8EXV_{t-1}^{-} + \sum_{i=1}^{j} \gamma_i \Delta CP_{t-i} + \sum_{i=0}^{k} (\delta_i^+ \Delta EPUt{+}{-}i + \delta i{-}\Delta EPUt{-}{-}i) + \sum_{i=0}^{m} (\theta i{+}\Delta VIXt{+}{-}i + \theta i{-}\Delta VIXt{-}{-}i) + \sum_{i=0}^{n} (\varphi i{+}\Delta OVXt{+}{-}i + \varphi i{-}\Delta OVXt^{-}{-}i) + \sum_{i=0}^{p} (\pi_i^+ \Delta EXVt{+}{-}i + \pi i{-}\Delta EXUt{-}{-}i) + t \quad (9)$$

where δ_i^+, δ_i^-, θ_i^+, θ_i^-, φ_i^+, φ_i^-, π_i^+, π_i^- are positive and negative short-run adjustments to changes in the controlled variable UV_t. Commodity price is represented by CP, stock market uncertainty by VIX, Oil volatility by OVX, exchange rate uncertainty by EXV and economic policy uncertainty by EPU. If $\delta i^+ = \delta i^-$ for all $i = 0, \dots p$ then it means it has asymmetric short run effect. However, by following the similar way if $\beta_1 = \beta_2$ then we may not discard symmetry in the long run. To study co-integration, we have used NARDL bounds test approach (Shin et al., 2014). The reason for using this method is its applicability when the variables are mutually co-integrated or if they are in I(0), I(1) states. However, to find a cointegration relationship there is no need for series to be integrated. The equation (8) of NARDL approach is implemented in the following four steps.

First, through standard OLS, AECM is calculated.

Second, to check the eligibility of uncertainty measures we have to performed Augmented Dickey

Fuller tests and it met all the specifications for NARDL approach. We have used BDM t-statistics (t-BDM) for this methodology (Banerjee, Dolado, & Mestre, 1998) and PSS F-statistics test (Pesaran & Shin., 2001). Thus, we have tested null-hypothesis of no co-integration. The hypothesis for FPSS is:

$$H_0 = \alpha._1 = \beta_{.1} = \beta._2 = \beta._3 = \beta_{.4} = \beta_{.5} = \beta_{.6} = \beta_{.7} = \beta._8$$

It shows that H_0 is not true against alternative hypothesis. This test contains two critical values and in case, have greater results as compared to upper bound we can assume the presence of cointegration. Alternatively, if test statistics approve lower bound among the boundaries than it represents no long-run association. Third, Wald test determine the asymmetries (in short and long run). Further, the null hypothesis of (short-run symmetry) is evaluated contrary to the alternative hypothesis (short-run asymmetry) and vice versa.

We evaluate,

$$H_0: \sum_{i=0}^{K} \delta_t^+ = \sum_{i=0}^{K} \delta_t^- \quad \text{versus} \quad H_1: \sum_{i=0}^{K} \delta_t^+ \neq \sum_{i=0}^{K} \delta_t^- \tag{10}$$

Lastly, the asymmetric cumulative dynamic multiplier impacts of unit changes in UV_j^+ and UV_j^-

on CP_i, are computed as in equation 11.

$$m_h^+ = \sum_{i=0}^{h} \frac{\partial CP_{t+i}}{\partial UV_t^+}, \; m_h^- = \sum_{i=0}^{h} \frac{\partial CP_{t+i}}{\partial UV_t^-}, \; h = 0,1,2 \tag{11}$$

whereas "$h \rightarrow \infty$, the $m_h^+ \rightarrow \beta^+$ and $m_h^- \rightarrow \beta^-$. Later we see that the long-run asymmetric coefficients are β^+ and β^- and can be calculated as $\beta^+ = -\theta^+/\rho$ & $\beta^- = -\theta^-/\rho$, respectively.

Results

Table 1 shows summary statistics of variables. Gold, silver, and soybean commodity prices have the highest returns. The standard deviation of wheat, corn, and soybean is higher than that of other commodity indices with high uncertainty. Except for soybean, rice, and sugar, along with two uncertainties, numerous variables are right-skewed. Furthermore, kurtosis is more than three rejects the hypothesis of normal distribution except EPU. The Jarque-Bera test indicates that the returns are not normally distributed.

Table 1 Summary statistics

	Mean	Median	Max	Min	SD	Skewness	Kurt	J-B
Gold	1.747	0.468	17.511	-6.201	5.026	1.210	4.834	19.597***
Silver	1.401	0.000	20.790	-6.694	5.423	1.826	6.916	60.916***
Energy	0.810	0.839	15.181	-9.410	4.551	0.403	4.172	4.295***
Wheat	0.484	0.558	66.523	-16.571	10.909	4.482	29.326	1643.514***
Corn	0.358	0.229	63.147	-19.488	11.319	3.250	20.800	763.125***
Soybean	1.459	1.429	12.530	-19.084	6.040	-0.814	4.860	12.989***
Rice	0.533	0.778	10.420	-13.780	3.790	-0.906	6.331	30.555***
Sugar	0.016	0.012	0.892	-1.507	0.448	-0.960	4.897	15.473***
EPU	2.218	3.938	101.437	-123.288	52.142	-0.215	2.551	5.823***
VIX	2.043	2.261	24.025	-23.176	7.227	-0.185	5.987	19.246***
OVX	0.401	0.000	9.313	-8.018	3.715	0.248	3.007	6.522***
EXV	0.041	0.038	1.297	-0.932	0.387	0.384	5.203	11.562***

The asterisks *** and ** indicate a rejection of the null hypothesis of normality at the 1% and 5% levels of significance, respectively.

The pairwise unconditional correlation of the prices of commodity with EPU, stock market volatility index, oil volatility and exchange rate volatility is shown in table 2. Wheat and corn has a negative correlation with EPU and exchange rate uncertainty index. The energy index has a negative correlation with the exchange rate uncertainty index. Remaining commodities are positively correlated with the uncertainties. However, the correlation between energy index and VIX is markedly higher at 1% level of significance.

Table 2 Correlations between EPU, VIX, OVX, EXV and commodity prices

Commodity	EPU	VIX	OVX	EXV
Gold	0.267**	0.273**	0.140	0.205
	(1.941)	(1.987)	(0.992)	(1.470)
Silver	0.158	0.073	0.109	0.245*
	(1.120)	(0.513)	(0.770)	(1.766)
Energy	0.018	0.723***	0.682***	-0.163
	(0.127)	(7.332)	(6.524)	(-1.154)
Wheat	-0.137	0.060	0.051	-0.038
	(-0.969)	(0.420)	(0.360)	(-0.266)
Corn	-0.018	0.176	0.166	-0.021
	(-0.125)	(1.254)	(1.181)	(-0.146)
Soybean	0.121	0.082	0.032	0.101
	(0.856)	(0.574)	(0.227)	(0.711)
Rice	0.032	0.017	0.283**	0.123
	(0.224)	(0.116)	(2.062)	(0.868)
Sugar	0.093	0.021	0.102	0.057
	(0.657)	(0.150)	(0.715)	(0.397)
Note: The values in () are the t statistics. *, **, and *** are 10%, 5%, and 1% significance levels				

Table 3 Bounds tests for Asymmetric Co-integration

	$F_{PSS\,Nonlinear}$	t_{BDM}
Gold	7.0263***	-6.9480***
Silver	5.7505***	-4.5497***
Energy	7.8832***	-7.6281***
Wheat	5.2715***	-6.0708***
Corn	4.2455***	-5.5108***
Soybean	4.1104***	-5.1559***

Rice	3.7941***	-4.9983***
Sugar	3.7598***	-4.0403***

Note: *** and ** are significance of bound test and t statistics at 1% and 5%.

To implement NARDL model, we test for the nonlinear long run association (cointegration) among the variables. The results of the bound test for co-integration among the prices of commodities and uncertainties such as VIX, EPU), OVX and ERU are reported in table 3. $FPSS$ and $tBDM$ tests found long run association occur among the prices of commodities and their explanatory variables. tBDM is significant when FPSS is more than the critical upper bound value (Pesaran et al., 2001; Banerjee et al., 1998). For all sample commodities the $FPSS$ and $tBDM$ in NARDL lies significantly above and under the upper bound critical value. Both tests shows the commodity prices and explanatory measures have a long run nonlinear association.

Table 4 NARDL

	Gold	Silver	Energy	Wheat	Corn	Soyabean	Rice	Sugar
Panel A								
Constant	3.073***	1.708***	23.458***	20.251****	29.797***	21.716***	1.022***	24.009**
CP_{t-1}	0.888***	-0.479***	-1.006***	-0.834***	-0.673***	-0.668***	-0.424***	-0.306***
EPU^{+}_{t-1}	0.297***	-0.177***	0.001	-0.289***	-0.009	-0.102***	-0.478***	-0.446**
EPU^{-}_{t-1}	0.024	-0.124***	0.007*	-0.145	0.017	0.017	-0.132***	-0.042**
VIX^{+}_{t-1}	0.440***	-0.239*	1.069***	-0.543***	-0.226	-0.207***	0.116***	-0.112***
VIX^{-}_{t-1}	0.413***	0.326*	0.980***	0.049	0.201	0.066	-0.021	-0.012
OVX^{+}_{t-1}	0.082	0.152	10.027***	1.969***	-1.227	0.250***	0.169	2.239
OVX^{-}_{t-1}	-0.398***	-0.200***	0.928	-3.397***	-12.881**	-8.700***	-0.017	8.568
EXR^{+}_{t-1}	0.509	0.060	-44.274***	62.801**	49.415	17.218	-0.207	39.286
EXR^{-}_{t-1}	1.210***	-0.601	20.749**	-24.579	-5.819	-14.898	0.700***	-8.407
ΔCP_{t-1}	0.480***							
ΔCP_{t-2}	0.261***			-0.252***				
ΔCP_{t-3}	0.291***							
ΔCP_{t-4}	0.349***							
ΔCP_{t-5}	0.378***							
ΔCP_{t-6}	0.227***						-0.192***	
ΔEPU^{+}_{t-2}	0.092***							
ΔVIX^{+}_{t}			0.673***				0.305***	
ΔVIX^{+}_{t-1}			-0.246***					

ΔVIX_{t-5}^{+}	-0.362***							
ΔVIX_{t}^{-}	0.908***	0.471***	0.924***					
ΔVIX_{t-2}^{-}	0.385***							
ΔOVX_{t}^{+}		0.816***	19.308***					
ΔEXR_{t}^{-}			7.333***					
Panel B: Long run dynamics								
L^{+}_{EPU}	-0.411***	-0.161***	0.001	-0.011	-0.014	0.001**	-0.184**	-0.149**
L^{-}_{EPU}	0.027	-0.049	0.007	-0.001	0.025	0.026	-0.076	-0.138*
W_{EPU}	17.539***	4.853***	6.268**	0.237	8.168***	4.135**	2.695**	2.032*
L_{+VIX}	0.496***	-0.499*	1.063***	-0.651***	-0.336	-0.310***	-0.387***	-0.368***
L_{-VIX}	0.465***	0.681*	0.975***	0.059	0.298	0.099	-0.148***	-0.041
$WVIX$	4.058**	6.274***	2.284**	13.871***	4.108**	2.412***	4.120***	3.181***
L^{+}_{OVX}	0.093	0.316	9.972***	2.362***	-1.822	0.375***	0.397	7.322***
L^{-}_{OVX}	-0.449***	-0.208	0.923***	-4.075**	-19.132**	-13.030***	-0.407**	28.017***
W_{OVX}	5.524**	0.555	12.515***	4.341***	1.644**	1.341***	3.944**	6.286***
L^{+}_{EXR}	0.574	0.126	- 44.029***	75.331**	73.395	25.785	-0.487	128.465
L^{-}_{EXR}	1.363***	-1.255	20.634**	-29.483	-8.643	-22.311	1.649**	-27.490
W_{EXR}	2.444*	0.125	10.031***	4.378**	0.728	0.357	1.190***	0.610
R^2	0.645	0.576	0.948	0.572	0.424	0.416	0.454	0.490
$X_{NORM}{}^2$	5.087**	5.456***	4.397***	3.185***	4.661***	5.698***	4.396***	6.498***
X_{SC2}	1.007	0.530	0.831	1.939	1.397	1.944	1.357	1.449
$X_{HET}{}^2$	0.981	0.422	2.549	0.367	0.316	1.321	0.331	10.778
X_{FF2}	9.403	1.076	0.579	0.540	0.025	0.190	1.438	0.076
CUSUM	S	S	S	S	S	S	S	S
$CUSUMSQ$	S	S	S	S	S	S	S	S

Note: The superscript "+" and "-" denote positive and negative cumulative sums, respectively. L+ and L− are the estimated long-run coefficients associated with positive and negative changes.

$X_{SC}{}^2$, $X_{FF}{}^2$, $X_{HET}{}^2$, $X_{NORM}{}^2$ is LM tests for serial correlation, normality, functional form and Heteroscedasticity.

Wald test for the null of long-run symmetry for respective variables.

*, **, *** indicate significance at 1%, 5% and 10% level respectively.

S denotes stable in CUSUM and CUSUMSQ

We continue with the findings of the short-run asymmetric effect of EPU, OVX, VIX, EXV on the commodity prices with the evidence of co-integration. Table 4 panel A shows shocks in commodity prices have positive effect on commodities at lag 1. The impact on gold prices is positive while the prices of other commodities may not affect. Shocks in commodity prices positively influence gold prices (0.261***) at lag 2 and negatively affect wheat prices (-0.252***). At lag 3, 4, 5 and 6 shocks in commodity prices directly affect gold and negative on rice at lag 6 (-0.192***).

EPU and commodity prices are directly associated at lag 2. Increase in EPU increases commodity prices in the short run. For VIX, it seems that negative and positive shocks affect commodity prices in a positive manner. However, the negative shock to VIX has more pronounced effects on commodity prices. Although the shocks to VIX have negative impact on the commodity prices at lag 1. These findings suggest that increase (decrease) in VIX shocks decreases (increases) the commodity prices in the short run. The negative shocks in VIX positively influence gold prices at lag 2 (0.385***), however other commodities may not be affected in the short run.

ΔOVX_t^{+} positive oil shocks have a positive effect on the commodity prices. Rise in oil shocks lead to increase commodity (silver and energy) prices in the short run (0.816***, 19.308***). Overall, an increase in one-unit EPU increases the prices of commodities by 9.2% (0.092***). Increase shocks in VIX has decreased the prices of the commodities. Increase in OVX directly impact commodities in the short run. However, the exchange rate uncertainty $\Delta EXVt-$ positively effect commodity prices in the short run (7.333***).

Table 4 panel B shows the long run dynamics. Wald test is used for the fitness of a nonlinear model and long run asymmetry. From the results, it reject the null hypothesis of long-run asymmetry of positive and negative components of selected variables. Long run coefficients of economic policy uncertainty (EPU) are statistically significant and show that uncertainty in economic policy decreases the commodities prices in the long run. The positive L^{+}_{EPU} EPU shocks has a negative effect on the gold, silver, rice and sugar while it has a significant positive effect on soybean (0.001**) at 5% level of significance. On the other hand, L^{-}_{EPU} negative economic policy uncertainty shock shows the significant impact on sugar (-0.138*). Overall EPU shocks have negatively affected commodity prices in the long run.

Positive Stock Market Uncertainty L^{+}_{VIX} has a significant negative effect on silver, wheat, soybean, rice and sugar (-0.499*, -0.651*** ,-0.310***, -0.387***,-0.368***). In case of positive VIX commodity prices of corn are weakly affected. While for gold and energy (0.496***,1.063***), L^{+}_{VIX} positive stock price shocks have a significant positive effect on commodity prices.

On the other hand, the L^{-}_{VIX} negative stock price shocks have a significant negative effect on gold, silver and energy commodity prices (0.465***, 0.681*, 0.975***, although the negative VIX has a significant positive effect on rice (-0.148***) which decreases in the long run. For gold, our results are in line with (Bĩlgin et al., 2018). VIX shocks negatively affect commodity prices in the long run, meaning when the stock market uncertainty increases the prices of commodities decrease.

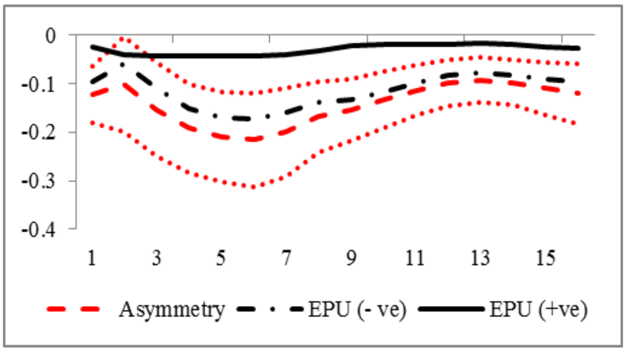
Considering estimated long-run factors of the asymmetric ARDL, we examine that the positive oil volatility shocks L^{+}_{OVX} positively impact the energy, soybean, wheat and sugar (9.972***, 2.362***, 0.375***, 7.322***) at 10% level of significance in the long run. This shows that commodities (energy, soybean, wheat and sugar) can provide protection against losses occurring with oil price uncertainty. This positive oil volatility (OVX) shocks weakly and statistically insignificant with corn, which shows that this commodity weakly react to a positive OVX uncertainty. Moreover, the commodity prices (gold -0.449***, corn -4.075**, soybean -19.132*-13.030*** *, rice and wheat -0.407**) significantly react positive to a negative oil volatility shock L^{-}_{OVX} except sugar and energy indices (28.017***,0.923***) they respond negatively to negative oil volatility shock. This result of positive response of gold price to negative shocks in oil price is similar to (Bilgin et al., 2018). The overall results support oil volatility shocks (OVX) positively impact the prices of commodities in the long run. Our findings for long-run asymmetric positive effect of oil shocks on commodity prices are consistent with Rafiq and Bloch, (2016). Likewise, prices of commodities response in positive and asymmetrical to OVX.

Positive exchange rate uncertainty shocks L^{+}_{EXR}, significantly increase the prices of wheat (75.331**) while negatively impact energy index (- 44.029***) in the long run whose value decreases with increases with exchange rate uncertainty. However negative exchange rate uncertainty shocks L^{-}_{EXR} have significant negative impact on commodities (gold, energy and rice: 1.363***, 20.634**, 1.649**) which increases in long run as the exchange rate uncertainty decreases. Concerning the gold-exchange rate association, our result similar to (Bĩlgin eŧ al.,

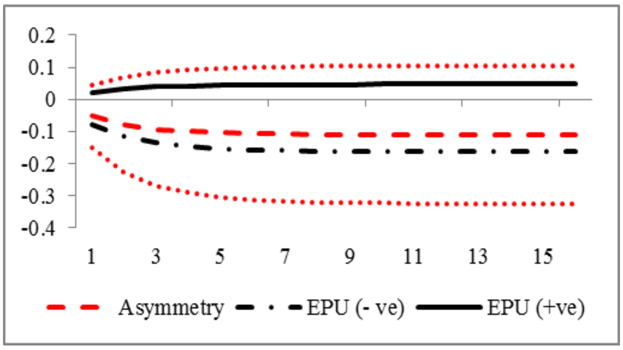
2018). The overall negative effect of EXV on the prices of commodities in the long run is determined.

Figure 1. Dynamic multiplier effect of Commodity prices to EPU

a) Gold

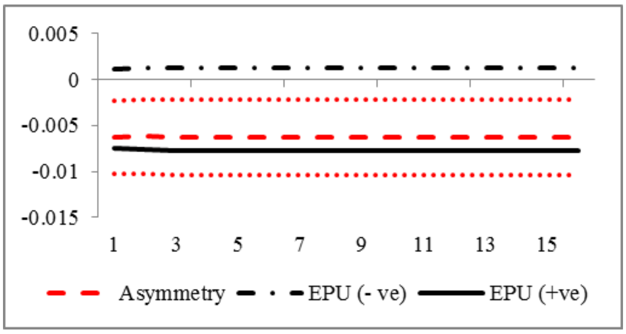


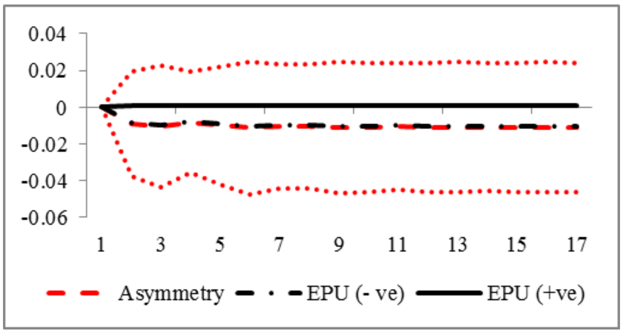
b) Silver



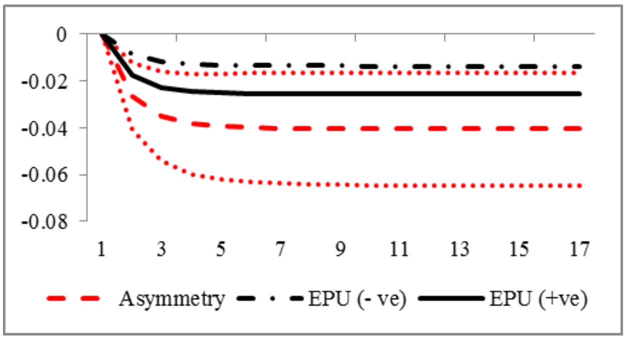
c) Energy

d) Wheat

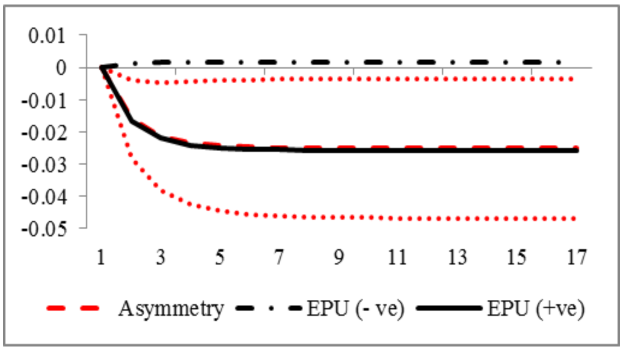




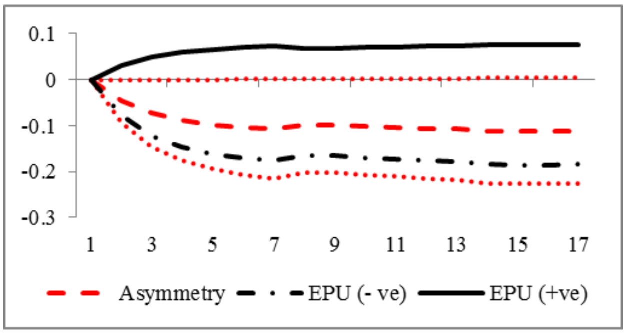
e) Corn



f) Soybean



g) Rice



h) Sugar

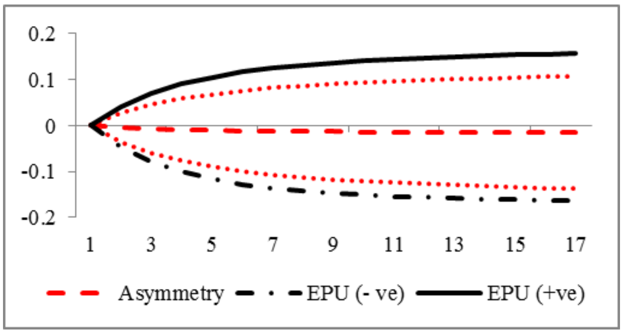


Fig. 1 Commodity prices Response to Economic Policy Uncertainty. Note: Black (dotted) lines show positive (negative) impact while red lines show asymmetry and confidence (upper and lower) bands.

Finally, plotting the multiplier effects further enriches the dynamic asymmetric association among selected variables. The changes in the prices of the commodities to a unit shock in EPU, VIX, OVX, and EXV from an initial level to their current equilibrium levels are seen in these dynamic multipliers (figs 1, 2, 3, 4). Based on the NARDL model, dynamic multipliers are estimated. The linear combinations of multipliers corresponding to the positive (black line) and negative (dashed black line) changes are presented through asymmetry curves. Dashed red lines depict overall asymmetry in positive and negative shocks, while dotted red lines depict the corresponding upper and lower bounds of asymmetry (at 95 percent confidence level).

Figure 1 shows the adjustments of each commodity price to negative and positive unitary EPU shocks. The dynamic multipliers show that when EPU increases, silver, rice, and sugar prices also increase. In the case of silver, less increase is being noticed. As the EPU increases, the price of silver increases by 0.3 units, but the price becomes stable after three days. In the case of rice, the price increases initially by 0.5 units, but after nine days, the prices become stable, and the price of sugar continues to increase as the EPU increases. In the case of wheat, the graph shows no effect when EPU increases. However, the price of grain decreases when EPU decreases by -0.01 units. In the case of energy, when EPU increases, the prices of energy commodities may decrease, and the value is stable from the very beginning and decreases up to -0.007 units. When EPU decreases, the prices of energy commodities increase by 0.001 units and remain stable from the start. The prices of corn and soybean decreased with the increase in EPU and became stable after two days at -0.02 units. However, the price of corn still decreases with the decrease in EPU by -0.02 units, but the price of soya beans slightly increases with the decrease in EPU. The price of gold decreases with the increase in EPU; however, it decreases less after day nine but decreases slightly more after day 14. The gold price still decreases with the decrease in EPU, but it slightly moves up on day two. After day two, the price decreases further, but after a few days, it again moves upwards but is still on the opposite side. Figure 1 shows that the EPU positively affects commodity prices except for energy and soybeans.

Figure 2 depicts the impact of VIX on commodity prices. The dynamic multipliers show that when the VIX shocks increase, the value of gold decreases; however, in a day or two, the price starts to decrease further, and then it starts to increase, and then after a few days, it again decreases by -0.4 units and still remains at the opposing side. When VIX decreases, the prices of gold increase; hence, the price of gold fluctuates so that sometimes prices go up, sometimes down, but remain optimistic. Silver, energy, wheat, corn, and soybean prices decreased with the increases in VIX shocks. In all these commodities, though, stability was reached after certain days, but on the opposing side. However, the prices of rice and sugar increase with the increase in VIX, but the increase is minimal; hence, stability reaches after a certain period. When the VIX decreases, silver, energy, and rice prices increase. After certain days, the prices of silver and energy commodities become stable. Still, the price of rice gradually decreases and, after a few days, reaches an equilibrium position and then again increases by 0.05 units. However, prices of wheat, soybean, and sugar decreased with the decrease in VIX. The price of grain fluctuates more on the negative side than soybean and sugar, though their prices become stable before the price of wheat on the negative side when VIX decreases. Fig. 2 shows that the VIX has a negative impact on the prices of commodities except sugar, where the effect is positive.

Figure 2. Dynamic multiplier effect of Commodity prices to VIX

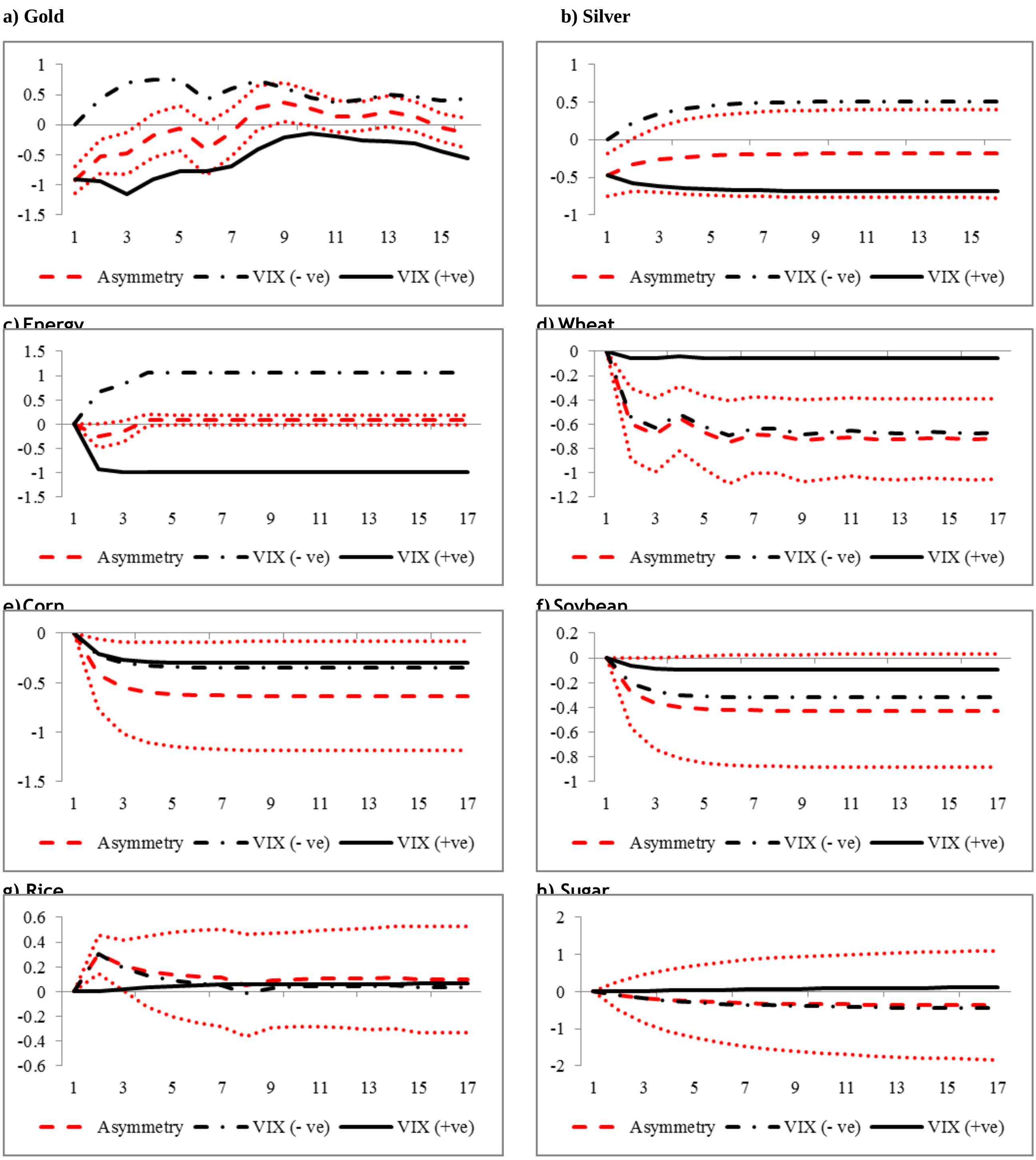
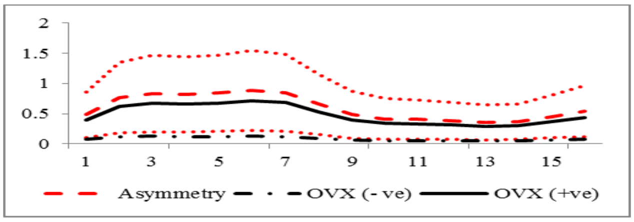


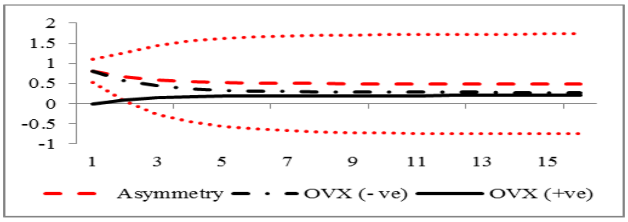
Fig. 2 Commodity prices Response to Stock market uncertainty.

Figure 3. Dynamic multiplier effect of Commodity prices to OVX

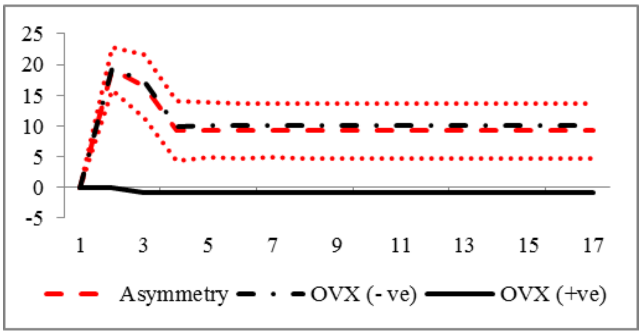
a) Gold



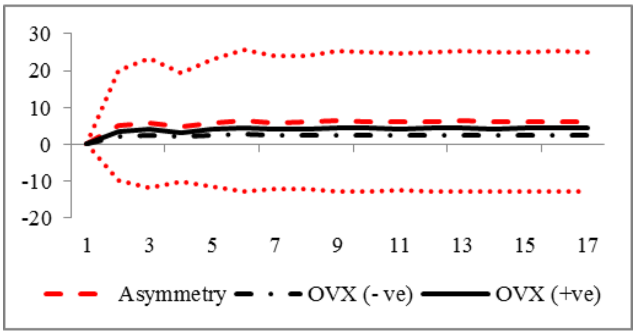
b) Silver



c) Energy



d) Wheat



e) Corn

f) Soyabean

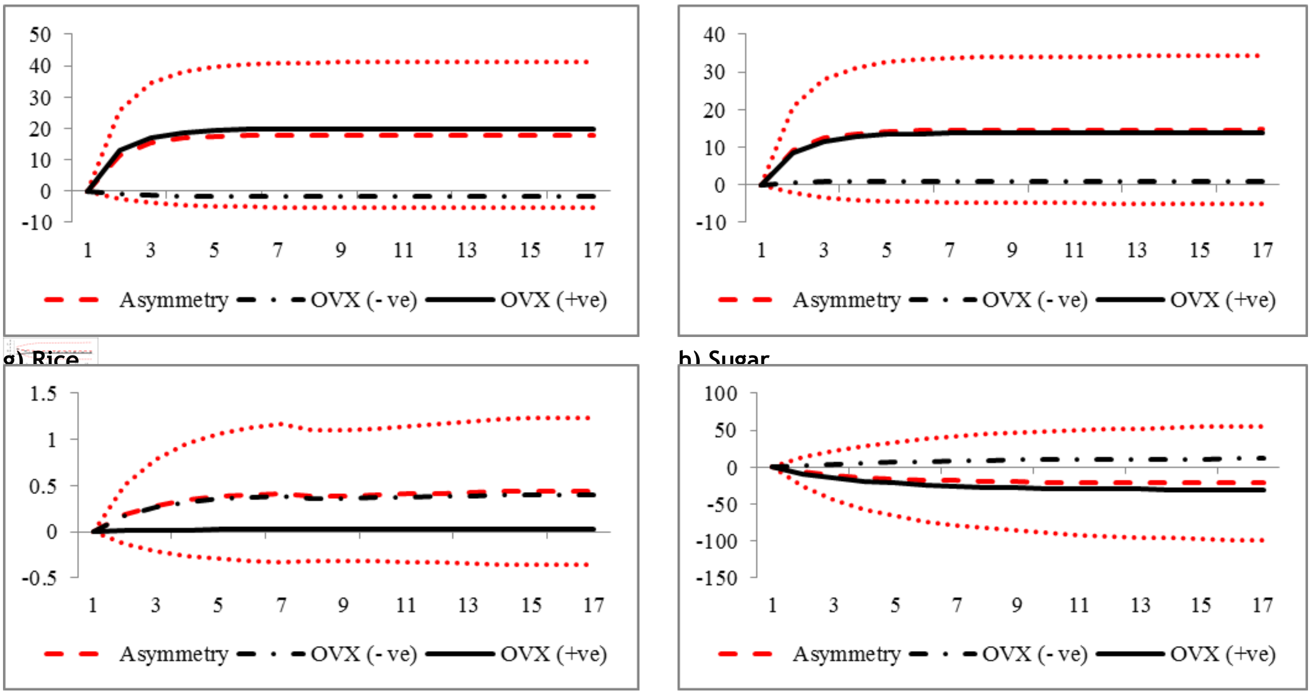


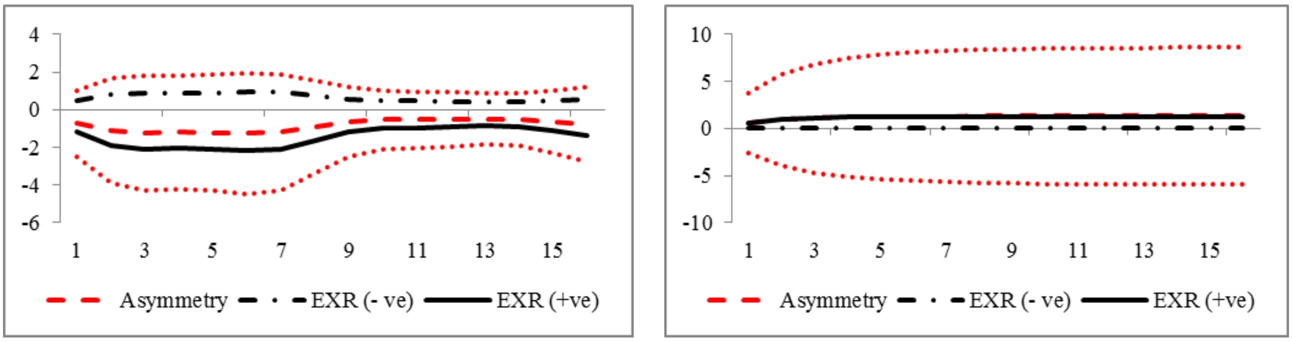
Fig. 3 Commodity prices Response to Oil Volatility.

Figure 3 shows the adjustments in the prices of the commodities with the positive and negative impact of oil volatility shocks. The prices of gold, silver, wheat, corn, and soya beans increase with oil volatility. In the beginning, when the oil volatility increases, the gold prices also increase by 0.6 units, but after some days, the price of gold moves downwards. Hence, continuous fluctuations may occur in the price of gold but remain positive. The price of silver and wheat slightly increases, as shown by graphs (b) and (d) in Figure 3, and then within a day, their price is stable where it initially arose. In the case of corn and soya beans, the prices increase as the oil volatility increases, and their increase is sufficiently incredible compared to the increase of silver and wheat. The price of sugar decreases with the increase in oil volatility, and after day 4 or 5, this price decrease becomes stable. The graph of energy and rice shows that when the oil volatility increases, their prices may not be affected. However, a slight downward shift may occur in energy prices, but that is not too much, according to the graph. In the case of gold, when oil volatility decreases, the price of gold increases, and after nine days, the price moves toward the equilibrium position, and there, it becomes stable. The prices of silver, energy, wheat, rice, and sugar also increase with the decrease in oil volatility. The price of sugar and wheat has not increased that much, just slightly higher from the equilibrium position. When oil volatility decreases, the price of corn moves somewhat downward from the equilibrium position, but that is not too much. Figure 3 shows that oil shock negatively impacts commodity prices except for the corn and soybean, where the impact is positive.

Finally, figure 4 shows the adjustments in the prices of the commodities with the positive and negative effects of exchange rate uncertainty. The prices of gold, energy, and rice decrease with the increase in EXV. Initially, the price of gold fluctuated more negatively, but after nine days, the price slightly fluctuated. Energy prices become stable after two days but on the opposing side. The increase in the exchange rate may not affect corn and sugar prices, and their prices remain in the equilibrium position while the price of soybean slightly increases with the increase EXV. The same is the case with silver and wheat. Their prices also increase with the increase in EXV, but their increase is slightly more significant than soybeans. When the exchange rate uncertainty decreases, the prices of gold, wheat, corn, soybean, and sugar increase. The price of gold becomes stable after nine to ten days. The increase in the price of grain is the greatest among all the commodities, while the increase in soybean price is just slightly above the equilibrium point. Figure 4 shows that EXV has a negative impact on the prices of commodities except silver, where the effect is positive. It is clear from the statistics that the impact of all the uncertainties on the prices of commodities is asymmetric.

Figure 4. Dynamic multiplier effect of Commodity prices to EXV

a) Gold **b) Silver**



c) Energy **d) Wheat**

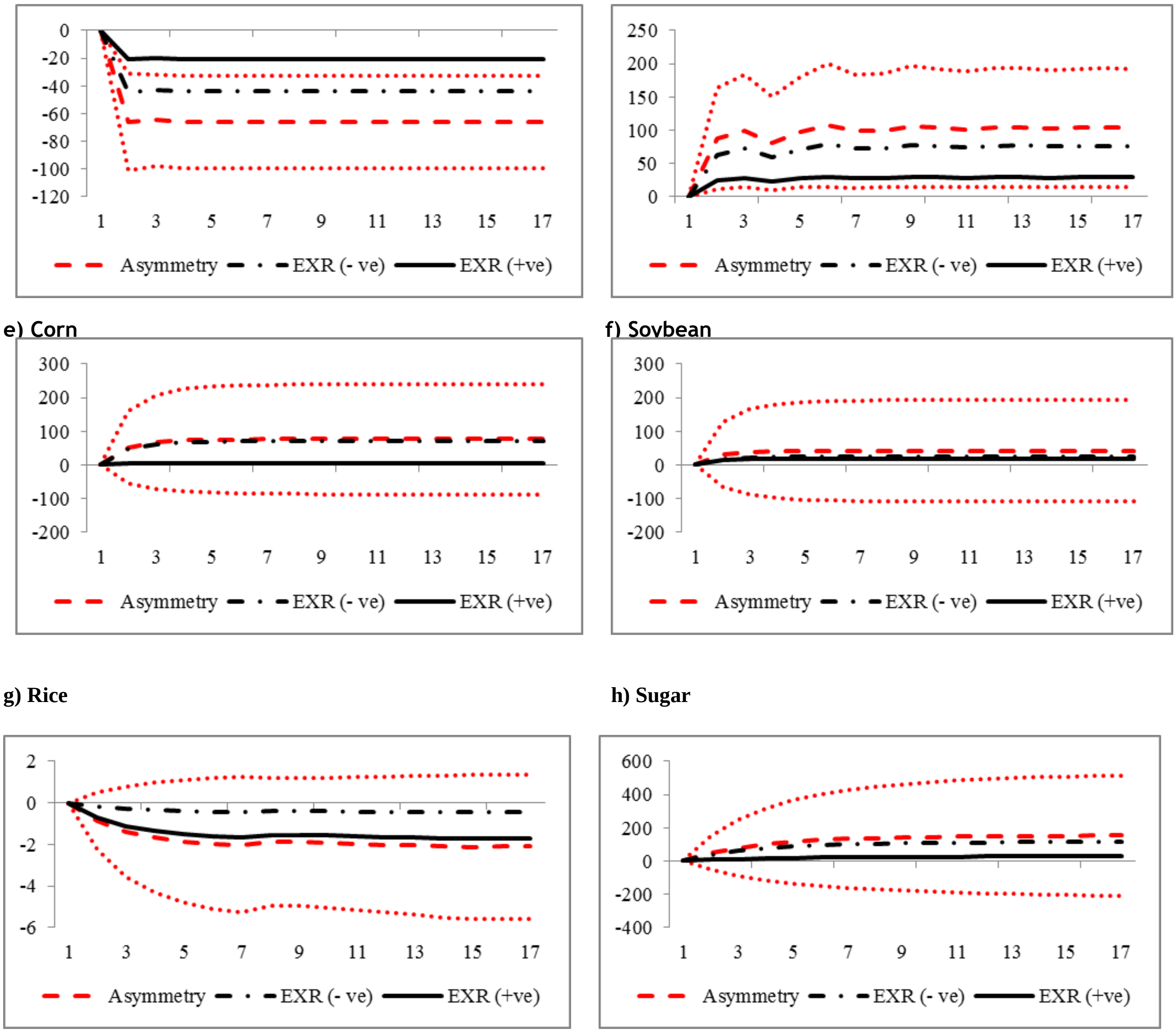


Fig. 4 Commodity prices Response to Exchange Rate Fluctuations.

Conclusion

This study examines the long and short-run asymmetric impact of uncertainty (EPU, VIX, OVX, and EXV) on the prices of commodities in the United States using the Non-linear autoregressive distributive lag model (NARDL). Wald test supports the existence of nonlinearity in the connections. These findings show that the effect of EPU EXV, OVX, and VIX on commodity prices is significant. EPU has a significant positive effect on commodity prices, while VIX has a negative impact on commodity prices. Oil volatility shows a positive effect on commodity prices, but there is no impact of exchange rate uncertainty on the prices of commodities in the short run. In the long run, EPU has a negative effect on commodity prices, which means an increase in EPU decreases commodity prices. Similarly, stock market uncertainty and exchange rate uncertainty also have a negative impact on the prices of commodities, which means when these uncertainties increase, the prices of commodities decrease. Conversely, positive (negative) changes in oil shocks increase (decrease) commodity prices in the long run.

5.1 Policy Implications

This study involves policymakers and investors. While formulating economic policies, policymakers should be aware of the complex connection between uncertainties and the prices of commodities to avoid unnecessary price fluctuations. On the one side, they should establish an organized policy structure to ease the negative effect of policy uncertainty on commodity markets. Conversely, policymakers may use a combination of categorical policies to balance the commodity markets. Given that uncertainty measures can trigger commodity price volatility, policymakers should consider the bases of uncertainty measures and offer effective counter-strategies to resolve the problem at its heart. This may aid in rapidly addressing the issues of uncertainty and reducing its overall negative effect on the economy. When it comes to investors, they should be cautious and take necessary measures as economic and political uncertainties change over time. Investors may use these findings to help them make portfolio decisions and manage asset allocation. Understanding the positive and negative effects can help them diversify portfolios to determine which commodities are appropriate for short and long-run investment. They should keep an eye on market changes because any structural changes in the economy will affect the prices of the commodities.

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Συμβολή των Ευρωπαϊκών Προγραμμάτων στην Ανάπτυξη – Ανταγωνιστικότητα

νάπτυξη – Ανταγωνιστικότητα – Καινοτομία και γενικότερα στην οικονομία για την περιφέρεια Πελοποννήσου για τα τελευταία 20 χρόνια στον τομέα της μεταποίησης

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Πίνακας περιεχομένων

Η Ευρωπαϊκή Ένωση διαδραματίζει πολύ σημαντικό ρόλο στην προώθηση της περιφερειακής ανάπτυξης, της ανταγωνιστικότητας στα κράτη μέλη, της καινοτομίας και μιας σειράς στρατηγικών χρηματοδοτικών πρωτοβουλιών. Τα τελευταία 20 χρόνια, η περιοχή της Πελοποννήσου στην Ελλάδα έχει επωφεληθεί σημαντικά από αυτά τα προγράμματα, ιδιαίτερα στον μεταποιητικό τομέα. Η παρούσα εργασία στοχεύει να εξετάσει τη συμβολή των ευρωπαϊκών προγραμμάτων στον οικονομικό μετασχηματισμό και την ανάπτυξη της Πελοποννήσου, με επίκεντρο τη μεταποιητική βιομηχανία της περιοχής.

1. Το Πλαίσιο Ευρωπαϊκής Ολοκλήρωσης και Περιφερειακής Ανάπτυξης

Η ευρωπαϊκή ολοκλήρωση έχει αναγνωριστεί εδώ και πολλά χρόνια ως μηχανισμός για την προώθηση της οικονομικής συνοχής, αλλά και για τη μείωση των ανισοτήτων μεταξύ των περιφερειών. Οι διαρθρωτικές πολιτικές της Ευρωπαϊκής Ένωσης έχουν σχεδιαστεί προσεκτικά για να υποστηρίζουν περιφέρειες που υστερούν στην ανάπτυξη, διασφαλίζοντας έτσι ότι όλα τα κράτη μέλη μπορούν να επωφεληθούν από τα κοινωνικά και οικονομικά πλεονεκτήματα της ένταξής τους σε αυτήν την Ένωση. Αυτές οι πολιτικές εφαρμόζονται κυρίως μέσω των Ευρωπαϊκών, των Διαρθρωτικών και Επενδυτικών Ταμείων (ΕΔΕΤ), τα οποία περιλαμβάνουν διάφορα χρηματοδοτικά μέσα που στοχεύουν στην ενίσχυση της κοινωνικής, οικονομικής και εδαφικής συνοχής (Ευρωπαϊκή Επιτροπή, 2021).

1.1 Στόχοι και Δομή των Ευρωπαϊκών Χρηματοδοτικών Προγραμμάτων

Στόχος των ευρωπαϊκών χρηματοδοτικών προγραμμάτων είναι η προώθηση της οικονομικής ανάπτυξης με τη βελτίωση των υποδομών και την ενίσχυση της ανταγωνιστικότητας των μικρομεσαίων επιχειρήσεων, καθώς και την προώθηση της καινοτομίας και της βιώσιμης ανάπτυξης. Αυτά τα προγράμματα διαρθρώνονται σε πολυετή πλαίσια με πολύ συγκεκριμένους στόχους και κονδύλια για διαφορετικές περιόδους. Μεταξύ αυτών των πλαισίων είναι τα λεγόμενα Κοινοτικά Πλαίσια Στήριξης (ΚΠΣ) για τα Εθνικά Στρατηγικά Πλαίσια Αναφοράς (ΕΣΠΑ), τα οποία παρέχουν στρατηγική κατεύθυνση και τους απαραίτητους οικονομικούς πόρους για πρωτοβουλίες περιφερειακής ανάπτυξης (Ευρωπαϊκή Επιτροπή, 2020).

Η Πελοπόννησος είναι μια ιστορικά σημαντική και στρατηγικής σημασίας περιοχή στη νότια Ελλάδα, ενώ έχει μοναδικά οικονομικά και αναπτυξιακά χαρακτηριστικά. Είναι γνωστή για την αγροτική της παραγωγή. Η περιοχή έχει κάνει πολύ σημαντικά βήματα για τη διαφοροποίηση της οικονομικής της βάσης. Με τη μεταποίηση να αναδεικνύεται ως βασικός τομέας, η αναπτυξιακή στρατηγική της περιοχής έχει υποστηριχθεί σε μεγάλο βαθμό από ευρωπαϊκά προγράμματα, όπου έχουν παράσχει σημαντική χρηματοδότηση για τη βελτίωση καινοτόμων πρωτοβουλιών και υποδομών (Kyriakopoulos, 2023).

Η παρούσα εργασία εξετάζει τον αντίκτυπο των ευρωπαϊκών προγραμμάτων στον μεταποιητικό τομέα της Πελοποννήσου τις τελευταίες δυο (2) δεκαετίες. Αναλύει τη συμβολή αυτών των προγραμμάτων όσον αφορά την ανάπτυξη υποδομών για την υποστήριξη των ΜΜΕ, την καινοτομία και την ανάπτυξη του ανθρώπινου κεφαλαίου με περιβαλλοντική βιωσιμότητα. Η ανάλυση βασίζεται σε δεδομένα και μελέτες περιπτώσεων από διάφορες περιφερειακές ενότητες της Πελοποννήσου, αναδεικνύοντας έτσι συγκεκριμένα έργα και τα αποτελέσματά τους.

2. Σημασία της Μελέτης

Η κατανόηση του αντίκτυπου των ευρωπαϊκών προγραμμάτων στην περιφερειακή ανάπτυξη είναι πολύ σημαντική για διάφορους λόγους. Αρχικά, παρέχει πληροφορίες σχετικά με την αποτελεσματικότητα των πολιτικών και των χρηματοδοτικών μηχανισμών της Ευρωπαϊκής Ένωσης για την επίτευξη των στόχων τους. Δευτερευόντως αναδεικνύει βέλτιστες πρακτικές αλλά και επιτυχημένες στρατηγικές, οι οποίες μπορούν να εφαρμοστούν σε άλλες περιοχές και τομείς. Υπογραμμίζει επίσης τη σημασία της συνεχιζόμενης στήριξης σε πρωτοβουλίες για την περιφερειακή ανάπτυξη, κυρίως όσον αφορά τις περιφέρειες που αντιμετωπίζουν οι οικονομικές προκλήσεις.

3. Ευρωπαϊκά Προγράμματα και Δομή

ΚΠΣ και ΕΣΠΑ: Για τη στήριξη και την οικονομική ανάπτυξη στις περιφέρειες, τα Ευρωπαϊκά και τα Επενδυτικά Ταμεία αποτελούν βασικά εργαλεία. Μπορούν να παράσχουν την απαραίτητη οικονομική στήριξη για την ενίσχυση των υποδομών.

Ο ρόλος των ΚΠΣ: Το πρώτο ΚΠΣ το 1989-1993 επικεντρώθηκε στη βελτίωση των υποδομών και οδήγησε στα πρώτα βήματα προς την οικονομική συνοχή. Το 1994-1999, λόγω της ανάπτυξης, ξεκίνησε η αντιμετώπιση των οικονομικών και κοινωνικών ανισοτήτων. Το τρίτο ΚΠΣ το 2000-2006 είχε μεγάλα έργα με στόχο την ενίσχυση της ανταγωνιστικότητας, ενώ το 4ο ΕΣΠΑ, που κάλυψε τα έτη 2007-1013 και 2014-2020, επικεντρώθηκε στην καινοτομία, τη βιώσιμη ανάπτυξη και την ένταξη στην ευρωπαϊκή οικονομία.

4. Επιπτώσεις στην Πελοπόννησο

Σπουδές

Οι μικρομεσαίες επιχειρήσεις στην περιοχή της Πελοποννήσου (Fletcher et al., 2021) έλαβαν πολύ σημαντική στήριξη μέσω δανείων, αλλά και επιχορηγήσεων, που στόχευαν στην ενίσχυση της ανταγωνιστικότητας μέσω της καινοτομίας, αλλά και της επιχειρηματικότητας. Το 2007-2013, το Πρόγραμμα Ανταγωνιστικότητας είχε κρίσιμης σημασίας χρηματοδότηση για έργα που σχετίζονται με τον εκσυγχρονισμό και την επέκταση. Δόθηκε έμφαση στην καινοτομία, η οποία οδήγησε σε πολλές επενδύσεις στην έρευνα και την ανάπτυξη. Η δημιουργία και η καινοτομία έχουν ενθαρρύνει τη συνεργασία μεταξύ πανεπιστημίων και βιομηχανιών και αυτό έχει οδηγήσει στη δημιουργία νέων προϊόντων και διαδικασιών που ενισχύουν το ανταγωνιστικό πλεονέκτημα για την περιοχή. Επενδύθηκαν μέσω προγραμμάτων κατάρτισης για το τοπικό εργατικό δυναμικό σε δεξιότητες που απαιτούνται για εφαρμογή σε ένα σύγχρονο περιβάλλον παραγωγής. Η Ευρωπαϊκή Ένωση έχει δώσει μεγάλη έμφαση στην επαγγελματική κατάρτιση και εκπαίδευση, ενώ ταυτόχρονα συμβάλλει στη μείωση της ανεργίας και τη βελτίωση της παραγωγικότητας (Behun et al., 2018). Υλοποιήθηκαν Προγράμματα που στοχεύουν στη βελτίωση της περιβαλλοντικής βιωσιμότητας για την υποστήριξη της υιοθέτησης των πράσινων τεχνολογιών στη μεταποίηση και συνέβαλαν όχι μόνο στη μείωση των περιβαλλοντικών επιπτώσεων, αλλά οδήγησαν τις Επιχειρήσεις σε θέσεις που συμμορφώνονται με τις αυστηρότερες κανονιστικές απαιτήσεις της Ευρωπαϊκής Ένωσης.

Περιφερειακή Ενότητα Αργολίδας

Στο πλαίσιο του Προγράμματος Ανταγωνιστικότητα και Επιχειρηματικότητα 2007 – 2013 υποβλήθηκαν 134 προτάσεις έργων συνολικού προϋπολογισμού 159,7 εκατ. ευρώ. Από αυτά εγκρίθηκαν 71 έργα, ενισχύοντας έτσι σημαντικά τις τοπικές παραγωγικές ικανότητες (Κυριακόπουλος, 2023).

Περιφερειακή Ενότητα Αρκαδίας

Η Αρκαδία επωφελήθηκε από τη σημαντική στήριξη της Ευρωπαϊκής Ένωσης με την υποβολή 193 προτάσεων στο ίδιο πρόγραμμα, με επίκεντρο όμως την αναβάθμιση των υποδομών και της βιομηχανίας. Αυτό είχε ενισχύσει την οικονομική ανθεκτικότητα και τις προοπτικές ανάπτυξης της περιοχής.

Περιφερειακή Ενότητα Κορινθίας:

Η Κορινθία έχει επιτύχει το υψηλότερο ποσοστό απορρόφησης κονδυλίων της Ευρωπαϊκής Ένωσης μεταξύ των περιφερειών της Πελοποννήσου με 391% σε ορισμένα προγράμματα, δείχνοντας αποτελεσματική αξιοποίηση των διαθέσιμων πόρων για οικονομική ανάπτυξη.

Περιφερειακή Ενότητα Λακωνίας:

Η βιομηχανική βιομηχανία σε κίνδυνο έχει δει σημαντικές περιπτώσεις, ιδίως όσον αφορά την ολοκλήρωση έργων, με 85 έργα να ολοκληρώθηκαν επιτυχώς στο πλαίσιο του Περιφερειακού Επιχειρησιακού Προγράμματος για τις ΜΜΕ (PwC Greece, 2022).

Περιφερειακή Ενότητα Μεσσηνίας

Η Μεσσηνία εστιάζει στην καινοτομία και τον εκσυγχρονισμό, με την υποστήριξη της Ευρωπαϊκής Ένωσης, υλοποιώντας πολυάριθμα έργα με στόχο τη βελτίωση της ανταγωνιστικότητας και την επέκταση της αγοράς.

4.1 Ανάλυση περιφερειακών επιπτώσεων

Τα κονδύλια που εκταμιεύθηκαν από την Ευρωπαϊκή Ένωση οδήγησαν σε μια άνευ προηγουμένου οικονομική ανάπτυξη για την περιοχή της Πελοποννήσου, δημιουργήθηκαν νέες επιχειρήσεις, ενώ οι υπάρχουσες επεκτάθηκαν και δημιούργησαν πολλές νέες θέσεις εργασίας, μειώνοντας έτσι σημαντικά τα ποσοστά ανεργίας και ενισχύοντας τις τοπικές οικονομίες (Ευρωπαϊκή Επιτροπή, 2021). Η Ευρωπαϊκή Ένωση, μετά από στοχευμένες επενδύσεις, έδωσε τη δυνατότητα στους κατασκευαστές να ενισχύσουν την ανταγωνιστικότητα που είχαν μέσω προηγμένων τεχνολογιών, εκσυγχρονίζοντας τις δραστηριότητές τους και καταφέρνοντας να βελτιώσουν την ποιότητα των προϊόντων τους. Επέκτειναν την αγορά τους στο εσωτερικό και σε διεθνές επίπεδο, με αποτέλεσμα να αυξήσουν την παραγωγική αποδοτικότητα. Τα προγράμματα υποστηρίζουν δραστηριότητες έρευνας και ανάπτυξης για να οδηγήσουν στη δημιουργία νέων προϊόντων και υπηρεσιών. Αυτή η καινοτομία ενίσχυσε τον τομέα της μεταποίησης, αλλά συνέβαλε επίσης στη συνολική οικονομική ανθεκτικότητα της περιοχής (Xie, Jiang, & Han, 2020). Συμπληρωματικά, τα προγράμματα έχουν σημαντικά κοινωνικά και περιβαλλοντικά οφέλη. Οι πράσινες τεχνολογίες και οι βιώσιμες πρακτικές μειώνουν σημαντικά το περιβαλλοντικό αποτύπωμα στον μεταποιητικό τομέα. Η έμφαση στην ανάπτυξη του ανθρώπινου δυναμικού βελτιώνει τις δεξιότητες σε ένα τοπικό εργατικό δυναμικό. Και τους οδηγεί σε καλύτερες προοπτικές απασχόλησης με υψηλότερο βιοτικό επίπεδο (Li, Li, & Ren, 2018).

5. Αναλυτική Συμβολή Προγραμμάτων

1. Πρόγραμμα Ανταγωνιστικότητας και Επιχειρηματικότητας (2007-2013): Το πρόγραμμα αυτό είχε ως στόχο την ενίσχυση της ανταγωνιστικότητας των Ελληνικών ΜΜΕ μέσω επενδύσεων στην καινοτομία, τη διεθνοποίηση και τον εκσυγχρονισμό. Η επιτυχία του προγράμματος στην Πελοπόννησο είναι εμφανής μέσα από τον μεγάλο αριθμό εγκεκριμένων έργων, αλλά και από την ουσιαστική οικονομική στήριξη που παρέχεται (Jarsulic, 2021).

2. Πρόγραμμα Ανταγωνιστικότητας, Επιχειρηματικότητας και Καινοτομίας (2014-2020): Με βάση την επιτυχία του προηγούμενου προγράμματος, το πρόγραμμα αυτό συνέχισε να υποστηρίζει τις ΜΜΕ στην Πελοπόννησο, παρέχοντας σημαντική χρηματοδότηση για την καινοτομία και την τεχνολογική πρόοδο. Αυτό το πρόγραμμα τόνισε τη σημασία της περιβαλλοντικής βιωσιμότητας αλλά και της ενεργειακής απόδοσης, η οποία ευθυγραμμίστηκε με τους ευρύτερους στόχους της Ευρωπαϊκής Ένωσης (Povolná & Švarcová, 2017).

3. Πρόγραμμα Έρευνα – Δημιουργία – Καινοτομία: Αυτή η πρωτοβουλία ήταν ζωτικής σημασίας για την προώθηση της συνεργασίας μεταξύ ακαδημαϊκών και βιομηχανίας. Με την υποστήριξη ερευνητικών έργων και καινοτόμων εγχειρημάτων, το πρόγραμμα διευκόλυνε την ανάπτυξη νέων τεχνολογιών και προϊόντων, ενισχύοντας έτσι το ανταγωνιστικό πλεονέκτημα της περιοχής.

5.1 Μελλοντικές προοπτικές

Τα συνεχιζόμενα προγράμματα της Ευρωπαϊκής Ένωσης για την περίοδο 2021 – 2027, συνεχίζουν να βασίζονται σε προηγούμενες επιτυχίες με νέες πρωτοβουλίες, οι οποίες προσαρμόζονται στις εξελισσόμενες ανάγκες του μεταποιητικού τομέα. Στόχος του προγράμματος σύγχρονης μεταποίησης είναι η ενίσχυση της ανταγωνιστικότητας των υφιστάμενων μεταποιητικών ΜΜΕ και η υποστήριξη της ίδρυσης νέων, με ιδιαίτερη έμφαση στην καινοτομία και τη διεθνοποίηση της αγοράς με έμφαση στην προώθηση βιώσιμων επιχειρηματικών πρακτικών. (Rutledge & Mayorga, 2022).

Συμπεράσματα

Τα ευρωπαϊκά προγράμματα διαδραματίζουν κρίσιμο ρόλο στον μετασχηματισμό του μεταποιητικού τομέα στην περιοχή της Πελοποννήσου, παρέχουν οικονομική υποστήριξη και προάγουν μια κουλτούρα καινοτομίας και βιωσιμότητας, όπου τα προγράμματα αυτά επέτρεψαν σημαντική οικονομική ανάπτυξη. Η περιοχή συνεχίζει να αξιοποιεί τη χρηματοδότηση από την Ευρωπαϊκή Ένωση και βρίσκεται σε καλή θέση για να επιτύχει περαιτέρω ανάπτυξη και ανταγωνιστικό πλεονέκτημα στην παγκόσμια αγορά (Fletcher, McNamara, & Wyatt, 2021). Τα διδάγματα και οι επιτυχίες που σημειώθηκαν στην Πελοπόννησο μπορούν να λειτουργήσουν ως πρότυπο για άλλες περιοχές που επιθυμούν να καρπωθούν τα οφέλη που προσφέρει η Ευρωπαϊκή Ένωση μέσω της ολοκλήρωσης και της υποστήριξης. Επικεντρώνεται στην καινοτομία, τη βιωσιμότητα και την ανταγωνιστικότητα, ενώ μπορεί να συνεχίσει να ευδοκιμεί και να συμβάλλει σημαντικά στην οικονομική ανάπτυξη της Ελλάδας. Τα μελλοντικά προγράμματα θα πρέπει να συνεχίσουν να αντιμετωπίζουν τις συγκεκριμένες ανάγκες της περιοχής, διασφαλίζοντας παράλληλα ότι ο μεταποιητικός τομέας παραμένει βασικός μοχλός της οικονομικής ανάπτυξης (Behun et al., 2018). Συμπερασματικά, η δέσμευση της Ευρωπαϊκής Ένωσης για την περιφερειακή ανάπτυξη μέσω διαφόρων χρηματοδοτικών προγραμμάτων έχει βαθύ αντίκτυπο στην Πελοπόννησο, (Ευρωπαϊκή Επιτροπή, 2021).

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Exploring the Contributing Factors of Patient-Physician Trust in Greece to Develop Relevant Marketing Strategies

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ABSTRACT

Trust plays a crucial role in the patient–physician relationship. Trust can improve health care effectiveness, whilst the lack of trust could have important consequences in health outcomes. By applying qualitative research, this study aims at exploring the factors which are essential for building a trustful patient- physician relationship. Seven in-depth semi-structured interviews with patients/individuals were conducted and analyzed using grounded theory methodology. Results demonstrated that active listening, providing evidence-based information and showing true interest in patients are the central elements for building trust from the patient's perspective. Based on these preliminary findings, medical providers could try to effectively design strategies to gain patients' trust which would have several benefits in a micro and macro level.

KEYWORDS

Trust, Medical Marketing, Distrust, Marketing Strategies

JEL CLASSIFICATION CODES
M30, M19

INTRODUCTION

Trust, which is“a state of favourable expectation regarding other people's actions and intentions” (Möllering, 2001; p. 404), applies to the patient-physician relationship (Lersch et al., 2024)According to Mayer et al. (1995; p.712), trust is “the willingness of a party to be vulnerable to the actions of another party based on the expectation that the other will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party”. As Anderson and Dedrick (1990) note, patients' trust is the set of prospects and expectations that the patient forms for the medical provider. Trust is crucial to patients to reveal their medical history, provide sensitive information and get physically examined (Safran et al., 1998). Moreover, trust is a basic requirement to search for medical care, according to several authors (e.g. Lau et al., 2000; Dunn and Perry 1997).

Nowadays, patients are more educated, better informed, as well as more critical and demanding. They also higher control over the health care received (Rodwin, 1994). Whetten et al. (2006), who studied trust between care providers and HIV/AIDS patients, found that increased trust is related to a more effective use of medications and more positive health outcomes. Prior research has also demonstrated a positive association between patients' trust in their provider and patient compliance (Trachtenberg et al., 2005; Piette et al., 2005).

The key types of trust are cognitive and affective (Aiken and Boush, 2006). Cognitive trust focuses on someone's willingness to rely on a provider's capability and is based on gathered knowledge, which permits to make predictions (Moormanet al., 1992). As Jonson and Grayson (2005) add, when the provider owns high reputation levels, cognitive trust could be built within one or just a few interactions. On the other hand, affective trust relies on emotions and summarizes someone's perceptions about a provider's level of care (Kim and Park, 2013).

According to Coleman (1990), gaining trust is connected to justification. Trust could be justified by the calculation of risk, gains, assurances, or rational thoughtful reflection. Brown (2009) argues that trust justification may stem from experience. Frederiksen (2014) and Möllering (2006) also agree that justification of trust is a prerequisite for actual trusting.

In Greece trust would be expected to be stronger compared to other countries, since Greek patients can choose any medical professional without restricted health plans (Mechanic, 1998). Nevertheless, as Vlassi et al. (2022) found, 69.7% totally distrust the Greek health care system. However, it is notable that in Vlassi et al. (2022) study, a few respondents commented on distrusting medical providers, as they do recognize their high skills.

As Hall et al. (2001) argue, the prior research on trust in the medical sector has been scarce. Chang et al. (2013) agree that the important concept of trust within the patient- medical provider relationship has not been deeply investigated, while Lerch et al. (2024) add that paste studies on patient-physician trust are limited. On top of that, Lerch et al. (2024), highlight that there is lack of studies which focus on factors which contribute to the patient-medical provider interpersonal trust relationship.

Based on the above, this paper aims at filling in the gap in the relevant literature by investigating the key elements which contribute to building trust within the doctor-patient relationship. Identifying the key components of trust could allow medical providers to invest on particular issues so as to gain and retain patients' trust. When patients trust their doctor, they have lower levels of worry (Griffin et al., 2024) and are more likely to follow the doctor's advice (Rothstein, 1996), which would in turn have more positive health outcomes in a micro and macro level (Rowe and Calnan, 2006).

METHODOLOGY

This study is based on a qualitative research design according to the grounded theory methodology, as the main goal is to deeper investigate thoughts, emotions, and attitudes. Data collection involved seven separate interviews with patients/individuals during May 2024. The paper adopts the typical approach of phenomenological interviewing (Moustakas, 1994), using an interview guide. In the beginning of the interviews, the researchers informed participants about the procedure and duration. All seven interviewees were volunteers who agreed to participate in the study. The researchers assured them regarding the confidentiality and anonymity of the data collected. Interviewees were also asked to sign the informed consent and give their permission to record them. Interviews were semi-structured; an interview guide was used. Interview questions included: "Have you ever felt that you immediately trust a doctor?", "What makes you trust a doctor?", "What would you make you distrust a doctor?", "How would you react if you felt to distrust a doctor?". Moreover, respondents were encouraged to describe situations in which they trusted or distrusted a doctor and give details on the elements which contributed to each situation. As a first stage of the analysis, the researchers read the transcripts of the seven interviews and made an initial coding. The codes are actually labels that researchers assign to words or sentences. At a second stage, a more profound analysis was conducted, and the final coding was performed.
The demographics of the interviewees are presented in Table 1, below:

Table 1. Interviewees' demographics

Participant	Age	Gender
1	48	F
2	47	M
3	61	F
4	55	F
5	30	M
6	52	M
7	78	F

RESULTS-DISCUSSION

Interviewees described that in certain cases trust emerged immediately (e.g., in the first visit), while in other situations they needed more time to feel trust or distrust.
[…], I decided to get a second opinion and visited a surgeon recommended by a friend. He gained my trust within the first couple of minutes of the visit. (interviewee #4)
Sometimes, it is difficult to tell if I trust them [doctors] or not […] maybe I need more time […]. There is another situation where I clearly trusted a doctor after the initial visit. (interviewee #3)
The participants stressed that it is important for them to describe in detail their health situation to the physicians. They want doctors to carefully listen to them, and give them adequate time to fully explain their symptoms, medical history, emotions, etc. For some interviewees this characteristic was crucial for trusting a doctor, since active listening was perceived as a proof that the doctor somehow care for them.
[I trusted the doctor] because he was prudently listening to me. He was looking me into the eyes. [the doctor's] facial expressions showed that he listened everything I said. (interviewee #1)

There are some doctors who are in hurry, just to make quickly. I feel that they do not have time to listen to me. I never trust someone who asks me to quickly describe my problem. (interviewee #4)

The above finding is consistent to Roter and Hall (1992) and Mechanic (1998) who note that the quality of patients' experience is improved when doctors carefully listen to them and give them the opportunity to early tell their stories. Thus, it is important that medical providers devote ample time to listening to their patients. Sometimes doctors are in hurry to prevent other patients waiting for long time which may cause dissatisfaction to the patient examined. Well-organized lengthy appointments that would enable patients to have plenty of time to explain their situation would be very helpful to build trust. Moreover, some preliminary information could be given online or via phone (e.g. to the provider's assistant or secretary) so as to save valuable time in the first visit. Similarly, if, for any reason (e.g. emergency call), the doctor is not able to dedicate the appropriate time to the patient, this should be communicated with honesty and find alternative ways to talk or meet again (for free, if the visit was paid).

Apart from active listening, patients expect doctors to show empathy, understand their pain/worries/anxiety and, in general, be treated with respect. Doctors who focus on money are usually distrusted, according to the results of the study.

I did not trust her [i.e., the doctors] because it was like trying to gain money from me. […] like she did not honestly care about my problem. (interviewee #7)

As Mechanic (1998) note, doctors should take into consideration financial constraints that patients may have. Moreover, in order to gain patient's trust the physicians should not primarily care about money. The promotion of patients' health and caring about their problem should be placed above money.

Caring about patients' needs was mentioned by all interviewees as a key factor of trust. All participants expect to be respected by the doctor who would also show empathy and warmth.

The doctor was so nice with me […] he explained my results in detail; I felt that he cared for me…like he tried to do his best. That is why I trust him. (interviewee #1)

When I was about to leave [the doctor's] office being quite upset, she touched my shoulder and said in a reassuring tone of voice "don't worry; everything will be just fine." (interviewee #3)

Patients want to feel unique and expect doctors to show truthful interest in their problem. A patient-centric approach is usually connected to trust, based on the respondents of the study. This finding mostly reflects affective trust (Aiken and Boush, 2006). According to Mechanic (1998), the perception that physicians do not care much about their patients could prevent information exchange, which may be necessary for trust building.

Another element which leads to trust, based on the study, was detailed information, thorough explanation of the health situation, treatment plan, plan options, etc.

I asked the doctor why all three prescribed medicines were essential. He answered something like "they just are" which I did not like at all. Actually, from that moment I was sure that I don't trust him and would get a second opinion. (interviewee #6)

I always want my doctor to explain everything in detail, […] to be sure that I understand everything related to my health. (interviewee #5)

I trust a doctor when he provides evidence, […] when it is apparent that his words are based on scientific knowledge, […] when it looks like he continuously reads and gets informed about new data. (interviewee #1)

According to previous studies (e.g. Waitzkin, 1985) medical providers sometimes underestimate patients' need to receive detailed information. They may assume that as they do not have adequate medical knowledge it is not necessary to give details about a disease, a medicine, or a treatment. However, as Mechanic (1998) argues, patients expect their physician to share all essential information and options they have regarding their treatment.

CONCLUSIONS, LIMITATIONS AND DIRECTIONS FOR FURTHER STUDY

Based on the results of the study, it is important for physicians to invest on building trust with their patients as such a trustful relationship is beneficial, according to the past literature. Patients expect physicians to be good active listeners, explain in detail every aspect of their condition, treatment, etc, and show true interest in their problem. These elements are essential for building and maintaining trust. The current study was based on a small sample in Greece and employed qualitative methodology to reveal some preliminary results. Further study could engage more participants and/or use quantitative research to validate results. Moreover, it would be interesting to explore the impact of demographics (e.g. gender, age, income, education level) on the determination of factors which compose trust. Finally, further research could concentrate on trust in public/ private hospitals and elements which compose trust in other providers, such as pharmacists, nurses, dietician, etc.

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Exploring the Existence of Crowding-out Effect and Influence of Macroeconomic Indicators on Capital Market in Bangladesh: A Vector Autoregressive Analysis

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Abstract

This study used a Vector Autoregressive Model to analyze the dynamic interplay between gross capital formation and macroeconomic indicators in Bangladesh's capital market. It utilized forecast error variance decomposition and impulse response functions to gauge macroeconomic factors' explanatory power, finding all to exhibit Granger causality with gross capital formation. A structural VAR model addressed potential contemporaneous biases, and the analysis of government spending and decomposition of investment indicated a crowding-out effect that highlighted challenges in capital market performance. Finally, the study concludes by presenting implications and recommendations drawn from the findings to enhance the capital market scenario in Bangladesh and pave the way for the future inclusion of green capital initiatives.

Keywords: capital market, macroeconomics, crowding out, financial economics

1.0 Introduction

A capital market functions as a marketplace for the exchange of financial instruments like stocks, bonds, and other securities. The capital market consists of the stock and bond markets, divided into two main types: primary and secondary. These markets enable the trading of various financial assets, such as bonds, options, loans, and more. In the primary market, companies raise new capital by issuing stocks and bonds to investors. In contrast, the secondary market allows traders and investors to exchange these securities among themselves, but it doesn't provide additional capital to the issuing firms (Investopedia, 2021).

The capital market serves a significant function in channeling funds. The capital market has a prime role in fostering economic growth and financial sustainability, which in turn, will pave the path of a country's sustainable, inclusive and green development. By examining the macroeconomic determinants, the study provides valuable insights into the broader economic context that influences the growth and functioning of the capital market in developing economies like Bangladesh. These state of capital market and its determinants signal to participants whether to expect higher or lower returns on their investments, and fluctuations in these factors can significantly affect capital market prices (Barakat, Elgazzar, & Hanafy, 2016).

The classic work of Eugene Fama's Efficient Markets Hypothesis (1970), highlights the critical role of macroeconomic information in influencing stock market returns. Fama suggests that beating the market consistently is difficult. Any discrepancies in how macroeconomic factors affect stock prices can result in market inefficiencies and mispricing (Fama, 1970). This makes consistently outperforming the market unlikely, except for those rare instances of remarkable luck (Baldridge, 2022). Such discrepancies could undermine stakeholder confidence and lead to the creation of policies that are theoretically sound but practically ineffective, and result in significant misjudgments in investment strategies. Following these concepts, the semi-strong form of market efficiency best represents real-world financial markets, where stock prices swiftly integrate all publicly available information, including macroeconomic data impacting companies. This underscores the importance of investors considering these factors in their investment assessments (Omodero, 2020), which in turn, will affect the market capitalization.

Ross's "Arbitrage Theory of Capital Asset Pricing" suggests that an asset's returns can be predicted by its expected returns and sensitivity to macroeconomic variables, such as inflation, interest rates, and economic growth (Ross, 1976). However, Naik and Padhi (2012) found that the impact of these variables on stock prices varies across different markets and time periods (Naik & Padhi, 2012). This indicates a need for specific country-contextual research to explore how macroeconomic factors interact with the capital market.

Merton (1987) explored the dynamics of capital market equilibrium in the presence of incomplete information and it provides a theoretical foundation for understanding how macroeconomic factors can affect financial equilibrium by influencing the quality and availability of information (Merton, 1987). While macroeconomic factors directly influence market capitalization, information about these conditions indirectly affects investment decisions and, consequently, capital market performance.

Contrarily, Tangjitprom (2012), empirically, challenged the EPH and Arbitrage Pricing Theory by showing that stock returns led macroeconomic indicators, not the other way around, with interest rates as the main influencer of stock return variations in the Thai stock market, using VAR (Tangjitprom, 2012). Despite this contradictory empirical findings, majority of the empirical research underscores the influence of macroeconomic factors on the capital market. For example, Issahaku (2013) utilized VECM found a long-term correlation between stock returns and variables like FDI, inflation rate, and supply of money and in the shorter period, there was a significant link between returns from stock and rate of interest, inflation rate, and supply of money stock, in Ghana (Issahaku, Ustarz, & Domanban, 2013). Sukuoglu and Nalin (2014) utilized dynamic panel model across European countries and discovered that while money supply and inflation negatively affected stock market growth, savings rates, liquidity ratios, and income had positive effects (Sukruoglu &

Nalin, 2014)[2]. Another study found causal links among the stock market index and money supply, interest rates, consumer price index, and exchange rate in Egypt, while in Tunisia, all but the consumer price index showed causal connections to the stock market index (Barakat, Elgazzar, & Hanafy, 2016). Additionally, Giri and Joshi (2017) found that inflation, FDI, exchange rates, and economic growth positively affected stock prices, while crude oil prices had a negative impact (Giri & Joshi, 2017).

Interestingly, while most studies have found a positive relationship between GDP growth and stock or capital market performance, Innocent et al. (2018) identified a counterintuitive finding in their analysis of Rwanda's stock market. Using VAR and Variance Decomposition analysis, they discovered that GDP, along with inflation, negatively affected stock performance. This study also noted that exchange rates and interest rates had little impact on the market. The negative association between GDP and stock performance remains unexplained (Innocent, Shukla, & Mulyungi, 2018). In our study of the capital market of Bangladesh, we have encountered a similar problem and by decomposition the public and private capital market, we found the existence of a dominant crowding out effect in Bangladeshi capital market. Our study strengthens the unusual capital market dynamics of Bangladesh found in Moazzem and Rahman (2011), where they investigated the relationship between regulatory decisions by the BSEC and market volatility in the DSE (Moazzem & Rahman, 2011).

The research timeframe of 1977 to 2022 allows for an in-depth analysis of short and long-term trends and patterns, facilitating a comprehensive understanding of sustainable growth over time. Policymakers and stakeholders can benefit from the study's findings to make informed decisions

[2] This finding is consistent with Hsing's (2014) study on Estonia using a GARCH model, which found that the stock market index positively correlated with real GDP, the debt-to-GDP ratio, and the German stock market index. Conversely, it exhibited a negative correlation with expected inflation, the exchange rate, domestic interest rates, and Euro area government bond yields (Hsing, 2014). .

that foster inclusive and sustainable financial market development that facilitates sustainable economic development for the well-being of all in Bangladesh. This study aims to examine the relationship between overall capital market performance and macroeconomic factors, acknowledging the tight link between stock prices and capital market health, while utilizing a systematic time series methodology.

Even though previous pieces of literature covered various aspects, dimensions, and scopes of the stock market of countries around the world, including Bangladesh, the overall performance, aspects, and dimensions of the capital market, which consists of both stock and non-stock components, are still not sufficiently explored. Only one such relevant study can be found where Omodero (2020) investigated the effects of GDP, exchange rate, rate of interest, and inflation rate on overall capital market capitalization (CMC) in Nigeria from 1998 to 2018 and discovered that GDP had a positive effect on CMC, while exchange rate and inflation rate had negligible and unfavorable effect (Omodero, 2020). Hence, this study addresses a significant research and knowledge gap in understanding the dynamics of the overall capital market dynamics in emerging countries like Bangladesh, which implicitly discusses the overall performance financial barometer associated with macroeconomic factors in a structured procedure.

The study investigates the impact of key macroeconomic determinants—real interest rate, inflation rate, GDP growth rate, and exchange rate—on the performance of Bangladesh's capital market. It also examines causal relationships among these factors. Utilizing a VAR Model, along with structural VAR and Granger causality test, with yearly data from 1977 to 2022, the research tests hypotheses related to the influence of macroeconomic factors on capital market performance and finds evidence of a crowding-out effect in the Bangladesh capital market.

Section 2 details the methods and materials used. Section 3 presents results, discussions, implications, and recommendations. The paper concludes with Section 4, summarizing key findings and offering conclusions. Detailed calculations and supporting data are provided in the appendix.

2.0 Research Methodology

2.1 Variables

2.1.1 Growth Rate of Real Gross Capital Formation (gcf_gr)

According to the World Bank, gross capital formation, once called gross domestic investment, covers spending aimed at boosting the economy's fixed assets and changes in inventory levels. Fixed assets encompass various additions like land improvements, machinery purchases, and infrastructure construction. Inventories refer to goods held by companies for production or sales fluctuations. The 2008 System of National Accounts also includes net acquisitions of valuable items in capital formation. The data is presented in constant 2015 prices in U.S. dollars. Growth rate of real gross capital formation measures the percentage change in gross capital formation from year to year (World Bank, 2022). The variable is presented as percentage (%) unit in this study. Gross capital formation has been used to gauge capital market performance, as shown in Omodero's (2020) study in Nigeria. This research will assess capital market performance by examining the yearly percentage change in total market capitalization across various financial instruments, using it as a proxy for performance. The study also focuses on growth rates to ensure consistency across variables.

2.1.2 Growth Rate of Real GDP (gdp_gr)

The Real GDP growth rate, adjusting for inflation, represents the percentage change in economic output over time, providing a measure of economic performance. It's calculated in constant 2015 U.S. dollars and presented as a percentage unit in this study.

2.1.3 Official Exchange Rate (er)

The official exchange rate is the rate set by a country's authorities or determined through a legally authorized exchange market. It is typically computed as an annual average using monthly averages and signifies the value of the local currency concerning the U.S. dollar. In this research, the official exchange rate is represented by the amount of Bangladeshi Taka required to purchase a single unit of the U.S. dollar (World Bank, 2022).

2.1.4 Inflation Rate (inf)

In this study, the inflation rate is determined by the annual growth rate of the GDP deflator, a comprehensive measure reflecting price changes across the economy. The GDP deflator, calculated by comparing current and constant local currency GDP, provides a broad inflation perspective by including all goods and services, not just a consumer basket like the Consumer Price Index (CPI). This makes it a vital tool for adjusting nominal GDP to real GDP, accounting for inflation's impact and covering capital goods beyond consumption items, offering a more relevant analysis variable (World Bank, 2022). Using the GDP deflator also helps in examining the effects of the real interest rate.

2.1.5 Real Interest Rate (rir)

As per the World Bank, the real interest rate represents the adjusted lending interest rate, factoring in inflation, typically measured by the GDP deflator (World Bank, 2022). The variable is presented as percentage (%) unit in this study. It serves as an accurate measure of the true cost of borrowing funds. While nominal lending and deposit interest rates in Bangladesh are controlled by the Bangladesh Bank, the real interest rate, which accounts for inflation, fluctuates over time.

2.2 Conceptual Framework

2.2.1 Growth rate of Gross Domestic Product and Growth Rate of Gross Capital Formation

As economic activity and GDP increase, there's a positive impact on company revenues, earnings, and market capitalization. In transitioning economies, capital markets might not play as significant a role as in industrialized ones. A country's economic well-being is often assessed through its GDP. Investors consider GDP reports for investment decisions (Draženović & Kusanović, 2016). Theoretically, GDP growth and gross capital formation growth are likely positively correlated. Positive GDP growth correlates with increased corporate profits and better stock market performance (Mburu, 2015). Households also use GDP as a measure of economic performance (Ostrom, 2000; Hardin, 2015). Including GDP growth rate in the study helps assess how economic changes influence capital formation (Stock & Watson, 2001). Since GDP is interconnected with other macroeconomic factors, including its growth rate makes the general equilibrium more representative of the real scenario.

2.2.2 Official Exchange Rate and growth rate of Gross Capital Formation

The Balassa-Samuelson hypothesis suggests that exchange rate fluctuations impact tradable and non-tradable goods, influencing capital formation (Balassa, 1964). Exchange rate movements affect foreign investment: a stronger domestic currency raises costs for foreign investors, reducing demand for domestic stocks; a weaker currency attracts foreign investors but may lead to withdrawals, prompting the central bank to raise interest rates, diverting investors to banks.

A falling exchange rate affects companies' costs, impacting financial performance. This may lead investors to sell shares and move funds to more profitable alternatives or bank savings accounts (Arianto & Siswanto, 2021). Empirically, Omoregie, Olofin, and Ikpesu (2020) used a non-linear autoregressive model on Nigerian data, revealing a changing causal relationship between the exchange rate and the capital market over time (Omoregie, Olofin, & Ikpesu, 2020).

2.2.3 Inflation Rate and growth rate of Gross Capital Formation

Gurloveleen & Bhatai (2015) theorized that rising inflation increases living costs, diverting resources from investments to household consumption (Gurloveleen & Bhatai, 2015). Inflation tends to negatively correlate with stock market performance as it reduces demand for stock investments. High inflation raises consumer goods prices, leading to reduced savings and decreased stock market investment. It also makes capital goods more expensive, further hindering capital formation (Fischer, 1993). Talla (2013) found that the inflation-stock market relationship depends on whether inflation is anticipated or unexpected. Expected inflation can drive stock prices up, while unexpected inflation redirects resources from investment to consumption, negatively impacting stock prices (Talla, 2013). Given Bangladesh's volatile inflation, considering the inflation rate is crucial when examining its capital market performance.

2.2.4 Rate of Real Interest and growth rate of Gross Capital Formation

Interest rate fluctuations swiftly impact capital markets. Mishkin (2004) notes the inverse relationship: rising rates lead to lower returns, causing drops in share and bond prices (Mishkin, 2004). Elevated real interest rates reduce investment, diminishing returns and potentially lowering earnings, dividends, and stock prices.

In developed markets, short-term rate changes significantly affect bond prices, while stocks are more influenced by long-term growth prospects. Long-term interest rate shifts can notably impact stock prices. Prolonged drops in real interest rates tend to boost investments and stock prices (Chovancová, 2001).

2.3 Macroeconomic Framework – Vector Autoregressive Model

For the purpose of this study, it is necessary to use a model containing various macroeconomic factors and capital market indicator in order to capture dynamic interactions among variables over time. An important development involved broadening general equilibrium theory to encompass dynamic stochastic models, where goods could be indexed based on time and events (Kydland & Prescott, 1991). In order to employ a method to capture the inter-dynamic situation with a quantitative analysis of business cycle variations and macroeconomic foundation of an economy, Vector Autoregressive Model (VAR) can be used since it possesses the strength to compute the equilibrium processes within dynamic stochastic economies. Additionally, this study would also like to use some extended versions of VAR and investigate the stability of the model.

In addition to that, since VAR models are estimated directly from data, this technique is particularly useful when the underlying economic theory is not well-established or when the dynamic relationship among the variables may change over time (Sims, 1980; Hamilton, 1994). Additionally, unlike any structural model, VAR models do not require any priori assumptions about the functional form or the direction of causality between variables. This flexibility is also desirable when the true nature of the economic relationship is not well understood, which, apparently, is the current scenario in the context of Bangladesh's capital market (Enders, 2015; Sims, 1980; Hamilton, 1994).

2.4 Source of Data

This study is a secondary data analysis where data has been sourced from World Development Indicators, and the Bangladesh Bureau of Statistics (BBS and spans across the years from 1977 to 2022 on an annual basis. The time frame is selected upon the fact that after liberation, the stock exchange began in 1976 and data is available up till 2022 (Naoaj, Khan, & Ahsan, 2021). The data was compiled in MS Excel format and was analyzed using Stata 16.0.

2.5 Methodological Steps

The data analysis process involved several key steps. Firstly, a trend analysis was conducted through Ordinary Least Squares (OLS) regression, and detrending was applied to variables exhibiting trends.

Stationarity tests, including Augmented Dickey-Fuller (ADF) tests, were performed to identify unit roots and achieve stationarity by differencing variables as needed. Seasonality was assessed using Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF), with de-seasonalization applied if required. The fourth step involved ensuring integration orders compatibility and choosing appropriate lags using selection criteria for Vector Error Correction Model (VECM) or Vector Autoregressive (VAR). Causality tests, specifically Granger Causality, were conducted for VAR models. The stability of VAR models was evaluated through eigenvalues. Forecast Error Variance Decomposition (FEVD) was performed using Choleksy decomposition, and Impulse Response Functions (IRF) were generated. Additionally, Structural Vector Autoregressive (SVAR) was considered to address contemporaneous bias in VAR results (Enders, 2015; Stock & Watson, 2001). In cases of unconventional results, the study introduced additional variables and repeated the seven-step process for thorough data analysis.

3.0 Findings

3.1 Result

The comprehensive trend, stationarity, ACF and PACF analyses, detailed in Appendices A (see Table A.1), B (see Table B.1), and C (see Figure C.1, Figure C.2, Figure C.3, Figure C.4, and Figure C.5), provide valuable insights into the macroeconomic determinants of Bangladesh's capital market. The integrated macroeconomic variables, including the growth rate of gross capital formation, detrended GDP growth rate, detrended exchange rate, inflation rate, and real interest rate, exhibit stationary behavior and white noise processes, except for an MA(1) process in detrended exchange rate. Adding a lag of detrended exchange rate (erhat) includes an extra error in the model and therefore, incorporates an MA(1) process in the VAR model (Enders, 2015; Kočenda & Černý, 2015).

Despite an optimal lag of 1 in the VAR model (see Table D.1 from Appendix D), in accordance with AIC, SBC and HQIC, practical coherence and significance arise with 2 lags (Appendix E). Taking 1 lag makes the coefficients of VAR insignificant and from table E.1 (Appendix E), it can be observed that apart from the lagged value of the variable itself, the variables are not associated with any other variable of the macroeconomic frame. However, it does not make sense since it is not possible for five major macroeconomic variables to be unrelated to each other. The Granger causality tests confirm significant unidirectional causal relationships from GDP growth rate, exchange rate, inflation rate, and real interest rate to gross capital formation (see Table H.1 from Appendix H) at lags 2. If the macroeconomic scenario arose from the VAR with 2 lags is found logical, and VAR is found stable afterwards, the analysis can stop since over-differencing will increase the noise in the system. Additionally, this issue recurs in other VAR models, leading this study to consistently use 2 lags in the VAR analysis for all cases.

Table 1: VAR (Growth Rate of GCF, Detrended Growth Rate of GDP, Detrended Exchange Rate, Lag of Detrended Exchange rate, Inflation Rate and Real Interest Rate, at lag=2)

VARIABLES	(1) gcf_gr	(2) gdp_grhat	(3) erhat	(4) L_erhat	(5) inf	(6) rir
L.gcf_gr	0.385**	0.0156	0.0278	-0**	0.233	-0.174
	(0.151)	(0.0473)	(0.0929)	(0)	(0.264)	(0.226)
L2.gcf_gr	-0.00530	-0.0331	-0.0578	0**	0.0815	-0.104
	(0.145)	(0.0454)	(0.0890)	(0)	(0.253)	(0.217)
L.gdp_grhat	-1.345***	-0.335**	0.466*	0	-0.512	0.544
	(0.418)	(0.131)	(0.257)	(0)	(0.731)	(0.627)
L2.gdp_grhat	-0.645	0.00262	0.403	-0	0.178	-0.0722
	(0.408)	(0.128)	(0.251)	(0)	(0.713)	(0.612)
L.erhat	0.668**	0.160*	0.818***	1***	0.0413	0.108
	(0.269)	(0.0845)	(0.166)	(0)	(0.471)	(0.404)
L2.erhat	-0.364	-0.133	0	0***	0.0299	-0.166
	(0.348)	(0.109)	(0)	(0)	(0.609)	(0)
L2.erhat	0	0	-0.463**	0	0	0
	(0)	(0)	(0.214)	(0)	(0)	(0.523)
L3.erhat	0.117	0.130	0.221	-0***	0.530	-0.430
	(0.261)	(0.0817)	(0.160)	(0)	(0.456)	(0.391)
L.inf	-1.577***	-0.581***	0.314	-0**	-0.628	1.529*
	(0.528)	(0.166)	(0.325)	(0)	(0.923)	(0.792)
L2.inf	1.880***	0.681***	-0.590	0***	0.623	-0.623
	(0.607)	(0.190)	(0.374)	(0)	(1.062)	(0.911)
L.rir	-2.019***	-0.693***	0.405	-0**	-0.817	1.821**
	(0.615)	(0.193)	(0.379)	(0)	(1.076)	(0.923)
L2.rir	2.221***	0.739***	-0.656	0**	0.593	-0.642

	(0.676)	(0.212)	(0.416)	(0)	(1.181)	(1.014)
Constant	1.485	-0.956	3.581	-0	5.469	-4.916
	(3.930)	(1.233)	(2.418)	(0)	(6.871)	(5.897)
Observations	43	43	43	43	43	43

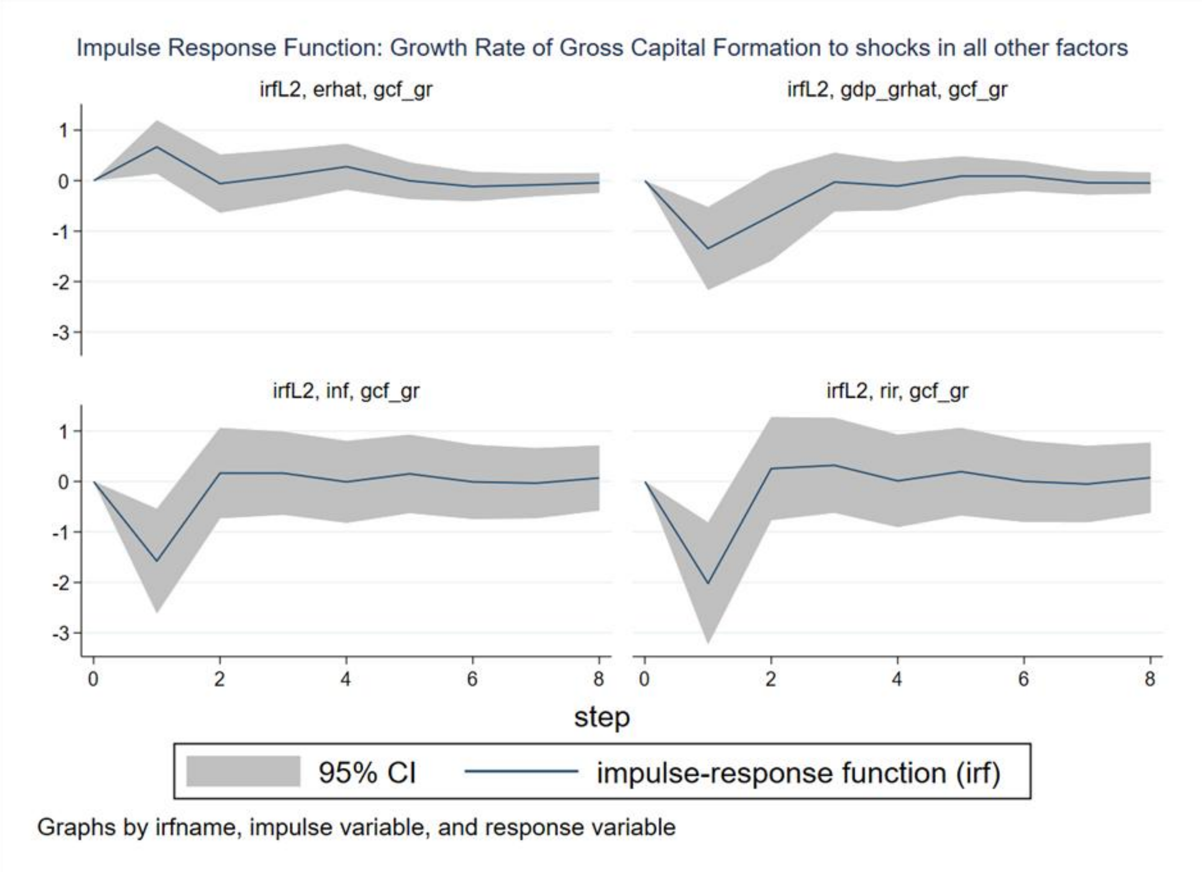
Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 1 and the Granger causality test in Table H.1 (Appendix H) reveal significant correlations and causal relationships between macroeconomic factors and the growth rate of gross capital formation in Bangladesh. Specifically, past values of exchange rate, GDP growth rate, inflation rate, and real interest rate significantly influence capital formation. A higher past exchange rate positively affects capital formation, indicating that depreciation of the Bangladeshi Taka encourages capital

Figure 1: Impulse Response Function

formation. Conversely, increases in GDP growth, inflation rate, and real interest rate negatively impact capital formation growth, with the negative effect of GDP growth on capital formation being theoretically unexpected. The causality tests confirm these relationships are unidirectional, with macroeconomic changes significantly affecting capital formation growth.



The impulse response functions in Figure 1 illustrate how the growth rate of domestic capital formation reacts to shocks in macroeconomic factors over time. An exchange rate shock initially increases the growth rate of gross capital formation, with the effect tapering off after the first period. A shock in the GDP growth rate causes an initial decline in capital formation growth, which then recovers from the second period onwards. Real interest rate and inflation rate shocks have a similar impact on capital formation growth, indicating a temporary effect that stabilizes over time. The VAR model is stable since all the modulus of eigen values are within the unit root (see Table F.1 in Appendix F). Lastly, the unexpected negative relationship between the growth rates of gross capital formation and GDP was further analyzed using structural VAR, confirming the negative correlation as significant (indicated by 2_1 in table J.1 from Appendix J). This analysis ruled out the possibility of contemporaneous bias, maintaining the direction of the relationship as negative. The VAR model's FEVD shows that the biggest influence on the variance of the growth rate of gross capital formation is from real interest rate shocks, explaining 14% to 15%. In contrast, GDP growth rate, exchange rate, and inflation collectively explain only 25% of the variance (see Table I.1 from Appendix I).

Additional analyses are undertaken to check whether the negative relationship between the growth rate of gross capital formation and GDP growth rate is spurious or not because of a missing variable. Hence, the growth rate of real government expenditure (g_gr)[3] is introduced in our framework. After testing for trend, stationarity, ACF and PACF, it is found that detrended growth rate of government spending[4] follows a white noise process with zero integration of order (see Table A.1 in Appendix A, Table B.1 in Appendix B and Figure C.6 in Appendix C). As before, the lag of the model is taken to be 2 despite the selection order criteria indicates the optimal lag to be 1 (see Table D.2 from Appendix D, see Table E.2 from Appendix E, see Table F.2 from Appendix F) because the interrelationships among the variables are trivial in lag 1 (see Table E.2 from Appendix E) and hence, no significant causality will be found in this case.

Table E.3 (Appendix E) indicates that government spending negatively affects capital formation growth in Bangladesh, a relationship confirmed by Granger causality tests at a 10% significance level (Table H.2 from Appendix H). Other macroeconomic factors have a significant causal relationship with capital formation growth at 5%, consistent with VAR model findings excluding government spending (Table E.3 from Appendix E). The negative link between capital formation growth and GDP growth persists, with structural VAR analysis showing no contemporaneous bias, indicated by 2_1 (Table J.2 from Appendix J). The VAR model remains stable (Table F.2 from

[3] This variable comprises the government consumption and government investment even though the transfer payment and loan payment of the government are not included because of data unavailability. However, the sum of government consumption and government investment is considered a good representative of government expenditure (Mankiw, 2012; Gruber, 2022). Growth Rate of Real Government Expenditure is taken as 2015 $US.

[4] Detrended growth rate of government spending is expressed as “g_grhat” in the framework.

Appendix F), and although macroeconomic shocks initially have a limited impact on capital formation, the role of real interest rate and inflation in explaining the forecast error variance of capital formation increases over a 15-year period (see Table I.1 from Appendix I).

In this stage, the study separates public and private components of gross capital formation, sourced from existing data source. Although the tests are indicating that growth rate of public GCF is stationary, the ACF and PACF tests did not definitively identify the process for the growth rate of private gross capital formation, leading to the adoption of the Portmanteau white noise test (see Table B.1 from Appendix B, see Figure C.7 and Figure C.8 from Appendix C). As mentioned before, the lag taken in these models are 2 although the optimal lag is 1 in the both cases (see Table D.3 and Table D.4 from Appendix D, see Table E.4 and Table E.5 from Appendix E). This test confirmed that the errors follow a white noise process (Table G.1 from Appendix G), concluding the variable as an AR(2) process. The growth rate of public[5] and private[6] GCF is found to be stationary.

The growth rate of public GCF shows no significant relationship with GDP growth rate. However, a detailed analysis from Granger causality tables reveals that the GDP growth rate positively influences the exchange rate, which subsequently reduces the growth rate of public GCF (see Table 2, Table H.3 from Appendix H). The other relationships are somewhat consistent. The VAR models are confirmed to be stable (refer to Table F.4 in Appendix F).

Table 2: VAR (Growth Rate of Public GCF, Detrended Growth Rate of GDP, Detrended Exchange Rate, Lag of Detrended Exchange rate, Inflation Rate and Real Rate of Interest, at lag=2)

VARIABLES	(1) gvinv_gr	(2) gdp_grhat	(3) erhat	(4) L_erhat	(5) rir	(6) inf
L.gvinv_gr	0.0441	0.0289	0.0310	-0	0.0738	-0.120
	(0.175)	(0.0207)	(0.0413)	(0)	(0.0999)	(0.114)
L2.gvinv_gr	0.288*	-0.0234	0.0140	0	-0.142	0.208**
	(0.160)	(0.0189)	(0.0378)	(0)	(0.0914)	(0.105)
L.gdp_grhat	-1.403	-0.197	0.558**	-0	0.738	-0.890

[5] In the tables and calculations, growth rate of public gross capital formation is expressed as “gvinv_gr”.
[6] In the tables and calculations, growth rate of private gross capital formation is expressed as “pvinv_gr”.

	(1.185)	(0.140)	(0.280)	(0)	(0.678)	(0.776)
L2.gdp_grhat	0.363	-0.0137	0.439*	-0	-0.357	0.476
	(1.058)	(0.125)	(0.250)	(0)	(0.606)	(0.693)
L.erhat	-1.168*	0.122	0.764***	1***	0.136	0.0337
	(0.710)	(0.0841)	(0.168)	(0)	(0.407)	(0.465)
L2.erhat	0.745	-0.0312	0	0	0	0
	(0.948)	(0)	(0)	(0)	(0)	(0.621)
L2.erhat	0	0	-0.365	-0***	0.0603	-0.303
	(0)	(0.112)	(0.224)	(0)	(0.543)	(0)
L3.erhat	0.550	0.0531	0.158	0***	-0.680	0.891*
	(0.737)	(0.0873)	(0.174)	(0)	(0.422)	(0.483)
L.rir	2.393	-0.761***	0.343	0***	1.759**	-0.743
	(1.523)	(0.180)	(0.360)	(0)	(0.872)	(0.997)
L2.rir	-3.340**	0.843***	-0.565	-0***	-0.374	0.253
	(1.688)	(0.200)	(0.399)	(0)	(0.966)	(1.105)
L.inf	2.116	-0.649***	0.247	0***	1.452*	-0.535
	(1.296)	(0.154)	(0.307)	(0)	(0.742)	(0.849)
L2.inf	-3.222**	0.783***	-0.513	-0***	-0.377	0.303
	(1.510)	(0.179)	(0.357)	(0)	(0.864)	(0.989)
Constant	18.10**	-1.563	2.753	0**	-8.921*	10.32*
	(9.066)	(1.074)	(2.144)	(0)	(5.189)	(5.936)
Observations	43	43	43	43	43	43

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Remarkably, past values of GDP growth rate are positively and significantly correlated with the growth rate of private investment at a 5% significance level. Additionally, past values of real interest rate and inflation rate show a negative significant relationship with private investment growth, aligning with theoretical expectations. However, apart from real interest rate and inflation rate, no other macroeconomic factors exhibit a Granger causal relationship with the growth rate of private investment, with the identified causal relationships being unidirectional (see Table H.4 in Appendix H).

3.2 Discussions

3.2.1 Real Interest Rate

The real interest rate, both in the initial and government expenditure-incorporated models, exhibits a significant negative relationship with market capital formation, aligning with theoretical expectations. While section 3.2.4 also deliberated on how interest rates impact the stock and bond markets differently, it's noteworthy that the overall capital market's response to a shock in the actual cost of borrowing appears theoretically and empirically sound, at least in the short term.

Moreover, it's worth emphasizing that the real interest rate plays a pivotal role in explaining the majority of the forecast error variance in capital formation. In simpler terms, among the integrated macroeconomic variables, the real interest rate predominantly influences Bangladesh's capital market. However, it's crucial to acknowledge that this explanatory proportion doesn't significantly surpass that of other countries. This indicates a somewhat exogenously functioning capital market in Bangladesh.

3.2.2 Inflation Rate

The inflation rate significantly impacts gross capital accumulation in Bangladesh, establishing a Granger causal relationship. This aligns with the theoretical background in section 3.2.3, where increased inflation leads to higher consumption at the expense of savings. In both macroeconomic frameworks, the inflation rate's effects are consistent, with differences in coefficient magnitudes. In the initial framework, the explanatory power stabilizes at around 6% after an initial increase, while the introduction of government expenditure notably enhances its explanatory strength over time. This enhancement suggests a dynamic relationship, potentially influenced by government spending responding to inflation. Past values of the inflation rate exhibit a significant relationship with capital formation growth, confirming the overall soundness of the inflation rate's dynamics in the macroeconomic capital market framework.

3.2.3 Exchange Rate

In this study, a depreciation of the Bangladeshi Taka, indicating an increase in its value against the US Dollar, significantly improves the capital accumulation rate. A notable Granger causal relationship exists from the exchange rate to capital accumulation in Bangladesh. In simpler terms, when more Bangladeshi Taka is required to buy one US Dollar, it makes investment more appealing to foreign investors, positively impacting capital formation.

Currency depreciation further boosts exports in countries like Bangladesh, leading to increased foreign currency inflow, particularly in US Dollars. This influx encourages business owners to invest in machinery or upgrade facilities. Despite potential rises in the cost of imported raw materials due to depreciation, producers benefit from enhanced purchasing power, empowering them to invest. The study empirically observes that a depreciation of the Bangladeshi Taka positively affects the growth rate of gross capital formation in both theoretical frameworks, with a significance level of 5%. This suggests that increased purchasing power tends to outweigh higher prices of imported raw materials. The role of the exchange rate in the macroeconomic framework's dynamics is theoretically sound and supported by empirical evidence from previous studies.

3.2.4 GDP Growth Rate

In the economy of Bangladesh, the GDP growth rate demonstrates a significant negative relationship with the overall capital accumulation rate. Additionally, the GDP growth rate has a notable causal impact on the rate of change in gross capital formation, particularly in the short run, and this relationship doesn't seem to hold in the reverse direction.

One potential explanation for this kind of result, especially considering the absence of contemporaneous bias in the model, is the presence of a crowding-out effect in the Bangladeshi capital market. To explore this possibility, we introduced the model that includes government expenditure. Tables E.3 (Appendix E) and H.2 (Appendix H) provide insights into this aspect. Notably, the past values of government expenditure growth rate exhibit a significant negative relationship with the growth rate of gross capital formation. Furthermore, changes in growth rate of government spending do not appear to have any meaningful relationship with GDP growth rate within the context of Bangladesh, as indicated in table E.3 (Appendix E). Moreover, the growth rate of public spending affects the growth rate of capitalization in Bangladesh at a 10% significance level. This suggests the potential of a crowding-out effect in the country's capital market due to the counterbalancing effects of increased government spending and decreased gross domestic investment.

Table 3: VAR (Growth Rate of Private GCF, Detrended Growth Rate of GDP, Detrended Exchange Rate, Lag of Detrended Exchange rate, Inflation Rate and Real Interest Rate, at lag=2)

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	pvinv_gr	gdp_grhat	erhat	L.erhat	rir	inf
L.pvinv_gr	0.356***	0.00641	-0.0425	-0	-0.121	0.128
	(0.122)	(0.0291)	(0.0562)	(0)	(0.139)	(0.162)
L2.pvinv_gr	0.230**	0.00795	-0.0205	-0	0.00165	-0.00879
	(0.113)	(0.0269)	(0.0520)	(0)	(0.129)	(0.150)
L.gdp_grhat	0.653	-0.321**	0.484*	0	0.369	-0.284
	(0.540)	(0.129)	(0.250)	(0)	(0.618)	(0.722)
L2.gdp_grhat	1.012**	-0.0409	0.375	0	-0.164	0.256
	(0.495)	(0.118)	(0.229)	(0)	(0.566)	(0.661)
L.erhat	0.0446	0.157*	0.790***	1***	0.138	-0.00984
	(0.350)	(0.0837)	(0.162)	(0)	(0.400)	(0.468)
L2.erhat	0.235	-0.110	0	-0	0	0.0997
	(0.432)	(0)	(0)	(0)	(0)	(0)
L2.erhat	0	0	-0.423**	0	-0.197	0
	(0)	(0.103)	(0.199)	(0)	(0.493)	(0.576)
L3.erhat	-0.135	0.118	0.194	-0	-0.453	0.540
	(0.335)	(0.0801)	(0.155)	(0)	(0.383)	(0.447)
L.rir	-3.122***	-0.714***	0.327	0	1.994**	-1.076
	(0.817)	(0.195)	(0.377)	(0)	(0.934)	(1.092)
L2.rir	3.659***	0.785***	-0.612	-0	-0.805	0.834
	(0.885)	(0.212)	(0.409)	(0)	(1.011)	(1.182)
L.inf	-2.881***	-0.607***	0.254	0	1.696**	-0.872
	(0.697)	(0.167)	(0.322)	(0)	(0.796)	(0.930)
L2.inf	3.390***	0.721***	-0.537	-0	-0.807	0.890
	(0.801)	(0.191)	(0.370)	(0)	(0.915)	(1.069)
Constant	-3.408	-1.441	4.077*	-0	-6.157	7.014
	(4.802)	(1.148)	(2.217)	(0)	(5.488)	(6.412)
Observations	43	43	43	43	43	43

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

To further investigate this idea, this study dissects the public and private components of total capital accumulation and analyze them individually within the VAR model. Table 3 offers valuable insights into this separation. It becomes evident that past values of GDP growth rate have a significant positive relationship with the growth rate of private investment at a 5% significance level. However, the GDP growth rate does not exhibit any significant relationship with the growth rate of government investment. This suggests government expenditure competes for private funds in the investment sphere, consistent with Saidjada and Jahan's (2016) work (Saidjada & Jahan, 2016). In order to validate the idea, this study introduces, for the sake of argument, the public gross capital formation in the model against private gross capital formation and found significant negative relationship in the first past lag and positive relationship in the second past lag, suggesting a high likelihood of crowding-out effect in the native capital market (see Table E.6 of Appendix E). Alternatively, cautious business sentiment, economic uncertainty, and weak institutional systems in Bangladesh can contribute to reduced capital flows and slower growth in capital formation, even during economic expansion. Finally, as we have seen before, since the overall explanatory strength of the macroeconomic factors affecting the proportion of variance in the growth rate of gross capital formation is not more than 25%, institutional failure can be one of the reasons (Levine, 1997; Porta, Lopez-de-Silanes, Shleifer, & Vishny, 2000; North, 1990).

3.3 Implications and Recommendations

In accordance with the discussion above, it is clear that the current scenario of the macroeconomic capital market is not well. From the study, some real-life implications and policy recommendations can be devised:

Institutional Development:

In the context of Bangladesh, enhancing institutional development is an urgent matter because according to the World Governance Indicator[7], the institutional structure of Bangladesh is in a weak position.

[7] See World Governance Indicator at http://info.worldbank.org/governance/wgi/

1. The government can strengthen regulatory bodies and legal frameworks to ensure investor protection, transparency, and accountability. This policy recommendation is consistent with the theoretical framework provided by Levine in 1997 (Levine, 1997).

2. Improve corporate governance practices to build investor confidence and attract more domestic and foreign investment.

3. The government can strengthen authorities tasked with controlling inflation, as its volatility undermines investor confidence. The government should prioritize stabilizing both inflation and real interest rates, given their moderate yet significant impact on the economy, as indicated by this study's findings.

Facilitate Private Capital Market Intensely

The presence of a crowding-out effect in the economy of Bangladesh has adverse effect on the GDP growth rate. While real GDP growth has improved over the years, it could have been significantly higher with more facilitation of private investment through reduced government spending and the strengthening of institutions to support the capital market.

Green and Sustainable Investment

While the world is undergoing an important momentum of transitioning towards green investment, it is currently a burning question among the economists whether Bangladesh should adopt green investment or not. One of the key challenges of climate-friendly green financing is that without the necessary infrastructure, policies, and frameworks in place, green investments may not be efficiently utilized. This could result in misallocation of resources, with investments not achieving their intended environmental or sustainability goals. give reference for this statement (Stern, 2007). Earlier, it was demonstrated that Bangladesh is in a weak position in terms of capital infrastructure although the macroeconomic tools are properly functioning.

Green investments frequently come with elevated initial expenditures and extended periods for recovering these costs, in contrast to conventional investments. When a nation is unprepared for these fiscal obligations, it could encounter heightened financial risks and the potential for economic instability. Additionally, developing sustainable and green investment requires rigorous capital market planning (Luo, 2011; Novethic, 2012). Hindered by external influences and limited regulatory control, the nation is ill-prepared for embracing green financing, potentially hampering the growth of a green capital market and further diminishing market efficiency. A viable solution proposed, from this study, is leveraging the private capital market to support green investments, aiming to minimize negative economic impacts and sustain GDP growth without overburdening the existing financial infrastructure.

4.0 Conclusion

In conclusion, despite the seemingly peculiar relationship between the GDP growth rate and the growth rate of gross capital formation, the macroeconomic framework of the capital market in Bangladesh exhibits a decent alignment with theoretical economics. This suggests that there is hope for reforming and restructuring the country's capital market. Despite certain limitations in this study, such as a relatively short time frame since Bangladesh's independence (only 22 years), a scarcity of relevant literature, and the lack of more granular data at a monthly or quarterly level, the study has rigorously explored the macroeconomic perspective of Bangladesh's capital market. The future direction of this research entails delving deeper into the interrelationships among macroeconomic variables and transitioning to a micro-level analysis over time, thus laying the groundwork for a flourishing capital market in Bangladesh. Recognizing that a stable, robust, and secure capital market is vital, further efforts should focus on reformation, political commitment, and transparency to fortify this foundation, paving the way for Bangladesh to achieve greater prosperity in the future. It is remarkable to witness Bangladesh's progress despite its current capital market challenges, highlighting the potential for a solid path to a brighter future with the right reforms, initiatives and political motive in place.

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Appendix

Appendix A: Detection of trend in each variable by regressing each variable against time

Table A.1: Regression result of bivariate regression between time and each variable

VARIABLES	(R1) gcf_gr	(R2) gdp_gr	(R3) er	(R4) inf	(R5) rir	(R6) g_gr	(R7) pvinv_gr	(R8) gvinv_gr
t	-0.085*	0.069***	1.75***	-0.097	0.044	0.001***	-0.003	-0.13*
	(0.048)	(0.01)	(0.028)	(0.06)	(0.063)	(0.0004)	(0.085)	(0.075)
Constant	178.2*	-132.4***	-3,44***	202.2	-82.90	-2.5***	15.09	272.85*
	(95.58)	(28.2)	(55.01)	(128.5)	(126.8)	(0.865)	(170.9)	149.5
Observations	46	46	46	46	46	45	46	46
R-squared	0.067	0.352	0.989	0.050	0.011	0.170	0.00	0.066

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: In the table given above, the bivariate regression results between time and other variables are summarized separately. R1 represents a bivariate regression between rate of expansion in gross capital formation (gcf_gr) and time. Similarly, regression R2, R3, R4, R5, R6, R7 and R8 are no exception as they represent the regression between growth rate of GDP (gdp_gr) and time, exchange rate (er) and time, inflation rate (inf) and time, and real rate of interest (rir) and time, growth rate of government spending and time, growth rate of private capital formation and time, and growth rate of public capital formation and time respectively.

Appendix B: Stationarity Test using Augmented Dickey Fuller (ADF) Test for Unit Root

Table B.1: ADF Test of Growth Rate of Real Gross Capital Formation (gcf_gr), Detrended Growth Rate of Real GDP (gdp_grhat), Detrended Exchange Rate (erhat), Inflation Rate (inf), Real Interest Rate (rir), Detrended Growth Rate of Government Spending (g_grhat), Growth Rate of Private Gross Capital Formation (pvinv_gr), Growth Rate of Public Gross Capital Formation (gvinv_gr)

Variable Name	Interpolated Dickey-Fuller				MacKinnon approximate p-value for Z(t)
	Test Statistics	1% Critical Value	5% Critical Value	10% Critical Value	
gcf_gr	-6.165	-3.614	-2.944	-2.606	0.0000
gdp_grhat	-9.015				0.0000
erhat	-3.065				0.0293
inf	-6.389				0.0000
rir	-5.378				0.0000
g_grhat	-5.100				0.0000
pvinv_gr	-4.699				0.0001
gvinv_gr	-5.838				0.0000

Appendix C: Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF) Analysis

Figure C.1: ACF and PACF of Growth Rate of GCF

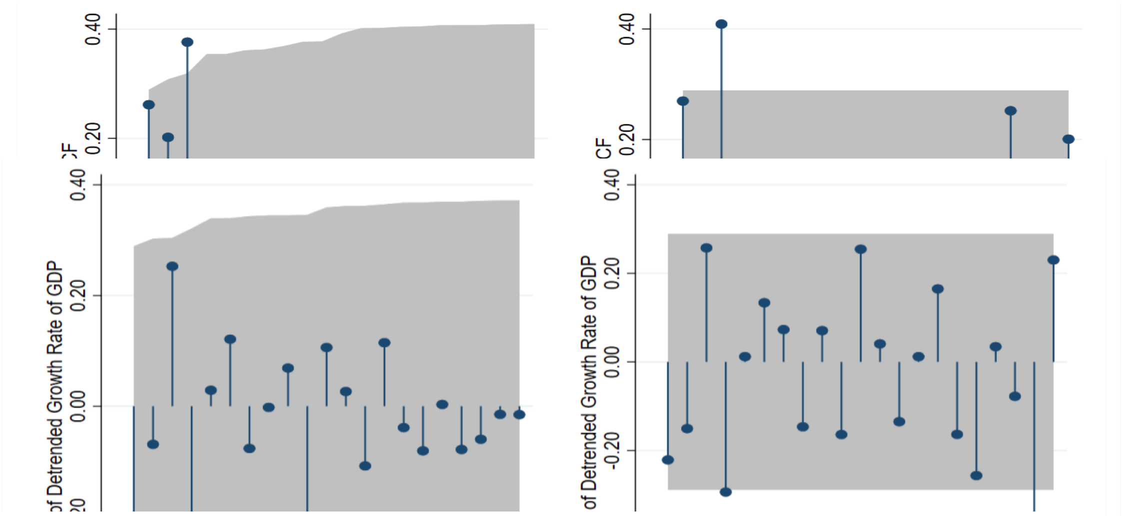


Figure C.3: ACF and PACF of Detrended Exchange Rate

Fig

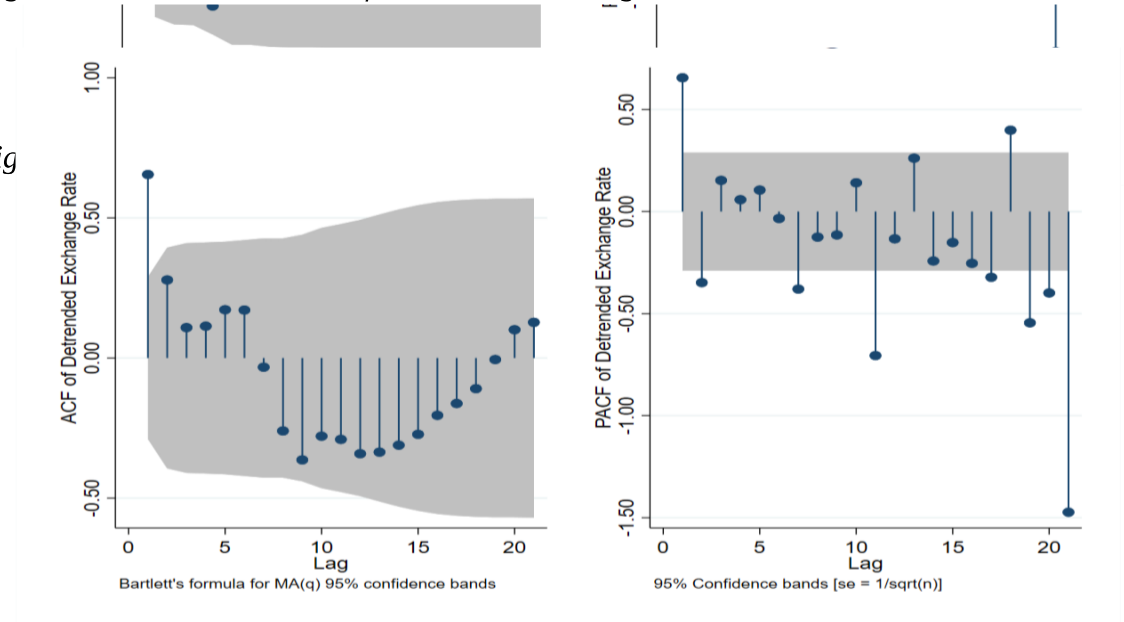


Figure C.4: ACF and PACF of Inflation Rate

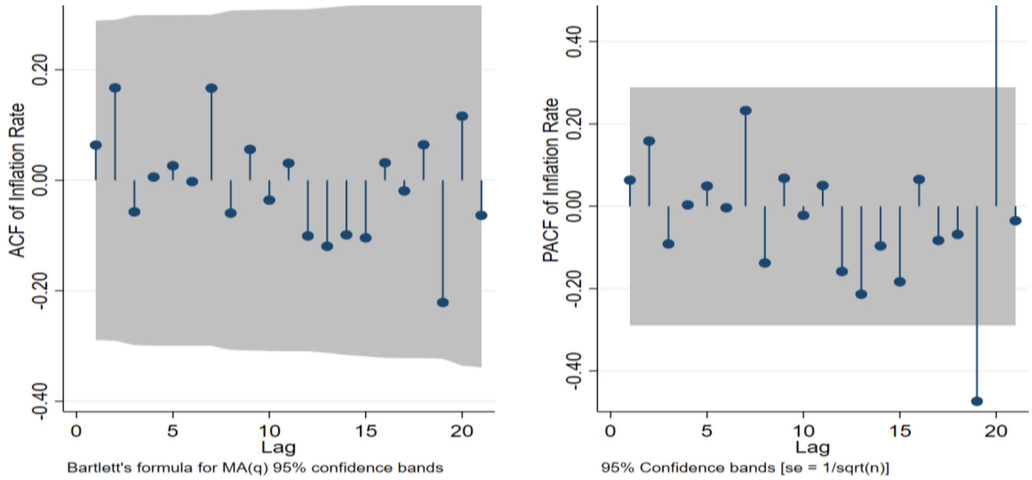


Figure C.5: ACF and PACF of Real Interest Rate

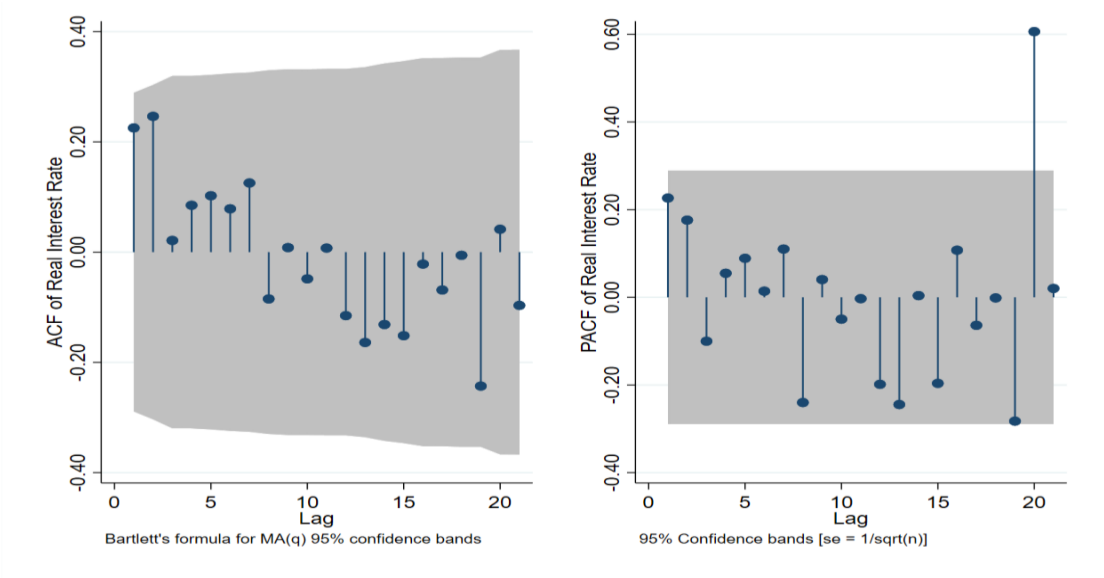


Figure C.6: ACF and PACF of Growth Rate of Detrended Growth Rate of Government

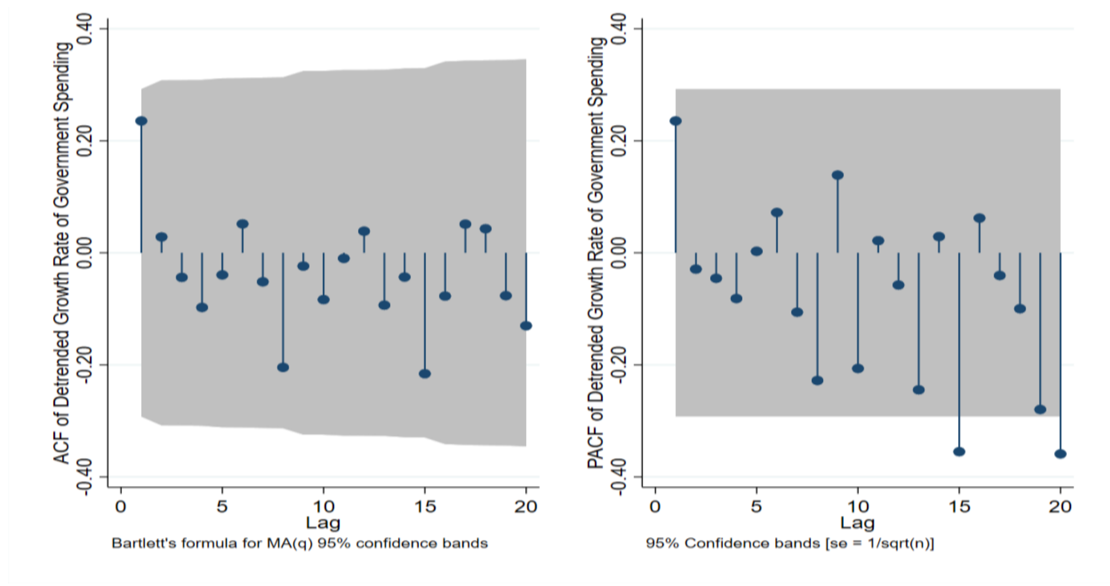


Figure C.7: ACF and PACF of Growth Rate of Public Gross Capital Formation

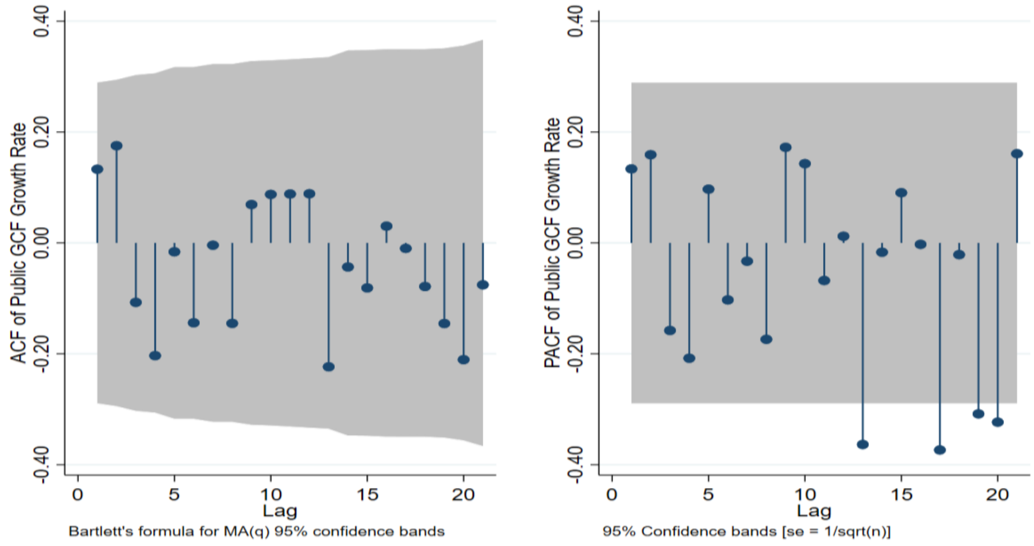
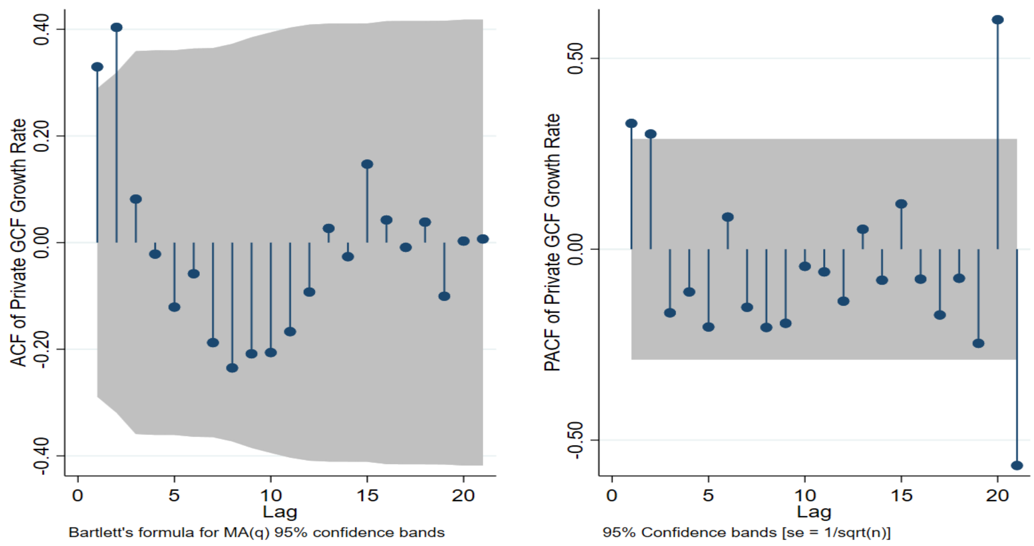


Figure C.8: ACF and PACF of Growth Rate of Private Gross Capital Formation



Appendix D: Selection Order Criteria

Table D.1: Selection Order Criteria of VAR using Growth Rate of GCF, Detrended Growth Rate of GDP, Detrended Exchange Rate, Lag of Detrended Exchange Rate, Real rate of Interest, Inflation Rate

lags	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-563.671				12953.3	26.4963	26.5869	26.7421
1	1069.33	3266*	36	0.000	7.3e-29*	-47.7829*	-47.1485*	-46.0626*
2	1060.61	-17.437	36		4.7e-28	-45.982	-44.8945	-43.033

Table D.2: Selection Order Criteria of VAR using Growth Rate of GCF, Detrended Growth Rate of GDP, Detrended Exchange Rate, Lag of Detrended Exchange Rate, Real rate of Interest, Inflation Rate and Detrended Growth Rate of Government Spending.

lags	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-446.096				9.36665	22.1022	22.2088	22.394
1	1097.74	3087.7	49	0.000	2.1e-31*	-50.8165*	-49.9642*	-48.47*
2	1120.95	46.418	49	0.578	6.1e-31	-49.8998	-48.4083	-45.80
3	1164.79	87.691	49	0.001	8.7e-31	-49.9899	-47.8592	-44.1386
4	1223.73	117.87*	49	0.000	9.9e-31	-50.8159	-48.046	-43.209

Table D.3: Selection Order Criteria of VAR using Growth Rate of Private GCF, Detrended Growth Rate of GDP, Detrended Exchange Rate, Lag of Detrended Exchange Rate, Real Rate of Interest, Inflation Rate.

lags	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-548.836				22879.2	27.0652	27.1565	27.316
1	985.109	3067.9	36	0.000	4.3e-28*	-46.0053*	-45.3661*	-44.25*
2	964.132	-41.954	36		5.6e-27	-43.5186	-42.4229	-40.5094
3	1023.3	118.33	36	0.000	1.7e-27	-44.9414	-43.3891	-40.6784
4	1069.33	92.068*	36	0.000	1.2e-27	-45.7236	-43.7146	-40.2067

Table D.4: Selection Order Criteria of VAR using Growth Rate of Public GCF, Detrended Growth Rate of GDP, Detrended Exchange Rate, Lag of Detrended Exchange Rate, Real Rate of Interest.

lags	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-571.987				9.36665	22.1022	22.2088	22.394
1	964.601	3073.2*	49	0.000	2.1e-31*	-50.8165*	-49.9642*	-48.47
2	985.294	41.386	49	0.578	6.1e-31	-49.8998	-48.4083	-45.80

3	993.289	15.991	49	0.001	8.7e-31	-49.9899	-47.8592	-44.1386
4	992.388	117.87*	49	0.000	9.9e-31	-50.8159	-48.046	-43.209

Appendix E: Results of Vector Autoregressive Models

Table E.1: VAR (Growth Rate of GCF, Detrended Growth Rate of GDP, Detrended Exchange Rate, Lag of Detrended Exchange rate, Inflation Rate and Real Interest Rate, at lag=1)

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	gcf_gr	gdp_grhat	erhat	L.erhat	inf	rir
L.gcf_gr	0.366**	0.0456	0.000766	-0	0.360	-0.276
	(0.158)	(0.0530)	(0.0832)	(0)	(0.230)	(0.197)
L.gdp_grhat	-0.787*	-0.387***	0.328	0	-0.759	0.668
	(0.449)	(0.150)	(0.236)	(0)	(0.650)	(0.558)
L.erhat	0.102	0.0187	0.903***	1***	-0.112	0.273
	(0.286)	(0.0959)	(0.150)	(0)	(0.415)	(0.356)
L2.erhat	0.0750	0.000801	-0.320**	0**	0.465	-0.546
	(0.289)	(0.0966)	(0.152)	(0)	(0.418)	(0.359)
L.inf	0.131	-0.0900	-0.171	0	-0.197	1.043***
	(0.297)	(0.0993)	(0.156)	(0)	(0.430)	(0.369)
L.rir	-0.0613	-0.0697	-0.169	0	-0.393	1.337***
	(0.310)	(0.104)	(0.163)	(0)	(0.449)	(0.386)
Constant	4.433	0.491	2.092	0	7.434	-6.826
	(4.230)	(1.416)	(2.221)	(0)	(6.130)	(5.262)
Observations	44	44	44	44	44	44

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table E.2: VAR (Growth Rate of GCF, Detrended Growth Rate of GDP, Detrended Exchange Rate, Lag of Detrended Exchange Rate, Detrended Growth Rate of Government Spending, Real Rate of Interest and Inflation Rate, at lag=1)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
VARIABLES	gcf_gr	gdp_grhat	erhat	L_erhat	g_grhat	inf	rir
L.gcf_gr	0.412***	0.0421	0.00325	-0	-0.00162	0.304	-0.235
	(0.154)	(0.0535)	(0.0841)	(0)	(0.00173)	(0.226)	(0.195)
L.gdp_grhat	-0.626	-0.399***	0.337	0	-0.00481	-0.954	0.812
	(0.438)	(0.153)	(0.240)	(0)	(0.00493)	(0.643)	(0.556)
L.erhat	0.152	0.0149	0.906***	1***	0.00288	-0.171	0.317
	(0.276)	(0.0961)	(0.151)	(0)	(0.00311)	(0.405)	(0.350)
L2.erhat	0.0673	0.00139	-0.321**	0**	-0.00320	0.474	-0.553
	(0.277)	(0.0964)	(0.152)	(0)	(0.00312)	(0.407)	(0.352)
L.g_grhat	-25.32**	1.934	-1.358	-0	0.274*	30.60	-22.60
	(12.90)	(4.493)	(7.061)	(0)	(0.145)	(18.94)	(16.38)
L.inf	0.225	-0.0972	-0.166	0	0.00175	-0.311	1.127***

	(0.288)	(0.100)	(0.158)	(0)	(0.00325)	(0.423)	(0.366)
L.rir	0.0303	-0.0767	-0.164	0	0.000191	-0.504	1.418***
	(0.301)	(0.105)	(0.165)	(0)	(0.00339)	(0.442)	(0.382)
Constant	2.925	0.606	2.011	0	-0.000759	9.257	-8.172
	(4.128)	(1.438)	(2.260)	(0)	(0.0465)	(6.062)	(5.243)
Observations	44	44	44	44	44	44	44

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table E.3: VAR (Growth Rate of GCF, Detrended Growth Rate of GDP, Detrended Exchange Rate, Lag of Detrended Exchange Rate, Detrended Growth Rate of Government Spending, Real Rate of Interest and Inflation Rate, at lag=2)

VARIABLES	(1) gcf_gr	(2) gdp_grhat	(3) erhat	(4) L_erhat	(5) g_grhat	(6) inf	(7) rir
L.gcf_gr	0.422***	0.0187	0.0167	-0*	-0.000576	0.104	-0.0883
	(0.153)	(0.0512)	(0.100)	(0)	(0.00180)	(0.273)	(0.236)
L2.gcf_gr	-0.0685	-0.0355	-0.0502	0**	-0.00253	0.219	-0.203
	(0.143)	(0.0478)	(0.0936)	(0)	(0.00168)	(0.254)	(0.220)
L.gdp_grhat	-1.097***	-0.335**	0.477*	0	-0.00868*	-0.761	0.764
	(0.411)	(0.138)	(0.270)	(0)	(0.00483)	(0.731)	(0.634)
L2.gdp_grhat	-0.591	-0.00122	0.421	0	-0.00608	0.236	-0.0890
	(0.395)	(0.132)	(0.259)	(0)	(0.00465)	(0.704)	(0.610)
L.erhat	0.693***	0.163*	0.807***	1***	0.00746**	-0.0719	0.182
	(0.259)	(0.0867)	(0.170)	(0)	(0.00305)	(0.461)	(0.400)
L2.erhat	-0.283	-0.135	0	0***	0	0	0
	(0.333)	(0.111)	(0)	(0)	(0)	(0)	(0)
L2.erhat	0	0	-0.453**	0	-0.0146***	-0.00380	-0.122
	(0)	(0)	(0.219)	(0)	(0.00391)	(0.593)	(0.514)
L3.erhat	0.0170	0.129	0.221	-0***	0.0112***	0.666	-0.539
	(0.248)	(0.0829)	(0.162)	(0)	(0.00291)	(0.441)	(0.382)
L.g_grhat	-26.70**	-0.486	0.958	-0	0.305**	42.26**	-32.64*
	(11.54)	(3.863)	(7.572)	(0)	(0.136)	(20.54)	(17.80)
L2.g_grhat	-0.578	0.540	-2.257	-0	-0.0357	-15.39	8.746
	(11.95)	(4.001)	(7.842)	(0)	(0.140)	(21.28)	(18.43)
L.inf	-1.516***	-0.583***	0.327	-0	0.00471	-0.620	1.543**
	(0.500)	(0.167)	(0.328)	(0)	(0.00588)	(0.890)	(0.771)
L2.inf	2.004***	0.683***	-0.593	0**	-0.00524	0.431	-0.474
	(0.571)	(0.191)	(0.375)	(0)	(0.00672)	(1.017)	(0.881)
L.rir	-1.986***	-0.695***	0.417	-0*	0.00362	-0.776	1.808**
	(0.580)	(0.194)	(0.381)	(0)	(0.00682)	(1.033)	(0.895)
L2.rir	2.306***	0.741***	-0.662	0**	-0.00571	0.438	-0.527
	(0.635)	(0.212)	(0.416)	(0)	(0.00746)	(1.130)	(0.979)
Constant	-0.207	-0.958	3.521	-0	0.0387	7.283	-6.484
	(3.769)	(1.261)	(2.472)	(0)	(0.0443)	(6.708)	(5.811)
Observations	43	43	43	43	43	43	43

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table E.4: VAR (Growth Rate of Public GCF, Detrended Growth Rate of GDP, Detrended Exchange Rate, Lag of Detrended Exchange rate, Inflation Rate and Real Rate of Interest, at lag=1)

VARIABLES	(1) gvinv_gr	(2) gdp_grhat	(3) erhat	(4) L_erhat	(5) rir	(6) inf
L.gvinv_gr	0.126	0.0355	0.0253	0	-0.00313	-0.00727
	(0.155)	(0.0227)	(0.0361)	(0)	(0.0879)	(0.103)
L.gdp_grhat	-0.568	-0.252*	0.392*	0	0.375	-0.405
	(1.014)	(0.148)	(0.236)	(0)	(0.574)	(0.673)
L.erhat	-0.839	-0.0255	0.888***	1***	0.412	-0.285
	(0.626)	(0.0916)	(0.146)	(0)	(0.354)	(0.415)
L2.erhat	1.200*	0.0408	-0.305**	0***	-0.658*	0.604
	(0.639)	(0.0936)	(0.149)	(0)	(0.362)	(0.424)
L.rir	-0.157	-0.0936	-0.167	0**	1.507***	-0.616
	(0.661)	(0.0967)	(0.154)	(0)	(0.374)	(0.438)
L.inf	0.0322	-0.120	-0.176	0*	1.184***	-0.379
	(0.641)	(0.0939)	(0.149)	(0)	(0.363)	(0.425)
Constant	7.481	0.923	1.920	-0**	-10.98**	12.93**
	(7.906)	(1.157)	(1.839)	(0)	(4.478)	(5.245)
Observations	44	44	44	44	44	44

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table E.5: VAR (Growth Rate of Private GCF, Detrended Growth Rate of GDP, Detrended Exchange Rate, Lag of Detrended Exchange rate, Inflation Rate and Real Interest Rate, at lag=1)

VARIABLES	(1) pvinv_gr	(2) gdp_grhat	(3) erhat	(4) L_erhat	(5) rir	(6) inf
L.pvinv_gr	0.455***	-0.0365	-0.0322	-0	-0.107	0.0959
	(0.120)	(0.0271)	(0.0428)	(0)	(0.103)	(0.121)
L.gdp_grhat	-0.181	-0.314**	0.352	0	0.458	-0.455
	(0.619)	(0.140)	(0.220)	(0)	(0.530)	(0.624)
L.erhat	-0.291	-0.0132	0.895***	1***	0.382	-0.265
	(0.405)	(0.0914)	(0.144)	(0)	(0.347)	(0.409)
L2.erhat	0.218	0.0229	-0.317**	0**	-0.645*	0.598
	(0.413)	(0.0932)	(0.147)	(0)	(0.354)	(0.417)
L.rir	-0.625	-0.123	-0.191	0	1.434***	-0.550
	(0.439)	(0.0991)	(0.156)	(0)	(0.376)	(0.443)
L.inf	-0.767*	-0.115	-0.172	0	1.179***	-0.376
	(0.419)	(0.0944)	(0.149)	(0)	(0.359)	(0.422)
Constant	12.94**	1.629	2.499	-0	-9.692**	11.70**
	(5.323)	(1.200)	(1.893)	(0)	(4.558)	(5.366)
Observations	44	44	44	44	44	44

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table E.6: VAR (Growth Rate of Private GCF, Detrended Growth Rate of GDP, Growth Rate of Public GCF, Detrended Exchange Rate, Lag of Detrended Exchange rate, Inflation rate and Real Interest Rate, at lag=2)

VARIABLES	(1) pvinv_gr	(2) gdp_grhat	(3) gvinv_gr	(4) erhat	(5) L_erhat	(5) rir	(6) inf
L.pvinv_gr	0.350***	0.0145	-0.249	-0.0358	-0	-0.223	0.246
	(0.126)	(0.0310)	(0.256)	(0.0618)	(0)	(0.145)	(0.166)
L2.pvinv_gr	0.247**	0.00856	-0.181	-0.0184	0	-0.0608	0.0689
	(0.109)	(0.0268)	(0.221)	(0.0534)	(0)	(0.125)	(0.143)
L.gdp_grhat	-0.0847	-0.187	-1.624	0.538*	-0	0.703	-0.849
	(0.597)	(0.147)	(1.215)	(0.294)	(0)	(0.687)	(0.788)
L2.gdp_grhat	0.929*	0.000795	0.0899	0.405	-0	-0.530	0.669
	(0.511)	(0.126)	(1.040)	(0.251)	(0)	(0.588)	(0.675)
L.gvinv_gr	-0.165*	0.0349	-0.0664	0.0167	-0	-0.00286	-0.0348
	(0.0900)	(0.0222)	(0.183)	(0.0443)	(0)	(0.104)	(0.119)
L2.gvinv_gr	0.150*	-0.0167	0.164	-0.00162	0	-0.224**	0.299***
	(0.0848)	(0.0209)	(0.173)	(0.0417)	(0)	(0.0976)	(0.112)
L.erhat	0.224	0.119	-1.096	0.771***	1***	0.151	0.0162
	(0.343)	(0.0848)	(0.699)	(0.169)	(0)	(0.395)	(0.453)
L2.erhat	-0.225	-0.0226	0.586	-0.385*	-0***	-0.0479	-0.183
	(0.455)	(0)	(0)	(0.224)	(0)	(0.523)	(0)
L2.erhat	0	0	0	0	0	0	0
	(0)	(0.112)	(0.925)	(0)	(0)	(0)	(0.600)
L3.erhat	0.244	0.0499	0.603	0.166	0***	-0.627	0.833*
	(0.353)	(0.0872)	(0.719)	(0.174)	(0)	(0.406)	(0.466)
L.rir	-2.875***	-0.749***	2.101	0.318	0***	1.723*	-0.698
	(0.774)	(0.191)	(1.575)	(0.381)	(0)	(0.891)	(1.022)
L2.rir	3.276***	0.851***	-3.423**	-0.587	-0***	-0.581	0.480
	(0.844)	(0.208)	(1.718)	(0.415)	(0)	(0.972)	(1.114)
L.inf	-2.642***	-0.645***	1.990	0.242	0***	1.508**	-0.595
	(0.660)	(0.163)	(1.343)	(0.325)	(0)	(0.760)	(0.871)
L2.inf	2.999***	0.782***	-3.159**	-0.517	-0***	-0.496	0.432
	(0.768)	(0.189)	(1.562)	(0.378)	(0)	(0.883)	(1.013)
Constant	-1.639	-1.982	25.88***	3.746	0	-3.625	4.435
	(4.934)	(1.218)	(10.04)	(2.426)	(0)	(5.676)	(6.510)
Observations	43	43	43	43	43	43	43

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Appendix F: Stability of VAR Models

Eigenvalue		Modulus
0.8845598	+ 0.07497263i	0.887731
0.8845598	- 0.07497263i	0.887731
0.2744802	+ 0.6322852i	0.689292
0.2744802	- 0.6322852i	0.689292
-0.2766824	+ 0.4947347i	0.566847

Table F.1: Stability of VAR (Growth Rate of GCF, Detrended Growth Rate of GDP, Detrended Exchange Rate, Lag of Detrended Exchange rate, Inflation Rate and Real Interest Rate, at lag=2)

-0.2766824	- 0.4947347i	0.566847
0.4745995	+ 0.2787208i	0.550391
0.4745995	- 0.2787208i	0.550391
-0.5273783		0.527378
-0.273938		0.273938
0.1496805		0.14968
1.522e-16		1.5e-16

Table F.2: Stability of VAR (Growth Rate of GCF, Detrended Growth Rate of GDP, Detrended Exchange Rate, Lag of Detrended Exchange Rate, Detrended Growth Rate of Government Spending, Real Interest Rate and Inflation Rate, at lag=1 (1) and at lag=2 (2), respectively)

Eigenvalue (1)		Modulus (1)	Eigenvalue (2)		Modulus (2)
0.957525		0.957525	0.8903565	+ 0.09066795i	0.894961
0.4722971	+ 0.3862187i	0.610106	0.8903565	- 0.09066795i	0.894961
0.4722971	- 0.3862187i	0.610106	0.2233278	+ 0.6688642i	0.705163
0.5914427		0.5914427	0.2244802	- 0.6688642i	0.705163
0.4444492		0.4444492	-0.647427		0.647427
-0.3187901	+ 0.07161704i	0.326736	0.5734553	+ 0.1977914i	0.606607
-0.3187901	- 0.07161704i	0.326736	0.5734553	- 0.1977914i	0.606607
			-0.3092992	+ 0.4991956i	0.58725
			-0.3092992	- 0.4991956i	0.58725
			0.3575725	+ 0.4274231i	0.557269
			0.3575725	- 0.4274231i	0.557269
			-0.2180136	+ 0.2736394i	0.349869
			-0.2180136	- 0.2736394i	0.349869
			-2.817e-16		2.8e-16

Table F.3: Stability of VAR [(1): Growth Rate of Public GCF, Detrended Growth Rate of GDP, Detrended Exchange Rate, Lag of Detrended Exchange Rate, Real Interest Rate and Inflation Rate, at lag=2] and Stability of VAR [(2): Growth Rate of Private GCF, Detrended Growth Rate of GDP, Detrended Exchange Rate, Lag of Detrended Exchange Rate, Real Interest Rate and Inflation Rate,

Eigenvalue (1)		Modulus (1)	Eigenvalue (2)		Modulus (2)
0.8748262	+ 0.1459631i	0.886919	0.9030227	+ 0.1265639i	0.911849
0.8748262	- 0.1459631i	0.886919	0.9030227	- 0.1265639i	0.911849
0.2890713	+ 0.6372082i	0.699712	0.2904219	+ 0.6348565i	0.698132
0.2890713	- 0.6372082i	0.699712	0.2904219	- 0.6348565i	0.698132
0.6493693		0.649396	0.5537764	+ 0.01421327i	0.553959
-0.2803031	+ 0.4628831i	0.541139	0.5537764	- 0.01421327i	0.553959
-0.2803031	- 0.4628831i	0.541139	-0.2724393	+ 0.4496569i	0.525751
-0.4338793	+ 0.03064285i	0.43496	-0.2724393	- 0.4496569i	0.525751
-0.4338793	- 0.03064285i	0.43496	-0.4662403	+ 0.1358076i	0.485617
0.3528113		0.352811	-0.4662403	- 0.1358076i	0.485617
-0.06631229		0.066312	-0.06957728		0.069577
1.168e-15		1.2e-15	-1.037e-15		1.0e-15

at lag=2]

Appendix G: White Noise Test of Growth Rate of Private GCF

Table G.1: Portmanteau Test for White Noise

Portmanteau (Q) statistic	=	30.2905
Prob > chi2(21)	=	0.0863[8]

[8] Do not reject null hypothesis of no autocorrelation and hence, Growth Rate of Private GCF is a white noise.

Appendix H: Granger Causality Test

Table H.1: Granger Casualty Test among Growth Rate of GCF, Detrended Growth Rate of GDP, Detrended Exchange Rate, Lag of Detrended Exchange rate, Inflation Rate and Real Interest rate, at lag=2.

Equation	Excluded	chi2	df	Prob > chi2
gcf_gr	gdp_grhat	10.693	2	0.005***
gcf_gr	erhat	6.7785	2	0.034**
gcf_gr	L.erhat	1.2459	2	0.536
gcf_gr	inf	9.9187	2	0.007***
gcf_gr	rir	11.3	2	0.004***
gcf_gr	ALL	25.637	9	0.002***
gdp_grhat	gcf_gr	0.53592	2	0.765
gdp_grhat	erhat	3.571	2	0.168
gdp_grhat	L.erhat	2.554	2	0.279
gdp_grhat	inf	13.406	2	0.001***
gdp_grhat	rir	13.161	2	0.001***
gdp_grhat	ALL	27.43	9	0.001***
erhat	gcf_gr	0.42461	2	0.809
erhat	gdp_grhat	4.4611	2	0.107
erhat	L.erhat	4.7029	2	0.095*
erhat	inf	3.2257	2	0.199
erhat	rir	3.2494	2	0.197
erhat	ALL	16.465	10	0.087*
inf	gcf_gr	1.2805	2	0.527
inf	gdp_grhat	0.7406	2	0.691
inf	erhat	0.0281	2	0.986
inf	L.erhat	2.8254	2	0.243
inf	rir	0.78322	2	0.676
inf	ALL	7.5272	9	0.526
rir	gcf_gr	1.2832	2	0.526
rir	gdp_grhat	0.92637	2	0.629
rir	erhat	0.10652	2	0.948
rir	L.erhat	3.5328	2	0.171
rir	inf	8.0886	2	0.018**
rir	ALL	15.878	9	0.069*

*** p<0.01, ** p<0.05, * p<0.1

Table H.2: Granger Causality Test Among Growth Rate of GCF, Detrended Growth Rate of GDP, Detrended Exchange Rate, Lag of Detrended Exchange Rate, Detrended Growth Rate of

Equation	Excluded	chi2	df	Prob > chi2
gcf_gr	gdp_grhat	7.4811	2	0.024**
gcf_gr	erhat	8.7166	2	0.013**
gcf_gr	L.erhat	1.2535	2	0.534
gcf_gr	g_grhat	5.9664	2	0.051*
gcf_gr	inf	12.301	2	0.002***
gcf_gr	rir	13.299	2	0.001***
gcf_gr	ALL	35.161	11	0.000***
gdp_grhat	gcf_gr	0.55457	2	0.758
gdp_grhat	erhat	3.5185	2	0.172
gdp_grhat	L.erhat	2.456	2	0.293
gdp_grhat	g_grhat	0.02617	2	0.987
gdp_grhat	inf	13.42	2	0.001***
gdp_grhat	rir	13.161	2	0.001***
gdp_grhat	ALL	27.43	11	0.004***
erhat	gcf_gr	0.29421	2	0.863
erhat	gdp_grhat	4.282	2	0.118
erhat	L.erhat	4.307	2	0.116
erhat	g_grhat	0.08453	2	0.959
erhat	inf	3.0307	2	0.220
erhat	rir	3.1675	2	0.205
erhat	ALL	16.582	12	0.166
g_grhat	gcf_gr	3.4995	2	0.174
g_grhat	gdp_grhat	3.7537	2	0.153
g_grhat	erhat	13.939	2	0.001***
g_grhat	L.erhat	16.999	2	0.000***
g_grhat	inf	0.67301	2	0.714
g_grhat	rir	0.72867	2	0.695
g_grhat	ALL	30.894	11	0.001***
inf	gcf_gr	1.4794	2	0.477
inf	gdp_grhat	1.6408	2	0.440
inf	erhat	0.0461	2	0.977
inf	L.erhat	4.401	2	0.111
inf	g_grhat	4.2427	2	0.120
inf	rir	1.0352	2	0.596
inf	ALL	12.513	11	0.326
rir	gcf_gr	1.6213	2	0.445
rir	gdp_grhat	1.8232	2	0.402
rir	erhat	0.21472	2	0.898
rir	L.erhat	4.873	2	0.087*
rir	g_grhat	3.3706	2	0.185
rir	inf	9.4789	2	0.009***
rir	ALL	15.878	11	0.039**
*** p<0.01, ** p<0.05, * p<0.1				

Government Spending, Real Rate of Interest and Inflation Rate, at lag=2

Table H.3: Granger Causality Test Among Growth Rate of Public GCF, Detrended Growth Rate of GDP, Detrended Exchange Rate, Lag of Detrended Exchange rate, Inflation rate and Real Rate of Interest, at lag=2.

Equation	Excluded	chi2	df	Prob > chi2
gvinv_gr	gdp_grhat	2.1058	2	0.349
gvinv_gr	erhat	2.927	2	0.231
gvinv_gr	L.erhat	4.7278	2	0.094*
gvinv_gr	rir	4.1884	2	0.123
gvinv_gr	inf	4.7229	2	0.094*
gvinv_gr	ALL	10.975	9	0.277
gdp_grhat	gvinv_gr	2.6934	2	0.260
gdp_grhat	erhat	3.0675	2	0.216
gdp_grhat	L.erhat	0.44351	2	0.801
gdp_grhat	rir	18.684	2	0.000***
gdp_grhat	inf	19.975	2	0.000***
gdp_grhat	ALL	30.921	9	0.000***
erhat	gvinv_gr	0.95056	2	0.622
erhat	gdp_grhat	5.166	2	0.076*
erhat	L.erhat	2.8785	2	0.237
erhat	rir	2.5989	2	0.273
erhat	inf	2.7895	2	0.248
erhat	ALL	17.185	10	0.070*
inf	gvinv_gr	4.2012	2	0.122
inf	gdp_grhat	2.7438	2	0.254
inf	erhat	0.36886	2	0.832
inf	L.erhat	5.2639	2	0.072*
inf	rir	1.6595	2	0.436
inf	ALL	10.86	9	0.285
rir	gvinv_gr	2.5103	2	0.285
rir	gdp_grhat	2.3199	2	0.314
rir	erhat	0.32935	2	0.848
rir	L.erhat	5.3774	2	0.068*
rir	inf	9.9481	2	0.007***
rir	ALL	17.509	9	0.041**
*** p<0.01, ** p<0.05, * p<0.1				

Table H.4: Granger Causality Test Among Growth Rate of Private GCF, Detrended Growth Rate of GDP, Detrended Exchange Rate, Lag of Detrended Exchange rate, Inflation rate and Real Rate of Interest, at lag=2.

Equation	Excluded	chi2	df	Prob > chi2
pvinv_gr	gdp_grhat	4.4554	2	0.108
pvinv_gr	erhat	0.68928	2	0.708
pvinv_gr	L.erhat	0.29754	2	0.862
pvinv_gr	inf	18.704	2	0.000***
pvinv_gr	rir	17.117	2	0.000***
pvinv_gr	ALL	32.394	11	0.000***
gdp_grhat	pvinv_gr	0.39938	2	0.819
gdp_grhat	erhat	3.5691	2	0.168
gdp_grhat	L.erhat	2.2854	2	0.319
gdp_grhat	inf	0.10296	2	0.001***
gdp_grhat	rir	19.975	2	0.001***
gdp_grhat	ALL	30.921	9	0.001***
erhat	pvinv_gr	1.5437	2	0.462
erhat	gdp_grhat	4.823	2	0.090*
erhat	L.erhat	4.5776	2	0.101
erhat	inf	3.1198	2	0.210
erhat	rir	3.6277	2	0.163
erhat	ALL	17.998	10	0.055*
inf	pvinv_gr	0.82657	2	0.661
inf	gdp_grhat	0.46652	2	0.792
inf	erhat	0.04408	2	0.978
inf	L.erhat	3.3518	2	0.187
inf	rir	1.1773	2	0.555
inf	ALL	7.0092	9	0.636
rir	pvinv_gr	4.2012	2	0.582
rir	gdp_grhat	2.7438	2	0.727
rir	erhat	0.36886	2	0.917
rir	L.erhat	5.2639	2	0.124
rir	inf	1.6595	2	0.013**
rir	ALL	10.86	9	0.075
*** p<0.01, ** p<0.05, * p<0.1				

Appendix I: Forecast Error Variance Decomposition

Table I.1: Forecast Error Variance Decomposition of VAR Model 1: Growth Rate of GCF, Detrended Growth Rate of GDP, Detrended Exchange Rate, Lagged Detrended Exchange Rate, *Inflation Rate and Real Rate of Interest (lag=2) and of Model 2: VAR containing Growth Rate of GCF, Detrended Growth Rate of GDP, Detrended Exchange Rate, Lagged Detrended Exchange Rate, Detrended Growth Rate of Government Spending, Inflation Rate and Real Rate of Interest (lag=2).*

Model 1						
Step	(1)	(2)	(3)	(4)	(5)	(6)
0	0	0	0	0	0	0
1	1	0	0	0	0	0
2	0. 782248	0.011676	0.019839	0.000778	0.037928	0.147531
3	0.750996	0.04349	0.019043	0.000754	0.041861	0.143856
4	0.726989	0.041727	0.025939	0.000728	0.063203	0.141415
5	0.713463	0.041642	0.04273	0.000714	0.062672	0.138778
6	0.712021	0.0417	0.042895	0.000719	0.062927	0.139737
7	0.710068	0.041575	0.045364	0.000717	0.062958	0.139318
8	0.708201	0.041974	0.047154	0.000715	0.062947	0.139009

Model 2							
Step	(1) fevd	(2) fevd	(3) fevd	(4) fevd	(5) fevd	(6) fevd	(7)
0	0	0	0	0	0	0	0
1	1	0	0	0	0	0	0
2	0.74358	0.002596	0.013593	0.00001	0.037928	0.027557	0.143289
3	0.708146	0.018146	0.015883	0.000023	0.053548	0.067798	0.136455
4	0.678717	0.024434	0.029276	0.000035	0.054072	0.082947	0.130519
5	0.650073	0.029214	0.058819	0.000035	0.05733	0.079553	0.124976
6	0.646513	0. 029144	0.058722	0.000035	0.059627	0.07931	0.126648
7	0.643148	0.029123	0.062255	0.000035	0.059731	0.078939	0.126768
8	0.639741	0.030528	0.062148	0.000035	0.059691	0.080337	0.12752
9	0.6344	0.031295	0.062241	0.059201	0.000035	0.081	0.131828
10	0.627683	0.031034	0.064255	0.058591	0.000035	0.081472	0.13693
11	0.621609	0.030719	0.065881	0.058139	0.000034	0.082639	0.140979
12	0.616665	0.030462	0.066853	0.057799	0.000034	0.083801	0.144385
13	0.611893	0.030285	0.068499	0.057428	0.000034	0.084754	0.147106
14	0.606751	0.030228	0.07112	0.056996	0.000034	0.085511	0.149361
15	0.601755	0.030352	0.074003	0.056568	0.000033	0.086052	0.151237

(1) impulse = gcf_gr, and response = gcf_gr

(2) impulse = gdp_grhat, and response = gcf_gr

(3) impulse = erhat, and response = gcf_gr

(4) impulse = L.erhat, and response = gcf_gr

(5) impulse = inf, and response = gcf_gr

(6) impulse = rir, and response = gcf_gr

(7) impulse = rir, and response = gcf_gr

Appendix J: Structural Vector Autoregressive Analysis

Table J.1: Structural VAR containing Growth Rate of GCF, Detrended Growth Rate of GDP, Detrended Exchange Rate, Lagged Detrended Exchange Rate, Inflation Rate and Real Rate of Interest, at lag=2.

VARIABLES	(1) /A	(2) /B	VARIABLES	(1) /A	(2) /B
1_1	1	2.579***	1_4	0	0
	(0)	(0.275)		(0)	(0)
2_1	-0.122***	0	2_4	0	0
	(0.0470)	(0)		(0)	(0)
3_1	0.213**	0	3_4	0	0
	(0.0903)	(0)		(0)	(0)
4_1	0.267	0	4_4	1	4.391***
	(0.293)	(0)		(0)	(0.468)
5_1	0.0344	0	5_4	0.845***	0
	(0.0381)	(0)		(0.0195)	(0)
1_2	0	0	1_5	0	0
	(0)	(0)		(0)	(0)
2_2	1	0.804***	2_5	0	0
	(0)	(0.0857)		(0)	(0)
3_2	-0.693**	0	3_5	0	0
	(0.270)	(0)		(0)	(0)
4_2	-0.221	0	4_5	0	0
	(0.883)	(0)		(0)	(0)
5_2	0.210*	0	5_5	1	0.567***
	(0.114)	(0)		(0)	(0.0604)
1_3	0	0			
	(0)	(0)			
2_3	0	0			
	(0)	(0)			
3_3	1	1.439***			
	(0)	(0.153)			
4_3	0.299	0			
	(0.460)	(0)			
5_3	-0.148**	0			
	(0.0597)	(0)			
Observations	44	44	Observations	44	44

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

1 = Growth Rate of Gross Capital Formation

2 = Growth Rate of Detrended GDP

3 = Exchange Rate

4 = Inflation Rate

5 = Real Rate of Interest

Table J.2: Structural VAR containing Growth Rate of GCF, Detrended Growth Rate of GDP, Detrended Exchange Rate, Lagged Detrended Exchange Rate, Detrended Growth Rate of Government Spending, Inflation Rate and Real Rate of Interest, at lag=2.

VARIABLES	(1) /A	(2) /B	VARIABLES	(1) /A	(2) /B
1_1	1	2.372***	1_4	0	0
	(0)	(0.256)		(0)	(0)
2_1	-0.175***	0	2_4	0	0
	(0.0452)	(0)		(0)	(0)
3_1	0.312***	0	3_4	0	0
	(0.105)	(0)		(0)	(0)
4_1	-0.00411*	0	4_4	1	0.0301***
	(0.00247)	(0)		(0)	(0.00325)
5_1	0.184	0	5_4	-19.72	0
	(0.362)	(0)		(21.67)	(0)
6_1	-0.0110	0	6_4	2.470	0
	(0.0459)	(0)		(2.767)	(0)
1_2	0	0	1_5	0	0
	(0)	(0)		(0)	(0)
2_2	1	0.702***	2_5	0	0
	(0)	(0.0757)		(0)	(0)
3_2	-0.933***	0	3_5	0	0
	(0.305)	(0)		(0)	(0)
4_2	-0.00187	0	4_5	0	0
	(0.00721)	(0)		(0)	(0)
5_2	-0.0181	0	5_5	1	4.276***
	(1.025)	(0)		(0)	(0.461)
6_2	0.311**	0	6_5	0.847***	0
	(0.130)	(0)		(0.0193)	(0)
1_3	0	0	1_6	0	0
	(0)	(0)		(0)	(0)
2_3	0	0	2_6	0	0
	(0)	(0)		(0)	(0)
3_3	1	1.404***	3_6	0	0
	(0)	(0.151)		(0)	(0)
4_3	-0.00458	0	4_6	0	0
	(0.00327)	(0)		(0)	(0)
5_3	0.309	0	5_6	0	0
	(0.475)	(0)		(0)	(0)
6_3	-0.176***	0	6_6	1	0.541***
	(0.0604)	(0)		(0)	(0.0583)
Observations	43	43	Observations	43	43

Standard errors in parentheses

* p<0.1,** p<0.05, *** p<0.01

1 = Growth Rate of Gross Capital Formation

2 = Growth Rate of Detrended GDP

4 = Government Spending

5 = Inflation Rate

Lights Out, Stress In: Assessing Stress Amidst Power and Energy Challenges in Bangladesh

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Abstract

In the midst of Bangladesh's power and energy crisis, our study introduces a pioneering approach by integrating the psychological Perceived Stress Scale-10 (PSS-10), customized for six distinct scenarios within the crisis, to measure household stress levels. Through a comprehensive national survey, we explore stress triggers and household perceptions towards the energy sector, focusing on the supply and pricing of electricity, gas, and fuel oil. This research focuses on socio-economic factors, political beliefs, and environmental attitudes as principal stress indicators while establishing the PSS-10's statistical reliability. By utilizing Multivariate Ordinary Least Square, Random Forest, and Ordered Probit models, we identify key variables - such as education, income, urban residency, geographical discrepancies, age of the household head, and several political and environmental beliefs - that significantly correlate with stress levels. In contrast, factors like household size and the sex of the household head show minimal impact. However, our analysis suggests that stress variation might also be significantly influenced by households' energy and power consumption behavior, an aspect beyond the scope of this study. Our findings mark a significant advancement in policy analysis, offering a nuanced understanding of public sentiment and paving the way for prioritized, effective policy interventions in Bangladesh's energy crisis landscape.

Keywords: Energy Economics; Energy Stressors; Power and Energy Crisis; PSS-10; Random Forest; Environmental Psychology, Household Stress from Energy

Abbreviations

BBS: Bangladesh Bureau of Statistics

GIS: Geographic Information System

GoB: Government of Bangladesh

HIES: Household Income and Expenditure Survey

IEPMP: Integrated Energy and Power Master Plan

LPG: Liquid Petroleum Gas

OLS: Ordinary Least Square

PSS: Perceived Stress Scale

SSC: Secondary School Certificate

1.0 Introduction

In an era where the relentless march of technological progress and urbanization has led to an insatiable appetite for energy, the plight of Bangladesh, grappling with a burgeoning energy and power crisis, presents a stark juxtaposition.

Bangladesh's energy crisis stems from a blend of rising demand due to population growth and economic development, coupled with a heavy reliance on imported fuel. Financial challenges in procuring these imports, frequent power outages, slow progress in renewable energy generation, and delays in new power plant projects add to the crisis. Moazzem, et al. (2023) showed that resource scarcity, factors such as the use of low-quality fuel oils, corruption at distribution points, inadequate maintenance, reduced gas supply pressure, and cuts in government subsidies for electricity and gas - mandated by the International Monetary Fund - further complicate the situation. These elements are poised to drive up the costs of electricity, fuel oil, and gas in the future. Additionally, poor management practices contribute to the deepening crisis. In response, the Government of Bangladesh (GoB) and other relevant stakeholders are proactively formulating, following and discussing policies such as the Mujib Climate Prosperity Plan 2022-2041, the Energy Efficiency and Conservation Master Plan up to 2030, and the Integrated Energy and Power Master Plan (IEPMP) 2023 etc. Therefore, understanding the perceptions of the population is paramount and crucial for policymakers, researchers, and energy providers to develop strategies for energy conservation, demand management, and promotion of sustainable energy sources that is more appropriate and suitable with perceived behavior (Spence, et al., 2010a). Thus, in an unconventional stroke, this study harnesses the power of psychological stress assessment to unveil the hidden currents of public opinion in Bangladesh, potentially rewriting the script of energy policy and redefine the nation's energy narrative from the ground up.

Determining policy priorities involves navigating complex factors such as government responsibilities, political changes, and public sentiment. Psychological studies play a crucial role in understanding public perceptions, offering insights into societal views on various issues (Smith, 1971). These studies delve into the emotional and psychological effects of events like energy shortages, identifying key areas for policy focus (Stern & Gardner, 1981). This research extends the dialogue on energy to include the stress and psychological impact on households during energy crises. This deeper understanding aids stakeholders in addressing the most impactful concerns, making perception studies invaluable for informed policymaking.

The primary goal of this study is to measure the stress levels of Bangladeshi households, directly resulting from the power and energy crisis. It aims to explore various factors influencing these stress levels, including environmental and political awareness, socio-economic status, and regional differences. By examining these determinants, the study seeks to provide a comprehensive view of the crisis's impact on households. It will also include a qualitative analysis of socio-economic, demographic factors, and the politics of environmental and climate change to offer a deeper insight into the crisis. Additionally, the study will assess the reliability of using stress levels as an indicator of the crisis's impact through quantitative measures.

The remainder of this paper is structured as follows: Section 2 highlights a review of the literature; Section 3 details the materials and methodology employed; Section 4 presents the results and discussion; and Section 5 concludes the paper with a summary of insights and implications.

2.0 Literature Review

The utilization of psychological studies and quantitative psychology for gauging perceptions or opinions is a well-established concept, with prior literature demonstrating various instances of its application. This section primarily focuses on a conceptual literature review, as our proposed analytical framework and concepts, while unique in their application, draw inspiration from existing works.

In their 1981 study, Stern and Gardner underscored the potential of psychological insights in shaping energy and power sector policies, highlighting how consumer behavior and perception are critical in formulating effective and sustainable strategies. This concept is further supported by findings from a subsequent study (Smith, 1971; Swim, Geiger, & Zawadzki, 2014). This study takes an attempt to bridge this gap, proposing an analytical framework that integrates psychological insights into energy policymaking.

Across the world, various psychological methods have been employed over the years to assess perceptions of the general population about energy and power sector. In our discussion on the scope of psychological research in energy policy, we now turn to Whitmarsh's (2011) study, which adeptly employs psychological techniques to measure skepticism and uncertainty about climate change among the UK public. Utilizing a multi-dimensional approach, Whitmarsh's methodology focused on developing and refining a measure of skepticism, building upon her previous qualitative work. Her objectives centered on examining the variations in public skepticism and uncertainty, especially in relation to individual and societal factors like demographics, lifestyle, knowledge, and values (Whitmarsh, 2011). Spence et al. (2010b) explored public attitudes towards climate change and different forms of energy production, as well as to investigate the evolution of these views over time. To achieve this, they employ surveys, supplemented with various psychological tools, to gauge and analyze public perceptions, underscoring the dynamic nature of public opinion amidst the rapidly shifting environmental and energy landscapes (Spence, et al, 2010b). In a separate study conducted by Carrus, et al. (2021), a meta-analysis was utilized to investigate the influence of various psychological factors, including attitudes, intentions, values, awareness, and emotions, in shaping behaviors related to energy conservation. This methodology facilitated a thorough examination of the robustness of the relationships between different psychological variables and individuals' intentions and actions towards saving energy (Carrus, et al., 2021)Psychological theories such as the Theory of Planned Behavior have been effectively used to design interventions that align consumer behavior with their environmental attitudes, as demonstrated by Litvine & Wüstenhagen (2011) in enhancing the uptake of green electricity in Switzerland. Investment behavior analysis, such as Salm's (2018) study, shows different risk preferences between incumbent utilities and institutional investors, highlighting the impact of financial incentives and risk exposure on renewable energy investments. Moreover, a study authored by Tiefenbeck, et al. (2013) indicated that environmental campaigns can sometimes lead to unintended behavioral spill overs, such as moral licensing, where an improvement in one environmental behavior causes a setback in another. These diverse applications underscore the importance of psychological tools and theories in designing more effective policies and interventions for promoting sustainable energy practices and investments.

In our study, we have employed perceived stress scale – 10 (PSS-10) to assess the stress faced by the households due to incidents associated with power and energy crisis in Bangladesh. We have discussed the details of the PSS-10 later in the methodology section. In the literature review section, we are going to discuss the flexibility of PSS-10 in various field of study across the world. Vlek (2000) highlighted the significance of measuring stress associated with power and energy since the power and energy sectors are pivotal components of modern society, and understanding the psychological and physiological responses to stressors linked to them is essential for safeguarding individual well-being, workplace health, and community relationships (Vlek, 2000). Townsend and Medvedev (2022) have demonstrated the remarkable adaptability of the PSS by highlighting its extensive utilization across diverse general and clinical contexts, amassing over 20,000 citations on Google Scholar. Furthermore, the PSS has exhibited its global reach, with translations available in 28 different languages by 2022 (Townsend & Medvedev, 2022). Several examples of utilizing PSS measures to examine stress levels include the research conducted by Lushchak et al. (2023), where they utilized the PSS-10 to gauge the extent of stress experienced by the Ukrainian populace in reaction to events associated with the Russian invasion of Ukraine (Lushchak, et al., 2023). Additionally, the Perceived Stress Scale (PSS) has been employed to assess stress levels in cancer and breast cancer patients, including its translation and validation in different languages for specific clinical studies and the exploration of alternative factor models to understand perceptions of stress in these populations (Mounjid, et al., 2022; Golden-Kreutz, et al., 2004). Moreover, the Perceived Stress Scale-10 (PSS-10) has been employed to assess stress levels in expectant mothers across culturally diverse settings and to compare stress levels between first-time mothers and those with previous childbirth experiences, demonstrating its utility in prenatal stress research (Katus, et al., 2022).

Islam (2020) demonstrated that the Bengali version of the Perceived Stress Scale (PSS-B) is a valid and reliable tool for assessing perceived stress among nonclinical individuals in Bangladesh, thereby expanding the utility of the PSS-10 in nonclinical settings within the country (Islam, 2020). Moreover, in a recent study by Mozumder (2022), it was demonstrated that the PSS-10 maintains its reliability and validity when applied in the context of Bangladesh, affirming the scale's robust psychometric properties and affirming its suitability as a valid and dependable tool for evaluating stress appraisal within Bengali-speaking and Bangladeshi populations (Mozumder, 2022). It validates and opens the scope of using PSS-10 in our study.

3.0 Methodology

3.1 Analytical Framework

To gauge household perceptions amidst the power and energy crisis in Bangladesh, the study employed the Perceived Stress Scale, specifically utilizing the Bengali translated PSS-10 version to evaluate stress levels experienced by households. To effectively measure PSS-10, the study necessitated participants to consider the previous month as the reference period from the survey date.

Perceived Stress Scale, originally developed by Cohen, Kamarck and Mermelstein (1983), the PSS was initially designed as a 14-item self-report questionnaire to measure the extent to which individuals perceive their lives as stressful. It evaluates how unpredictable, uncontrollable, and overloaded individuals perceive their experiences. The PSS-10 is a shorter adaptation of the original PSS, consisting of 10 items, and has gained popularity for its brevity and efficiency in measuring perceived stress (Cohen, Kamarck, & Mermelstein, 1983). Since the Bengali version of the PSS-10 questionnaire has been validated and proven reliable for the Bengali-speaking population in Bangladesh, particularly in nonclinical settings, and the robust psychometric properties of the PSS-10 in the context of the

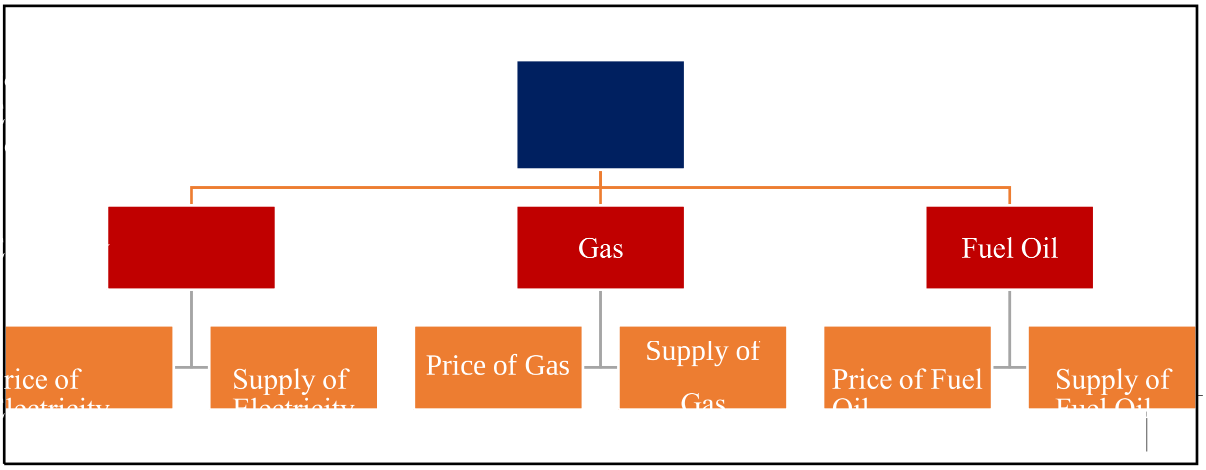
Bangladeshi population have been firmly established, it serves as a valuable, culturally, and academically appropriate tool for assessing perceived stress in this specific demographic.

For the purpose of our analytical framework, this study has segmented the power and energy sector in Bangladesh into three primary categories: electricity, gas, and fuel oil. Within each of these categories, two dimensions have been identified: the price aspect and the supply aspect. In essence, this approach results in the identification of six distinct categories that encompass the overall energy and power crisis in Bangladesh. Subsequently, the Bengali version of the PSS-10 questionnaire was tailored to address the specific contexts of each power and energy crisis scenario in Bangladesh (see Figure 1). As a result, our questionnaire comprises a total of 60 questions that assess household stress levels arising from incidents associated with these six categorized power and energy crises. Each of these broad scenarios is represented by a set of PSS-10 questions, totaling 10 questions per scenario.

The Bengali version of the PSS-10 questionnaire, which was utilized as a reference for developing a modified version to incorporate the context of the power and energy crisis, draws its foundation from two primary sources: one developed by Keya (2006) and the other by Laboratory for the Study of Stress at Carnegie Mellon University[1]. This adaptation aimed to retain the psychological essence of each question while tailoring the scenarios or contexts to match the experiences of the participants associated with power and energy crisis of Bangladesh (Islam, 2020; Keya, 2006). In the subsequent phase, the questionnaire underwent a thorough review process involving experts from the fields of psychology, behavioral economics, and power and energy sector.

This study categorizes the crises within the power and energy sector into six key scenarios. Broadly, the 'Supply of Electricity' scenario encompasses load-shedding, low voltage, corruptions in bill payments, and unexpected outages etc. The 'Price of Electricity' scenario covers increases in prices, inaccurate meter readings, billing mistakes, pricing uncertainties and so on. For 'Supply of Gas', issues include line

Figure 1: 6 broad scenarios of power and energy crisis of Bangladesh.



[1] https://www.cmu.edu/dietrich/psychology/stress-immunity-disease-lab/scales/pdf/perceived_stress_scale_bengali_translation.pdf

leakages, outages, low pressure, and LPG cylinder scarcity etc. The 'Price of Gas' scenario reflects rising LPG connection costs, cylinder prices, national grid gas prices, and maintenance expenses etc. The 'Supply of Fuel Oil' scenario captures problems with fuel oil quality, corruption at filling stations, and availability issues. Finally, the 'Price of Fuel Oil' scenario deals with billing errors, price hikes, and pricing uncertainties etc. These scenarios were developed through literature reviews of newspapers, articles, reports, and consultations with power and energy sector experts.

After data collection, this study calculates PSS-10 scores using established methods, followed by a qualitative analysis of these scores. To assess regional stress level disparities across divisions for each scenario, including the overall situation, we will use Geographic Information System (GIS) technology. We will then apply Multivariate OLS and Random Forest models to scenario-specific stress scores to examine the impact of socioeconomic factors, as well as political and environmental opinions, on stress levels. Lastly, an Ordered Probit model will analyze how these socioeconomic factors influence households' transitions between different stress ranges.

3.2 Sampling Techniques and Sample Characteristics

Sampling Techniques

This study surveyed 1000 households across 36 sub-districts in 8 divisions of Bangladesh, focusing on households with access to both gas and electricity. Respondents were household heads aged 18 or above.

The division-wise sample size was determined based on household distributions extracted from the Population Census of 2022. Larger divisions, in terms of household numbers, were allocated a proportionally larger sample size. Subsequently, the assigned sample for each division was evenly distributed among the randomly selected sub-districts, with any fractional figures rounded randomly. For divisions with higher overall sample allocations, such as Dhaka, the selection process of the number of sub-districts within a division ensures that its sub-districts also receive a higher sample size compared to the sub-districts of divisions with lower allocations, like Mymensingh (see Appendix A). To ensure dataset heterogeneity and representation, a minimum of four sub-districts were chosen within each division.

At least four sub-districts were selected per division using a computer-generated random process, targeting areas with moderate to low poverty levels according to the HIES 2016 Poverty Map. Household selection within sub-districts followed a systematic sampling method. If the initially selected household lacked both gas and electricity connections, the subsequent household possessing both utilities was surveyed. Subsequently, the next household was chosen while maintaining the same interval and the process is repeated.

Sample Distribution (Urban and Sub-urban distribution)

63% of the total sample resides in sub-urban neighborhoods, with the remainder spread across urban neighborhoods. Notably, there are no rural neighborhoods included in the sample, as they were excluded due to a precondition requiring confirmed availability of gas and electricity in the households.

Sex[2] of the Household Head

96% of the participants in the study are identified as male household heads. Consequently, incorporating the factor of the sex of household head into our analysis may pose challenges due to the significantly smaller proportion of female-headed households.

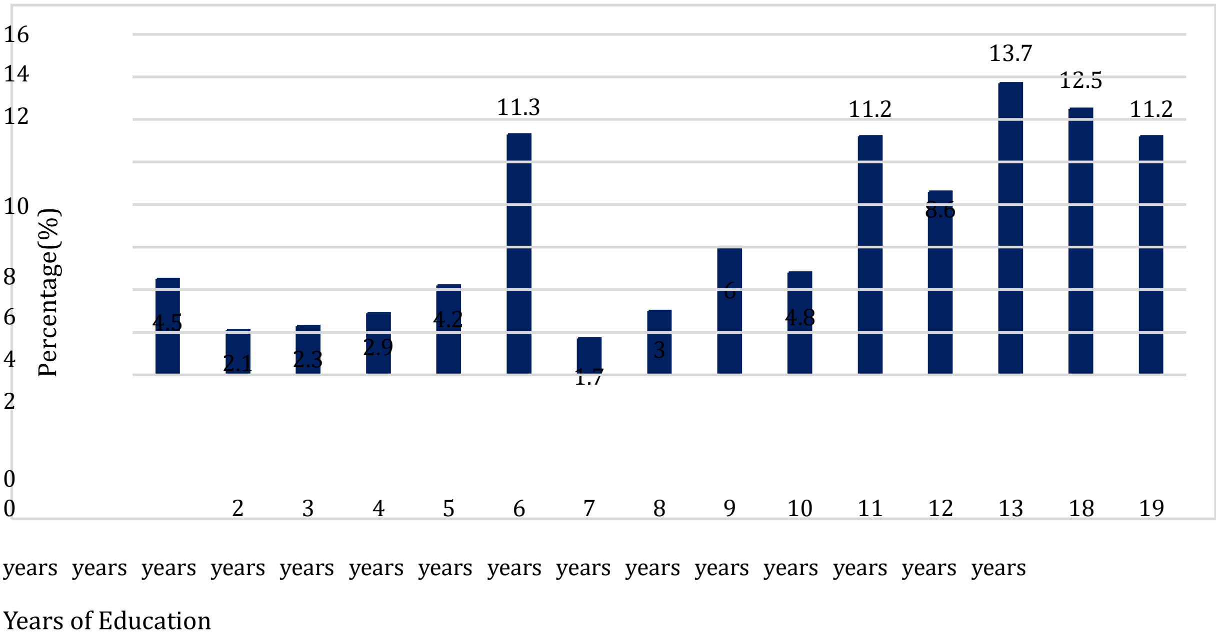
Age Distribution of The Household Heads

The mean age of household heads is 42.5 years, ranging from 18 to 65 years. These justify the inclusion of age as a relevant factor in our analysis.

Distribution of the Years of Education Across the Households Heads

Our calculation illustrated in Figure 2 shows the distribution of years of education across the household heads. The mean education years for all households is 10.91.

Figure 2: Distribution of the Years of Education across the Household Heads



Analysis shows female household heads have an average education of 8.76 years versus 11.01 for males, indicating a gender education gap in Bangladesh, with more females having no education. Urban heads average 11.37 years of education compared to 10.65 in sub-urban areas, aligning with the literature on higher urban education (USDA, 2017).

In our study, sex is defined as a set of biological attributes associated with physical and physiological features, with a binary sex categorization (male/female) typically assigned at birth.

8

Household Size

The sample shows an average household size of 4.71, slightly above the HIES-2022 figure (BBS, 2023) with sizes ranging from 2 to 24. Urban households average 4.3 members, compared to 4.9 in sub-urban areas. Male-headed households have more members (4.7) than female-headed ones (4.3), in line with Bangladesh's typical household patterns (Saad, et al., 2022).

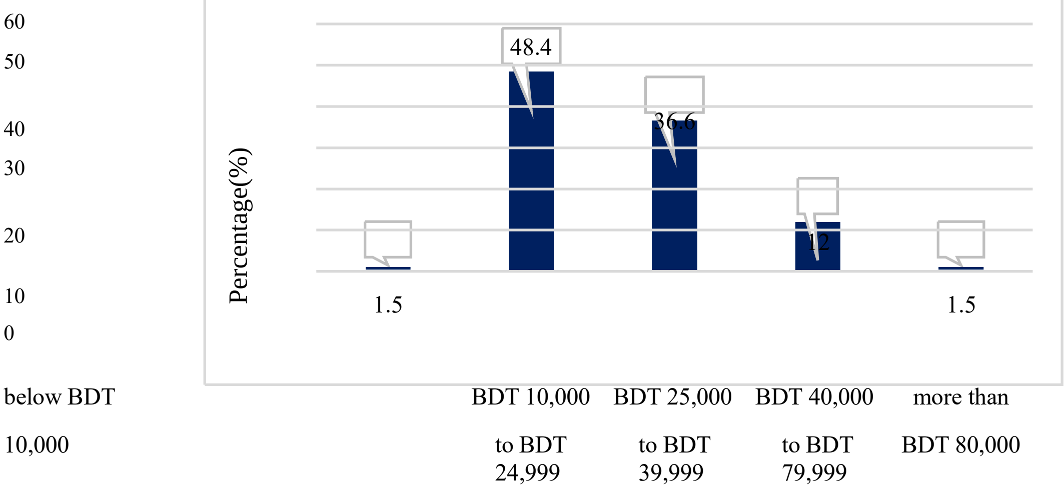
Number of Students in a Household

On average, the households have 1.47 students, ranging from 0 to 13, with male-headed homes having slightly more (1.47) compared to female-headed ones (1.36). This pattern, not clearly indicating a preference in male-headed households, coincides with existing studies (Bose-Duker, Henry, & Strobl, 2021). Notably, sub-urban households report more students than urban ones, likely due to their generally larger family sizes.

Primary Income Source

Our analysis reveals that 72% of the sampled households primarily derive their income from the service sector, while the figures for the industry and agriculture sectors stand at 19% and 9%, respectively. Our analysis shows that sub-urban households are more reliant on agriculture for income, while urban households tend to be more engaged in the industry sector.

Figure 3: Income Distribution of Households



Income Distributions of the Households

Our calculation, illustrated in Figure 3, shows that at least 80% of households earn between BDT 10,000 to BDT 39,999 per month, reflecting a prevalent middle-income status consistent with national surveys like HIES 2022 (BBS, 2023). Additionally, higher-income households are more clustered in urban areas, a trend seen in prior research (Tripathi, 2020). Moreover, female-headed households tend to have lower incomes than their male-headed counterparts, signifying an economic gap, consistent with conventional literatures.

9

Availability of Personal and/or Office Vehicles in The Households

Our analysis reveals that merely 30% of households possess personal and/or office vehicles.

Overall, the sample characteristics, indicated by years of education of the household head, household size, primary income source distribution, income distribution of the households, and availability of personal or office vehicles, validates the national representativeness of the sample.

3.3 Survey and Data Collection Methodology

The survey was conducted from 31st October to 23rd November 2023, during a significant heatwave with temperatures consistently ranging between 21℃ and 34℃ (AccuWeather, 2023). Surveyors, selected for their university education in psychology, received two days of training to ensure uniform data collection methods. Household heads provided informed consent and participated voluntarily without incentives, with confidentiality assured. Each household was given a unique identifier derived from two contact numbers. The duration of each survey ranged from 45 to 60 minutes.

3.4 Variables

3.4.1 Psychological Variables

Table 1: PSS Variables and Descriptions

Variables	Variable Description
pss_elcs	PSS for the ‘Supply of Electricity’ scenario.
pss_elcp	PSS for the ‘Price of Electricity’ scenario.
pss_gassp	PSS for the ‘Supply of Gas’ scenario.
pss_gaspr	PSS for the ‘Price of Gas’ scenario.
pss_fuelsp	PSS for the ‘Supply of Fuel Oil’ scenario.
pss_fuelpr	PSS for the ‘Price of Fuel Oil’ scenario.
pss	PSS for the overall power and energy scenario.
pss_elcs_rng	PSS for the ‘Supply of Electricity’ scenario, expressed as various stress range.
pss_elcp_rng	PSS for the ‘Price of Electricity’ scenario, expressed as various stress range.
pss_gassp_rng	PSS for the ‘Supply of Gas’ scenario, expressed as various stress range.
pss_gaspr_rng	PSS for the ‘Price of Gas’ scenario, expressed as various stress range.
pss_fuelsp_rng	PSS for the ‘Supply of Fuel Oil’ scenario, expressed as various stress range.
pss_fuelpr_rng	PSS for the ‘Price of Fuel Oil’ scenario, expressed as various stress range.
pss_rng	PSS for the overall power and energy scenario, expressed as various stress range.

The Perceived Stress Scale-10 (PSS-10) features ten items rated on a 5-point Likert scale from 0 ("never") to 4 ("very often"). To compute a total stress score, responses to items 4, 5, 7, and 8 are reversed before summing all item scores, yielding a range from 0 to 40, where higher scores denote greater perceived stress. Stress levels for each scenario are categorized into low (0-13), moderate (13-26), and high (27-40) based on the scores obtained (Carnegie Mellon University, 2010). For this study, we created a set of questions for each scenario, averaging them for the overall stress calculation. The variables employed for denoting various stress variables are tabulated in Table 1.

3.4.2 Socio-economic Variables

Table 2 presents the socio-economic and regional variables used in our study to account for their impact on household stress levels, with detailed explanations of variables marked with an asterisk available in Appendix B.

Table 2: Socio-Economic Variable List

Variable Name	Variable Description
urban*	Urban (urban and sub-urban) characteristics of a household
division_code_dhk	Division code: Dhaka. This is the base division.
division_code_bar*	Division code: Barisal
division_code_ctg*	Division code: Chattogram
division_code_khl*	Division code: Khulna
division_code_mym*	Division code: Mymensingh
division_code_raj*	Division code: Rajshahi
division_code_rang*	Division code: Rangpur
division_code_syl*	Division code: Sylhet
a_5	Sex of the household head
a_6	Age of the household head
a_7	Years of education of a household head
a_8	Number of members in a household
a_9	Number of students in a household
a_10_agri	Household's primary source of income: Agriculture. This is the base category of households' source of primary income.
a_10_serv*	Household's primary source of income: Service
a_10_ind*	Household's primary source of income: Industry
a_11_10k	Household's monthly income: Below BDT 10,000
a_11_25k*	Household's monthly income: BDT 10,000 to BDT 24,999
a_11_40k*	Household's monthly income: BDT 25,000 to BDT 39,999
a_11_80k*	Household's monthly income: BDT 40,000 to BDT 79,999
a_11_a80k*	Household's monthly income: above BDT 80,000
a_12	Availability of personal/office vehicles

3.4.3 Environmental and Political Values

The variables used to assess the environmental and political values of the households are presented in Appendix B. These variables are measured on a Likert scale, with scores ranging from 1 to 5, where 1 represents 'strongly disagree,' 2 for 'roughly disagree,' 3 for 'neutral,' 4 for ' roughly agree,' and 5 for 'strongly agree.' The variables are denoted as 'e-variables' in this study.

3.5 Calculation and Econometric Model

3.5.1 Overall PSS-10:

The overall PSS-10 score is calculated by averaging the scores from the six scenario-specific PSS-10 assessments. The use of averaging is justified for our purpose as it captures both direct and indirect effects[3] of fuel oil on households, including those without direct usage, reflecting concerns through public transportation, generator fuel, and other means. The resulting average score is then rounded to align with the established ranges commonly used in academic psychology.

3.5.2 Multivariate OLS

A multivariate OLS model is employed for our purpose of investigating how various socio-economic and regional factors affect stress level and the specification of the econometric model is given below:

$$pss_{ij} = \alpha_0 + \beta' X_i + \gamma' Z_i + \mu_{ij}$$

Here,

- $i = 1, 2, 3......1000^{th}$ household
- pss_{ij} = PSS-10 for 'j' scenario for 'i'-th household
- j = 1, 2, 3, 4, 5, 6 represents 'pss_elcs', 'pss_elcp', 'pss_gassp', 'pss_gaspr', 'pss_fuelsp', 'pss' for 'i'-th household respectively
- $\beta' X_i$ = Vector of linear combination of socioeconomic factors for 'i'-th household
- $\gamma' Z_i$ = Vector of linear combination of environmental and political consciousness variable for 'i'-th household
- μ_{ij} = Residual term of the model for 'i'-th household in 'j' scenario

Our initial analysis indicates that some explanatory variables, particularly those related to political and environmental opinions, do not adhere to a normal distribution although these Likert variables are internally consistent (see Appendix C and Appendix D). Consequently, incorporating these variables into a linear model and estimating coefficients could yield spurious and misleading results.

3.5.3 Random Forest

[3] Some households might not have any direct use of fuel oil.

In order to address and solve the non-normal distribution of the explanatory variables, this study employs the Random Forest ensemble learning technique to predict stress levels (PSS scores) across seven different scenarios. Random Forests are ensemble models that consist of multiple decision trees, and for regression tasks like predicting PSS scores, they aggregate the predictions of individual trees to make the final prediction. For each scenario 'j', we build a separate Random Forest model to predict the corresponding PSS score (PSS_j) using a set of explanatory variables (V_j).

For each scenario 'j', a Random Forest model is constructed to predict the corresponding Perceived Stress Scale (PSS), denoted as PSS_j. The model is formulated as:

$$pss_j = RF_j(V_j) + \varepsilon_j$$

Here,

- pss_j = PSS-10 for 'j' scenario
- V_j represents the set of independent variables, which is divided into two parts, mentioned as X_i and Z_i previously
- RF_j is the Random Forest model trained for scenario 'j'
- ε_j represents the residual error term

To assess the generalization performance of the Random Forest models, in our study, a simple train-test split approach is used instead of k-fold cross-validation. Specifically, the dataset is split into training and testing sets, with 80% of the data used for training and 20% used for testing.

Prior to building the Random Forest models, we perform feature selection to identify the most relevant independent variables V_j for predicting PSS scores in each scenario. In the analysis, feature importance is visualized for top ten features for each scenario, helping to understand which independent variables most significantly impact stress levels. For each scenario, we train a Random Forest model (RF_j) using the selected features V_j.

The performance of each Random Forest model is evaluated using regression metrics such as the Mean Squared Error (MSE) and R-square (R^2). These metrics provide insights into the model's accuracy and the proportion of variance in the dependent variable that is predictable from the independent variables.

3.5.4 Ordered Probit

Another model that will be employed in this study to investigate the factors that is associated with the households shifting from one stress range to another in each specific and overall scenario is an ordered probit model. The specification of the model is:

$$Pr(pss\_rng_{ij} = k) = \Phi_i(\alpha_{jk} - \delta'X - \lambda'Z)$$

and the theoretical latent variable assumed to be embedded here:

$pss_{ij} = \alpha_0 + \beta' X_i + \gamma' Z_i + \mu_{ij}$

Here:

- pss_rng$_{ij}$ = the ordered dependent variable (PSS-10 range) for 'i'-th household and 'j'-scenario PSS-10 score
- k = the stress range (e.g., Low, Moderate, High), where k = 1, 2, 3 represent 'Low Stress', 'Moderate Stress', and 'High Stress' respectively
- Φ_j = the cumulative distribution function of the standard normal distribution in the context of 'j'-scenario PSS-10 score
- α_{jk} = the threshold parameter for the k-th category in the context of 'j'-scenario PSS-10 score
- $\delta' X$ = Vector of the linear combination of socio-economic independent variables
- $\lambda' Z$ = Vector of the linear combination of environmentally and politically conscious variables

For the defined stress ranges,

$$Pr(pss\_rng_{ij} = 1) = \Phi_i(\alpha_{j1} - \delta' X - \lambda' Z), when, 0 \le pss_{ij} \le 13$$

$$Pr(pss\_rng_{ij} = 2) = \Phi_i(\alpha_{j2} - \delta' X - \lambda' Z), when, 14 \le pss_{ij} \le 26$$

$$Pr(pss\_rng_{ij} = 3) = \Phi_i(\alpha_{j3} - \delta' X - \lambda' Z), when, 27 \le pss_{ij} \le 40$$

In addition, we intend to conduct a post-estimation analysis to calculate marginal effects from the ordered probit models. These marginal effects will provide valuable insights into the influence of various socio-economic and regional factors on households' shifts from one stress range to another within each specific and overall scenario.

3.5.5 Geographic Information System

To illustrate regional disparities in stress levels due to energy and power crises across Bangladesh's eight divisions, we used Python, using geospatial shapefiles from reliable online sources[4].

3.6 Statistical Tests

The study will implement Breusch-Pagan test to investigate heteroscedasticity. Should the error variances demonstrate heteroscedasticity, the issue will be addressed by applying robust variance method (Gujarati, 2003). Additionally, the study will employ a pairwise correlation coefficient matrix to detect multicollinearity (Gujarati, 2003) and the Shapiro-Wilk W-test to assess normality (Ramachandran & Tsokos, 2021).

[4] https://github.com/yasserius/bangladesh_geojson_shapefile?tab=readme-ov-file

To ascertain the validity and reliability of the PSS-10 in measuring six scenario-specific scores and an overall score, Cronbach's alpha is calculated (Mozumder, 2022). The similar measure is employed to investigate the internal consistency of environmental and political variables.

4.0 Result and Discussion

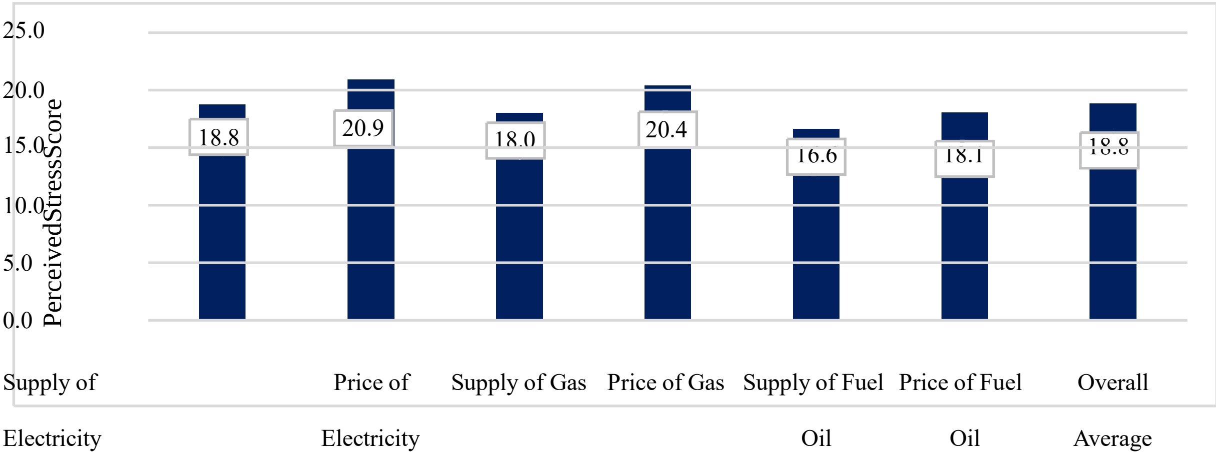
4.1 Reliability of the Perceived Stress Scores

Cronbach's alpha calculations show a reliability coefficient above 0.8 for both specific and overall stress scores related to power and energy crises, indicating strong internal consistency and reliability of our modified PSS-10 questionnaire for Bangladesh's context (see Appendix E).

4.2 Qualitative Analysis of Perceived Stress Scores for Various Scenarios

Our calculation outlined in Figure 4 and Table 3 shows, on an average, households mostly fall within the moderate stress range across scenarios, with scenarios of electricity and gas prices causing the highest average stress levels nationwide. Stress linked to the cost of electricity, gas, and fuel oil notably exceeds that related to supply scenarios.

Figure 4: Mean Perceived Stress Scale Under Various Scenarios



Sl. No.	Scenarios	Low Stress Level	Moderate Stress Level	High Stress Level
1	Supply of Electricity	15.8%	79%	5.2%
2	Price of Electricity	10.4%	77.5%	12.1%
3	Supply of Gas	16.2%	80.2%	3.6%
4	Price of Gas	11.1%	80%	8.9%
5	Supply of Fuel Oil	18.7%	80.20%	1.1%
6	Price of Fuel Oil	16.9%	76.9%	6.2%
7	Overall	13.2%	83.5%	3.3%

Table 3: Household Distribution Across Various Stress Ranges

The proportion of households experiencing higher stress levels is comparatively smaller when juxtaposed with those encountering lower stress levels. It is disconcerting that, across all six individual

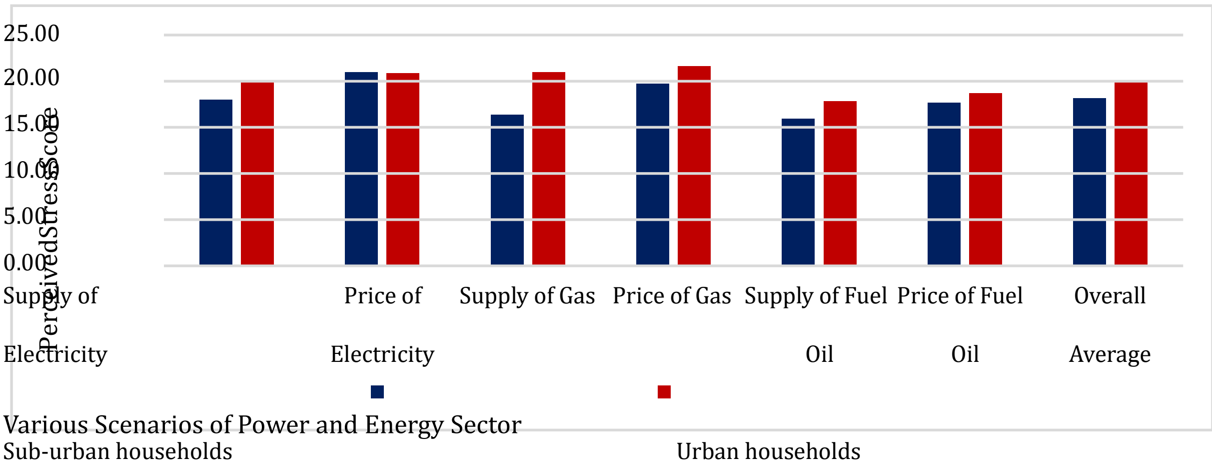
scenarios related to the power and energy crisis in Bangladesh, at least 77.5% of households find themselves in the realm of moderate stress.

Table 3 shows over 88% of households experience moderate to high stress regarding electricity pricing (Sl. No. 1), while supply concerns (Sl. No.2) evoke lower stress levels. Similarly, our calculation suggests a more pessimistic view of the power and energy sector's pricing (Sl. No. 2, Sl. No. 4, Sl. No.6) than other aspects, with analysis indicating lower stress levels for fuel oil pricing and supply compared to electricity and gas scenarios.

Stress Analysis Across Urban and Sub-urban Neighborhoods

Our calculation illustrated in Figure 5 reveals that, on an average, urban households experience higher stress levels than sub-urban ones across all power and energy scenarios in Bangladesh, with a notable disparity in gas supply and pricing scenarios, underscoring the need for government action on gas availability and affordability in urban areas in accordance with their demand.

Figure 5: Average Perceived Stress Scale Under Various Scenarios (Across Urban and Sub-urban Households)



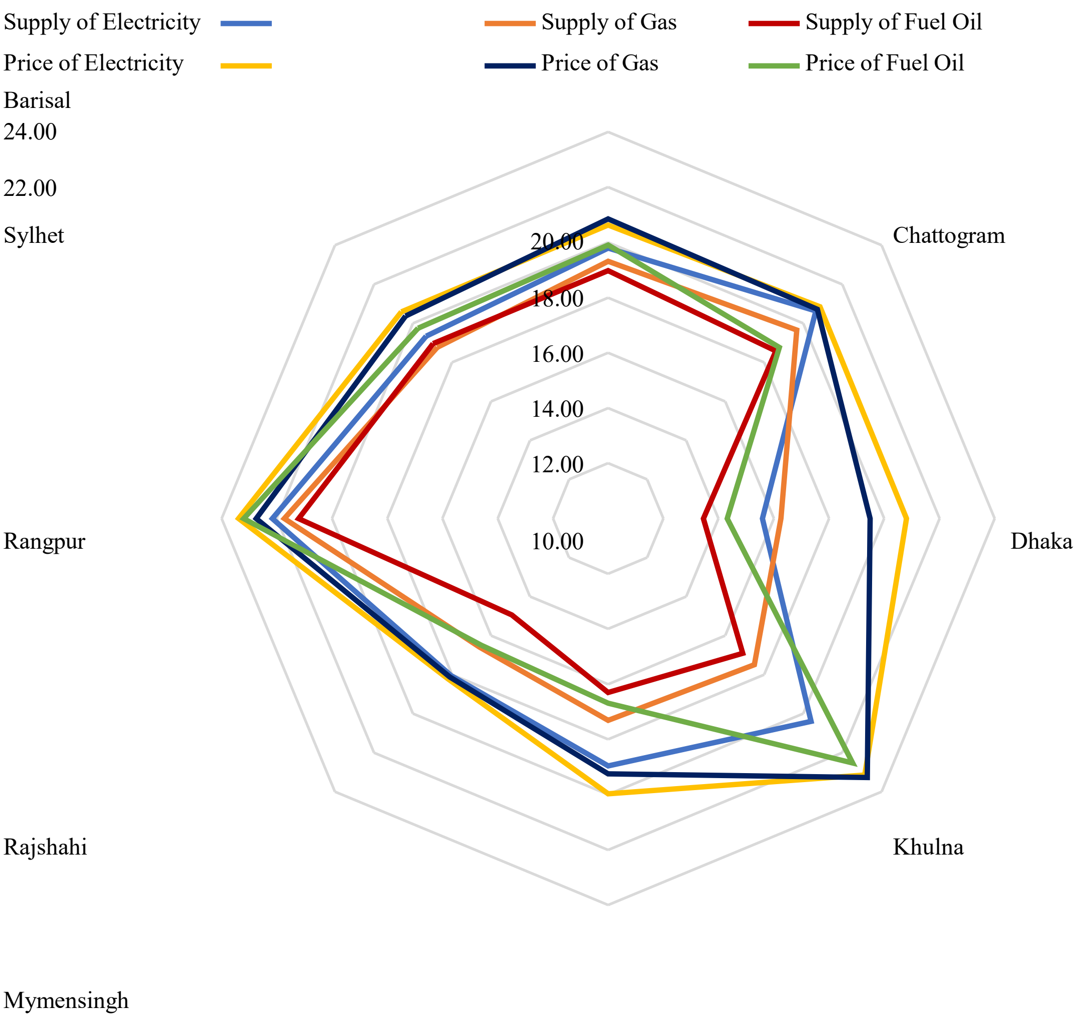
While stress levels concerning electricity pricing show minimal urban and sub-urban differences, indicating nationwide concern, the stress associated with both aspects fuel oil is comparatively lower than the other energies, highlighting different dimensions of stress in the energy sector and pointing to targeted areas for policy intervention. Another interesting observation illustrated in Figure 5 is that in the case of the gas supply scenario, sub-urban households experience less stress than their urban counterparts, likely due to a greater reliance on LPG cylinders which offer advantages such as fewer issues with low pressure and more individual control over gas availability, making them a more stable and convenient option compared to line gas.

Stress Analysis Across Divisions

To investigate potential regional disparities in perceived stress scores, the study has incorporated regional dynamics by considering various divisions and analyzing the situation accordingly.

Our calculation, summarized in Figure 6, showcases Dhaka with lower stress levels from electricity supply issues compared to Rangpur, Chattogram, and Khulna, where stress is markedly higher, aligning with BPDB's reports of frequent load-shedding, especially in Rangpur (Moazzem, et al., 2023).

Figure 6: Average Perceived Stress Score Across Divisions: Six Different Scenarios



Despite fewer outages, Chattogram, Khulna, and Barisal report higher stress, suggesting Dhaka's residents have better adapted to electricity disruptions. Rajshahi reports the lowest stress from electricity prices, while Rangpur and Khulna face the highest, indicating significant concern over electricity costs under uncertain situations. Regarding gas supply, Rangpur Division experiences the most stress, hinting at severe supply issues or inadequate infrastructure, while Dhaka and Rajshahi show the least stress, possibly due to less severe problems or available LPG distributors or more effective coping mechanisms. Stress from gas pricing overshadows other supply concerns, with all divisions expressing high stress over gas costs, pointing to a universal issue with financial impacts. Rajshahi shows the least stress in gas cost story, suggesting better affordability or less impact from gas costs, whereas Rangpur and Khulna bear the brunt, highlighting potential economic disparities despite centrally regulated gas prices. Furthermore, Rangpur also faces high stress from fuel oil prices. Conversely, Dhaka, benefiting from better public transportation or higher incomes, shows minimal stress, while Khulna also indicates significant concern. Overall, fuel oil pricing stress is less than that associated with electricity and gas.

Figure 7: Average Perceived Stress Scale Across Divisions: Overall Stress Level

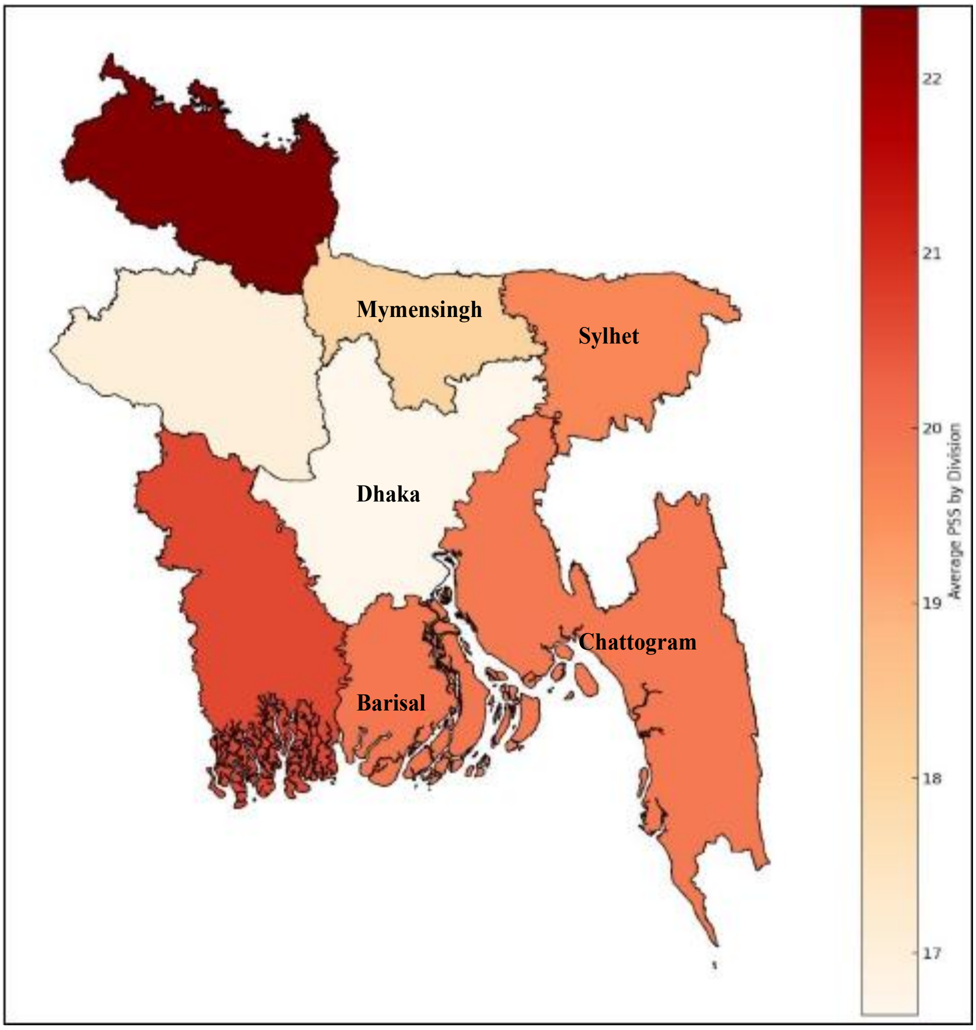


Figure 7 highlights this regional disparity, signaling the North's critical need for support and highlighting the divisional priorities the government should establish to alleviate stress among the populace. In conclusion, the Rangpur division emerges as the most stressed across nearly all scenarios, underscoring the need for urgent intervention. Contrastingly, Dhaka exhibits the lowest stress levels, suggesting better supply quality, economic strength, and coping strategies. This disparity suggests a central focus in policy and operation that may neglect regional needs.

4.3 Statistical Tests

Our analysis indicates the absence of multicollinearity issues. Our analysis indicates the presence of heteroskedasticity, which can potentially affect the reliability of our regression results. To address this issue, we have employed robust standard errors in our analysis. However, it's important to note that certain Likert variables representing environmental and political opinions, as shown in Appendix 2, do not follow a normal distribution.

4.4 Summary Results of the Political and Environmental Opinions

Here, we provide a summary table (see Table 4) that presents the frequency distribution of political and environmental opinions, as detailed in the findings.

Table 4: Summary results of environmental and political opinions

Variables	Completely Disagree	Roughly Disagree	Neutral	Roughly Agree	Completely Agree
e_1	2.1%	6.5%	13.3%	24.6%	53.5%
e_2	3.5%	8.8%	20.9%	36.9%	29.9%
e_3	3.6%	8.3%	22.5%	24.6%	41%
e_4	3.9%	9.6%	30.8%	26.5%	29.2%
e_5	3.4%	15.1%	33%	22.1%	26.4%
e_6	8.7%	10.7%	36.4%	28.2%	16%
e_7	5.6%	13.1%	42.5%	22.1%	16.7%
e_8	9.3%	10.5%	41.7%	23.5%	15%
e_9	4%	12.1%	27.4%	28%	28.5%

4.5 Result and Discussion from Multivariate OLS Model

The result of the regression analysis is tabulated in Table 5.

Table 5: Result of Multivariate OLS Model

(1)		(2)	(3)	(4)	(5)	(6)	(7)
VARIABLES	pss_elcs	pss_elcp	pss_gassp	pss_gaspr	pss_fuelsp	pss_fuelpr	pss
urban	2.80***	0.978**	5.371***	2.535***	2.987***	2.188***	2.811***
(0.359)		(0.413)	(0.378)	(0.374)	(0.327)	(0.371)	(0.267)
division_ code_bar	4.85***	0.642	3.808***	1.885**	5.805***	4.974***	3.660***
	(0.712)	(0.788)	(0.691)	(0.831)	(0.753)	(0.709)	(0.516)
division_ code_ctg	4.25***	-0.0671	2.432***	0.584	4.163***	3.555***	2.486***
	(0.495)	(0.582)	(0.508)	(0.538)	(0.396)	(0.457)	(0.340)
division_ code_khl	5.18***	3.120***	1.819***	3.494***	2.805***	7.445***	3.978***
	(0.896)	(0.982)	(0.692)	(0.970)	(0.612)	(0.951)	(0.663)
division_ code_mym	1.87***	-1.060*	-1.088*	-1.625**	0.521	0.108	-0.213
	(0.567)	(0.614)	(0.620)	(0.655)	(0.492)	(0.583)	(0.445)
division_ code_raj	0.857	-3.562***	-1.239*	-2.846***	-0.628	-0.642	-1.343**
	(0.680)	(0.798)	(0.747)	(0.706)	(0.687)	(0.762)	(0.557)
division_ code_rang	7.05***	2.959***	6.409***	3.112***	7.010***	7.106***	5.607***
	(0.635)	(0.761)	(0.593)	(0.655)	(0.572)	(0.720)	(0.459)
division_ code_syl	4.95***	0.857	4.719***	2.162**	6.493***	5.981***	4.194***
(0.767)		(0.906)	(0.746)	(0.839)	(0.712)	(0.801)	(0.631)
a_5	-1.195	-1.253	-2.092**	-1.205	-1.269	-1.901*	-1.486

(1.160)		(1.372)	(0.956)	(1.350)	(0.870)	(1.032)	(0.929)
a_6	-0.0203	-0.0216	-0.0381**	-0.0139	-0.0597***	-0.0477***	-0.0336***
(0.017)		(0.0186)	(0.0156)	(0.0174)	(0.0137)	(0.0170)	(0.0124)
a_7	-0.068**	-0.000272	-0.165***	-0.0417	-0.0814***	0.0422	-0.0525**
(0.034)		(0.0391)	(0.0361)	(0.0360)	(0.0311)	(0.0370)	(0.0266)
a_8	-0.0141	0.258*	0.0263	-0.0227	0.00244	-0.0362	0.0357
(0.134)		(0.147)	(0.131)	(0.147)	(0.111)	(0.142)	(0.102)
a_9	0.0656	-0.325	-0.0965	-0.0975	0.145	-0.127	-0.0726
(0.219)		(0.247)	(0.207)	(0.234)	(0.172)	(0.217)	(0.162)
a_10_serv	-0.914**	-1.212**	-1.048**	-1.178**	-2.238***	-2.104***	-1.449***
(0.422)		(0.505)	(0.440)	(0.489)	(0.402)	(0.439)	(0.343)
a_10_ind	0.122	-0.0401	0.718	0.115	-0.803	-1.129*	-0.169
(0.613)		(0.697)	(0.682)	(0.651)	(0.619)	(0.674)	(0.474)
a_11_25k	-0.815	1.547	-2.113*	0.462	-1.327	0.386	-0.310
(1.376)		(1.450)	(1.178)	(1.441)	(0.948)	(1.323)	(1.082)
a_11_40k	-0.153	1.884	-1.618	0.804	-0.838	0.798	0.146
(1.402)		(1.464)	(1.213)	(1.460)	(0.969)	(1.342)	(1.100)
a_11_80k	-1.540	0.474	-1.394	-0.543	-1.704	-0.559	-0.878
(1.512)		(1.645)	(1.378)	(1.597)	(1.078)	(1.452)	(1.175)
a_11_a80k	-1.772	2.899	-5.056***	-2.175	-1.642	-0.127	-1.312
(2.264)		(2.746)	(1.762)	(2.639)	(1.741)	(2.053)	(1.862)
a_12	0.962**	0.293	1.296***	0.865**	2.658***	2.885***	1.493***
(0.409)		(0.453)	(0.395)	(0.421)	(0.377)	(0.488)	(0.313)
e_1	-0.63***	-0.419**	-0.775***	-0.353**	-0.542***	-0.466**	-0.532***
(0.164)		(0.175)	(0.169)	(0.176)	(0.174)	(0.184)	(0.125)
e_2	-0.214	0.681***	-0.121	0.396*	-0.375**	-0.0701	0.0496
(0.194)		(0.233)	(0.195)	(0.209)	(0.174)	(0.201)	(0.155)
e_3	0.00429	0.157	-0.428**	-0.247	-0.356**	-0.557***	-0.238*
(0.167)		(0.194)	(0.181)	(0.180)	(0.162)	(0.174)	(0.128)
e_4	0.173	0.773***	0.0240	-0.373	0.131	-0.213	0.0858
(0.198)		(0.257)	(0.208)	(0.241)	(0.191)	(0.229)	(0.155)
e_5	1.14***	0.0819	0.822***	0.861***	0.437***	1.076***	0.736***
(0.188)		(0.227)	(0.183)	(0.197)	(0.163)	(0.214)	(0.142)
e_6	0.52***	-0.323	0.918***	0.482**	1.241***	0.794***	0.605***
(0.185)		(0.223)	(0.188)	(0.189)	(0.168)	(0.203)	(0.138)
e_7	0.78***	0.681***	1.045***	0.793***	1.142***	1.005***	0.907***
(0.197)		(0.219)	(0.191)	(0.200)	(0.168)	(0.194)	(0.146)
e_8	-0.61***	-0.434**	-0.194	-0.358*	-0.395**	-0.297*	-0.381***
(0.187)		(0.210)	(0.194)	(0.188)	(0.161)	(0.174)	(0.137)
e_9	-0.59***	-0.827***	-0.870***	-0.552***	-0.784***	-0.458***	-0.681***
(0.182)		(0.207)	(0.186)	(0.194)	(0.158)	(0.174)	(0.132)
Constant	16.1***	18.55***	19.84***	18.63***	17.67***	14.87***	17.61***
(1.750)		(1.874)	(1.693)	(1.865)	(1.317)	(1.787)	(1.372)
Observations	1,000	1,000	1,000	1,000	1,000	1,000	1,000
R-squared	0.302	0.143	0.399	0.196	0.479	0.397	0.403

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

From Table 5, it can be observed that urban households consistently exhibit increased stress across various power and energy scenarios compared to sub-urban households, which serve as the baseline. The analysis of stress levels across different power and energy scenarios in Bangladesh reveals consistent regional disparities when compared to the baseline division of Dhaka. The results corroborate our earlier analysis.

Sex of the household head, represented by ‘a_5’, does not significantly or consistently impact stress levels, possibly due to lower sample size of female led households. Conversely, the age of the household head, ‘a_6’, suggests older individuals might experience lower stress levels, hinting at resilience or effective coping strategies against energy supply challenges. This occurs possibly due to a combination of more life experience, adaptability, higher income levels, and well-developed coping mechanisms, suggesting policy focus might be more effectively directed towards supporting areas predominantly inhabited by households with younger household heads. The variable ‘a_7’, representing years of education of household heads, shows a significant relationship with stress levels in various power and energy scenarios. In scenarios where its impact is significant, a higher level of education generally is inversely related to stress levels underscoring the importance of awareness and knowledge in effectively managing energy-related stress. Additionally, higher educational attainment might be linked to improved access to resources or information that can mitigate the impact of power and energy challenges.

Household size, ‘a_8’, and the presence of students, ‘a_9’, do not markedly influence stress levels. This aspect of the analysis suggests that while household size might affect other the lifestyle of a household, the composition of the household does not distinctly sway perceptions or experiences of stress concerning power and energy issues. Households' primary income sources influence their stress levels regarding power and energy, with service sector (a_10_serv) employment linked to lower stress compared to agriculture or industry (a_10_ind). This highlights the varied effects of job stability on households' stress experiences regarding energy issues.

Income levels do not display a clear pattern of influence on stress levels, suggesting a complex interplay of factors beyond financial status in shaping energy-related stress, with the baseline being an income below BDT 10,000. However, higher-income households, particularly those earning above BDT 80,000 (a_11_a80k), show a unique negative association with stress levels regarding gas supply, possibly due to the fact that these higher-income households often reside in affluent areas with better infrastructure and resource allocation, ensuring more consistent energy supplies and possibly prioritizing them in supply distribution, thereby reducing their susceptibility to general supply disruptions. An intriguing observation reveals that stress levels linked to the price of electricity, gas, and fuel oil remain consistent across all income brackets, indicating a widespread and uniform concern over power and energy expenses among households, regardless of their economic standing.

Vehicle ownership (a_12) within households correlates with increased stress, reflecting the additional energy demands and heightened awareness of energy costs and supply issues such as availability, reliance on consistent energy supplies for transportation needs. The presence of vehicles in a household may also reflect a lifestyle with greater dependence on energy resources, thereby making these households more sensitive to disruptions or changes in the energy sector and policies must be designed by keeping this factor in account as well.

Our analysis of environmental and political opinion variables ('e_1' through 'e_9') reveals a nuanced relationship between individual beliefs, awareness, and stress levels in power and energy scenarios. Households acknowledging the impact of environmental pollution on climate change ('e_1') tend to experience less stress level, likely due to a deeper understanding of environmental implications on energy and power crisis. Those attributing primary responsibility for climate action to international organizations ('e_2') or the government ('e_3') show varied stress levels, possibly reflecting their perceptions of global vs. local agency in addressing energy and environmental challenges. Households believing international organizations are chiefly responsible for addressing climate change exhibit increased stress related to electricity pricing, likely due to their awareness of future uncertainties in this area. Households attributing primary responsibility for climate action to the government exhibit lower stress levels in fuel oil pricing and supply scenarios, as well as gas supply issues. This pattern suggests that expectations of governmental efficacy in environmental management can significantly shape stress responses to power and energy challenges. Hence, enhancing government transparency, responsibility, and practicality in policy formulation and execution becomes imperative.

Beliefs in the indispensability of nuclear ('e_4') and renewable energy ('e_5') for resolving the energy crisis similarly influence stress levels, highlighting the role of individual views in ensuring energy sustainability and security in stress experiences. Households viewing nuclear energy as key to solving the energy crisis report higher stress regarding electricity pricing, underscoring their anticipation of pricing stability through increased electricity supply. Households prioritizing renewable energy may experience increased stress in almost every scenario. This could be due to concerns about the current energy mix's sustainability and the urgency of transitioning to greener energy sources. Households believing Bangladesh is ready for nuclear energy ('e_6') face higher stress across most energy and power crisis scenarios, suggesting an urgent desire for transitioning to stable, alternative energy sources and reflecting their perception of nuclear energy as a feasible and safe option.

Skepticism towards media portrayal of the energy crisis ('e_7') and willingness to accept nuclear power plants nearby ('e_8') or to reduce energy and power consumption for environmental reasons ('e_9') also correlate with stress levels, indicating how personal proximity to energy solutions, media perceptions, and environmental consciousness shape stress responses. Our analysis shows that skepticism towards media reports often increases stress, likely due to feelings of being misinformed about energy issues. Conversely, households open to nearby nuclear facilities generally experience less stress in various crisis scenarios, indicating a broader acceptance of nuclear energy as a feasible solution. Additionally, households willing to cut energy consumption for environmental reasons report lower stress levels, suggesting that a strong environmental consciousness contributes to a more resilient attitude towards energy crises.

Our outcomes further demonstrate that higher environmental consciousness correlates with lower stress levels across all scenarios, underscoring the value of promoting environmental education at the household level to alleviate stress and enhance energy conservation in Bangladesh's power sector, which is consistent with previous literature in Bangladesh (Moazzem & Quaiyyum, 2024)..

4.6 Results and Discussions from Random Forest Model

The table 6 presents the R^2 values and MSE (mean squared error) associated with the fitted values obtained from the Random Forest model:

Table 4: R^2 values and MSE from Random Forest Models

Dependent Variables	R^2 Values	MSE
pss_elcs	0.56	15.82
pss_elcp	0.423	24.14
pss_gassp	0.65	16.23
pss_gaspr	0.51	19.12
pss_fuelsp	0.66	12.95
pss_fuelpr	0.61	17.8
pss	0.7	7.95

The analysis of Random Forest models applied to stress levels across various power and energy crisis scenarios reveals a high effectiveness in explaining the variance in stress, with R^2 values indicating a substantial explanation of the variance and generally moderate to low MSE values highlighting the models' accuracy. Overall, these models exhibit strong predictive power, effectively capturing the underlying factors influencing perceived stress in different energy and power crisis contexts. Despite their robust performance, a notable portion of variance in stress levels remains unexplained, suggesting room for further model refinement and investigation into additional explanatory variables.

Table 5: Top 10 Key Features Influencing Stress Scores in Various Scenarios (From Most Important to Less Important)[5]

Rank	pss_elcs	pss_elcp	pss_gassp	pss_gaspr	pss_fuelsp	pss_fuelpr	pss
1	a_6 (0.0769)	a_6 (0.1)	urban (0.105)	e_5 (0.09)	e_6 (0.09)	e_6 (0.09)	division_ code_khl (0.0692)
2	e_5 (0.0767)	e_6 (0.08)	e_6 (0.101)	a_6 (0.084)	e_7 (0.08)	a_12 (0.086)	e_7 (0.0691)

[5] The importance score of each feature is presented in the parenthesis.

3	e_7 (0.072)	a_7 (0.07)	e_1 (0.1)	a_7 (0.079)	e_1 (0.071)	division_ code_khl (0.08)	e_6 (0.067)
4	division_ code_khl (0.0718)	e_5 (0.066)	e_7 (0.07)	e_6 (0.07)	a_12 (0.065)	e_2 (0.079)	division_ code_raj (0.066)
5	e_2 (0.067)	e_9 (0.0652)	a_12 (0.063)	e_4 (0.062)	e_2 (0.062)	e_5 (0.069)	a_6 (0.065)
6	a_7 (0.058)	e_2 (0.0634)	e_2 (0.061)	e_8 (0.058)	division_ code_raj (0.058)	a_6 (0.065)	a_7 (0.059)
7	e_6 (0.056)	e_4 (0.057)	a_7 (0.055)	e_9 (0.056)	a_6 (0.057)	e_7 (0.064)	e_9 (0.053)
8	e_9 (0.056)	division_ code_khl (0.051)	a_6 (0.048)	e_2 (0.051)	urban (0.048)	a_7 (0.053)	e_5 (0.05)
9	e_8 (0.054)	e_8 (0.05)	e_8 (0.045)	division_ code_khl (0.0497)	a_7 (0.047)	e_4 (0.042)	division_ code_rang (0.0512)
10	e_1 (0.048)	e_7 (0.045)	e_5 (0.039)	a_8 (0.0493)	e_8 (0.046)	e_9 (0.038)	e_4 (0.05)

Age of the household head (‘a_6’) emerges as a consistently influential factor, indicating a demographic sensitivity across various scenarios including the supply and pricing of electricity, and the pricing of gas and fuel oil.

Urban residency (‘urban’) is highlighted as a key determinant in the supply of gas (‘pss_gassp’), reflecting the unique challenges faced by urban households in terms of gas availability. Yet, its influence appears less pronounced in electricity and fuel oil scenarios, suggesting that the urban stress response is particularly acute when it comes to gas supply. The regional factor is another significant influencer of stress levels, especially prominent in shaping the overall power and energy stress scenario (‘pss’).

Perception-based features, especially regarding renewable energy (‘e_5’) and the readiness for nuclear energy (‘e_6’), feature heavily across the board, underscoring a significant link between personal beliefs about energy and power related stress. The recurring importance of household’s perceptions in readiness for nuclear energy in the pricing scenarios signifies a strong connection between stress level associated with power and energy challenges, and views on nuclear energy as a solution.

Economic status, reflected through various income brackets, and educational levels (‘a_7’), while varying in their ranking, indicate the nuanced influence of socioeconomic status on perceived energy stress. The fluctuating positions of these socioeconomic variables reflect the complex ways in which financial stability and knowledge levels intersect with energy stress perceptions. Further research is necessary to capture the whole inter-dynamics of these two factors.

Synthesizing these insights, it can be observed that demographic characteristics, urban versus rural residency, economic standing, educational attainment, and personal beliefs about energy policies, environment and politics collectively shape the stress landscape in relation to energy supply and pricing. The consistent patterns observed within related supply and pricing scenarios of the same energy type suggest that there are shared factors contributing to the stress levels across various scenarios, each exerting its influence to varying degrees depending on the scenario. The outcomes from random forest models are consistent with those of OLS models, which strengthens the robustness of our analyses.

4.7 Results and Discussion from Ordered Probit Model

In Appendix G, Table G.1, we present the ordered probit model results. The primary interest of our study is on the marginal effects of variables on the probability of transitioning between stress ranges.

In Appendix G, Tables ranging from G.2 to G.7 reveal that urban residency, compared to sub-urban, significantly affects stress levels associated with all power and energy crisis, with urban households more likely to experience higher stress range. Moreover, consistent with our past two models, regional disparities are significantly present.

From Table G.2 and G.3, it can be observed that households with service-based incomes are more likely to experience lower stress compared to those reliant on agriculture, particularly in electricity supply issues, and tend to fall within the lower to moderate stress range for electricity pricing scenarios. Meanwhile, economic factors across different income brackets (‘a_11_25k’, ‘a_11_40k’, ‘a_11_80k’, ‘a_11_a80k’) are not consistently significant, indicating that income level is not a major differentiator in stress levels associated with electricity supply and price incidents, within the ranges considered. Environmental and political opinions significantly affect stress levels related to electricity supply and pricing. Beliefs in the impact of environmental pollution on climate change (‘e_1’), alongside a willingness to have a nuclear power plant nearby (‘e_8’) and to reduce power consumption (‘e_9’), correlate with higher probability of lower stress levels for electricity supply. In contrast, views on international and governmental responsibility for climate change, the necessity of nuclear energy (‘e_4’), and media exaggeration of the energy crisis (‘e_7’) are linked to higher probability of lower stress levels concerning electricity pricing. However, other significant variables demonstrate an opposite effect, highlighting the complex interplay between environmental and policy beliefs and their impact on stress perceptions within the electricity sector.

Our analysis illustrated in Table G.4 and Table G.5 uncovers that the service sector as the primary source of income, when compared to agriculture, shows an increased likelihood of being in the lower stress range, reflecting perhaps a greater ability of households in this sector to absorb or offset the stress caused by gas supply and gas prices. Households earning above BDT 10,000, especially those with incomes over BDT 80,000, show less stress from gas supply issues, suggesting higher income acts as a stress buffer. Yet, income's impact on stress from gas pricing is minimal across brackets, indicating income beyond a threshold doesn't significantly affect stress levels. Environmental and political opinions also play a role; for example, environmental awareness, seen in pollution concerns (‘e_1’) and a readiness to cut energy use for fighting climate change (‘e_9’), correlates with a lower chance of high stress from gas supply issues. Similarly, pollution concerns and skepticism about media portrayals (‘e_7’) link to a higher likelihood of increased stress from gas pricing, highlighting the nuanced impact of environmental consciousness on stress responses to gas-related issues. The other significant relevant opinions of households follow an opposite trend.

Our analysis, as detailed in Tables G.6 and G.7 (Appendix G), reveals that the primary source of income being in the service sector (a_10_serv), as opposed to agriculture, lowers the chance of experiencing higher stress, suggesting agricultural workers may be more impacted by fuel oil supply and prices. Income levels, especially in the highest bracket (a_11_a80k), do not show a consistent influence on stress levels from fuel oil prices, indicating that income is not a straightforward predictor of stress from fuel oil costs. Owning a vehicle (a_12) significantly raises the likelihood of higher stress levels due to fuel oil prices, reflecting the direct impact of fuel oil costs on households with transportation needs. Environmental and political views, such as skepticism towards the media’s portrayal of the energy crisis (‘e_7’) and belief in the necessity of nuclear energy (‘e_6’), are linked to increased stress levels, underscoring how perceptions of energy sources and media influence stress responses to fuel supply issues. The notable negative impact of renewable energy advocacy (‘e_5’), support for nuclear energy (‘e_6’), and media skepticism (‘e_7’) on the lowest stress range from gas pricing illustrates how perceptions of media exaggeration are correlated with heightened stress about gas prices. Contrastingly, other significant household opinions exhibit an inverse pattern.

Table G.8 illustrates into how different factors influence the probability of a household's stress level transitioning between ranges in the context of the overall power and energy crisis. Regional disparities are evident in the power and energy crisis response, with Rangpur experiencing the highest stress levels, underscoring stark differences across divisions compared to Dhaka. Socio-economic factors such as the primary source of income also play a role. Households with service as their primary income source (a_10_serv), as opposed to agriculture, show a higher probability of being in a lower stress range, suggesting that those engaged in the service sector may be less affected by energy and power crises. Meanwhile, income levels above the baseline (below BDT 10,000) do not significantly influence the probability of being in different stress ranges, except for the highest income bracket (a_11_a80k), which displays a trend towards decreased stress, although not statistically significant. Environmental and political opinions are also influential. Households that agree with statements highlighting concerns over environmental issues (e_1, e_5, e_7, and e_9) show varying probabilities of transitioning between stress ranges, indicating that environmental consciousness correlates with stress levels concerning the energy crisis. Specifically, households concerned about environmental pollution and its effects on climate (e_1) and those willing to reduce energy consumption for environmental protection (e_9) are less likely to be in the lowest stress range.

5.0 Conclusion and Policy Implications

In conclusion, this study represents a pioneering approach to policy analysis by delving into the nuanced experiences of households amid a power and energy crisis. By adapting the Perceived Stress Scale-10 (PSS-10) to specific scenarios, we have uncovered a new dimension of understanding, directly engaging with the lived realities and the psychological burden borne by households. This methodology does not merely quantify the crisis's impact but also captures the human response to the policy environment and infrastructure challenges.

Major policy implications from our analysis include the following: Firstly, urban households, which suffer more during power and energy crises due to their high dependence on these resources and reduced resilience from lifestyle factors and higher temperatures, should be addressed urgently in times of crisis. Rural and suburban households should be included in long-term sustainable planning. Secondly, policy designs need to consider regional differences in stress levels to effectively target areas most in need. Thirdly, urgent attention should be given to urban areas with a high concentration of lower-income households. Fourthly, regions with a younger population and household heads should be prioritized for interventions. Finally, our findings indicate that households with a higher awareness of climate and environmental issues experience lower stress levels. Therefore, promoting environmental education and encouraging self-sufficient energy practices through incentive-based policies are essential for helping communities manage stress and enhance resilience during energy crises.

This study opens the door to a more empathetic and targeted policy-making process, where the subjective experiences of households can inform more effective and humane responses to energy challenges. However, there remains ample room for expansion and further refinement. Future research could integrate household power and energy consumption behavior to provide a more detailed picture of the stress dynamics at play. Such an approach would allow us to see not only how households are affected by the crisis but also how their behavior and decisions may contribute to or alleviate their stress levels.

The integration of behavioral insights into policymaking, particularly in the energy sector, marks a significant step forward. It emphasizes the need for a holistic approach that considers not just the economic or technical aspects but also the psychological well-being of the populations affected. In doing so, we pave the way for more compassionate and effective interventions that recognize the full spectrum of challenges faced by households in times of crisis.

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Due to the sensitive nature of the questions (household identifier information) asked in this study, survey respondents were assured raw data would remain confidential, would not be shared in public and would not be used in other purpose except for research.

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Appendix

Appendix A: Sample Distribution

Table A.1: Sample Distribution

Division Name	Sub-district Name[6]	Number of Samples
Barishal	Talhati (23.9)	13
	Banaripara (21.7)	13
	Bhola Sadar (15)	14
	Mathbaria (28.6)	14
Total		**54**
Chattogram	Halishahar (8.7)	37
	Chandpur Sadar (21.6)	37
	Bijoynagar (12.4)	37
	Muradnagar (26.2)	37
	Companiganj (23.1)	36
Total		**184**
Dhaka	Khilgaon (18.6)	40
	Kapasia (13.6)	41
	Madaripur Sadar (3.2)	40
	Roypura (15.9)	41
	Ghatail (20.5)	41
	Adabor (28.6)	40
	Belabo (13.2)	41
Total		**284**
Khulna	Kachua (22.5)	28
	Kalia (16.5)	28
	Khulna Sadar (28.6)	27
	Kaliganj (14)	27
Total		**110**
Mymensingh	Mymensingh Sadar (27.4)	19
	Bhaluka (15.5)	18
	Nakla (35.3)	18
	Jamalpur Sadar (49.3)	19
Total		**74**
Rajshahi	Kahaloo (17.1)	33
	Kalai (21.5)	32
	Matihar (17.4)	33
	Sirajganj Sadar	32
Total		**130**
Rangpur	Dinajpur Sadar (64.1)	28
	Kaliganj (36.9)	27
	Debiganj (17.8)	28
	Taraganj (38.1)	27
Total		**110**
Sylhet	Jagannathpur (22.6)	14
	Nabiganj (16.9)	13
	Barlekha (10.4)	14
	Fenchuganj (19)	13
Total		**54**
Total Sample		**1000**

[6] In parentheses, headcount ratio of upper poverty level is illustrated from HIES-2016.

Appendix B: Variable Description

Table B.1: Explanation of the variables

Variable	Explanation
urban*	This variable indicates whether the households surveyed fall in urban neighborhoods or sub-urban neighborhoods. By the precondition of gas and electricity availability in the households, the rural households are not included. If urban = 0, it means sub-urban, and if urban= 1, otherwise.
division_code _bar*	Division code: Barisal. If division_code_bar = 1, it indicates Barisal, or otherwise.
division_code _ctg*	Division code: Chattogram. If division_code_ctg = 1, it indicates Chattogram, or otherwise.
division_code _khl*	Division code: Khulna. If division_code_khl = 1, it indicates Khulna, or otherwise.
division_code _mym*	Division code: Mymensingh. If division_code_mym = 1, it indicates Mymensingh, or otherwise.
division_code _raj*	Division code: Rajshahi. If division_code_raj = 1, it indicates Rajshahi, or otherwise.
division_code _rang*	Division code: Rangpur. If division_code_rang = 1, it indicates Rangpur, or otherwise.
division_code _syl*	Division code: Sylhet. If division_code_syl = 1, it indicates Sylhet, or otherwise.
a_5*	Sex of the household head. If a_5 = 0, then the household head is male. If a_5 = 1, the household head is female.
a_10_serv*	Household's primary source of income: Service. If a_10_serv = 1, then the household's primary source of income is service sector, or, if a_10_serv = 0, otherwise.
a_10_ind*	Household's primary source of income: Industry. If a_10_ind = 1, then the household's primary source of income is industry sector, or, if a_10_ind = 0, otherwise.
a_11_25k*	Household's monthly income: BDT 10,000 to BDT 24,999. If a_11_25k = 1, then household's monthly income falls in the range of BDT 10,000 to BDT 24,999. If a_11_25k = 0, otherwise.
a_11_40k*	Household's monthly income: BDT 25,000 to BDT 39,999. If a_11_40k = 1, then household's monthly income falls in the range of BDT 25,000 to BDT 39,999. If a_11_40k = 0, otherwise.

a_11_80k*	Household's monthly income: BDT 40,000 to BDT 79,999. If a_11_80k = 1, then household's monthly income falls in the range of BDT 40,000 to BDT 79,999. If a_11_80k = 0, otherwise.
a_11_a80k*	Household's monthly income: above BDT 80,000. If a_11_a80k = 1, then household's monthly income falls in the category of households with income above BDT 80,000. If a_11_a80k, otherwise.
e_1	Statement: Environmental pollution has adverse effects on weather and climate change.
e_2	Statement: International organizations are mainly responsible for fighting climate change.
e_3	Statement: Government and relevant authorities are mainly responsible for fighting climate change.
e_4	Statement: Without nuclear energy, energy crisis will not resolve.
e_5	Statement: Without renewable energy, energy crisis will not resolve.
e_6	Statement: Bangladesh is ready for nuclear energy production.
e_7	Statement: The media is overexaggerating the crisis.
e_8	Statement: The respondent has no problem in establishing a nuclear power plant in the neighbourhood.
e_9	Statement: The household is prepared to reduce power and energy consumption to save environment and climate.

Appendix C: Shapiro-Wilk W test for normal data

Table C.1: Shapiro-Wilk W test for normal data

Variable	Observation	W	V	z	Prob>z
e_1	1,000	0.9688	19.676	7.378	0.000***
e_2	1,000	0.98526	9.295	5.521	0.000***
e_3	1,000	0.98881	7.055	4.838	0.000***
e_4	1,000	0.99618	2.411	2.18	0.014***
e_5	1,000	0.99656	2.172	1.921	0.027***
e_6	1,000	0.99493	3.201	2.881	0.002***
e_7	1,000	0.9984	1.007	0.017	0.500
e_8	1,000	0.9966	2.146	1.891	0.029***
e_9	1,000	0.99567	2.732	2.489	0.006***

**** Variables that are not normally distributed*

Appendix D: Internal Consistency Test of Variables Associated with Environmental and Political Opinions (e-variables: e_1, e_2, e_3, e_4, e_5, e_6, e_7, e_8, e_9)

Table D.1: Internal Consistency Test of E-values

Average interitem covariance:	0.273498
Number of items in the scale:	9
Scale reliability coefficient:	0.7225

Appendix E: Internal Consistency Test of PSS-10 Values Associated with Power and Energy Crisis Scenarios

Table E.1: Internal Consistency Test for PSS-10 values

Variable Name	Average interitem covariance	Number of items in the scale	Scale reliability coefficient
pss_elcs	0.51428	10	0.8368
pss_elcp	0.608461	10	0.8677
pss_gassp	0.843214	10	0.894
pss_gaspr	0.60014	10	0.8627
pss_fuelsp	1.101739	10	0.9252
pss_fuelpr	1.24061	10	0.9248
pss	22.15277	6	0.877

Appendix F: Econometric Test

Table F.1: Pairwise Correlation test for Multicollinearity (Part-1)

	urban	division_ code_bar	division_ code_ctg	division_ code_khl	division_ code_mym	division_ code_raj	division_ code_rang
urban	1.00						
division_ code_bar	-0.05	1.00					
division_ code_ctg	0.04	-0.11	1.00				
division_ code_khl	-0.09	-0.08	-0.17	1.00			
division_ code_mym	0.09	-0.07	-0.13	-0.10	1.00		
division_	0.11	-0.09	-0.18	-0.14	-0.11	1.00	

code_raj							
division_ code_rang	-0.08	-0.08	-0.17	-0.12	-0.10	-0.14	1.00
division_ code_syl	-0.18	-0.06	-0.11	-0.08	-0.07	-0.09	-0.08
a_5	-0.02	-0.03	0.00	0.07	0.00	-0.02	-0.07
a_6	0.01	0.00	0.02	-0.02	0.06	-0.14	0.01
a_7	0.06	0.10	-0.16	0.02	-0.04	0.20	0.14
a_8	-0.17	0.04	0.17	-0.02	-0.02	-0.22	-0.01
a_9	-0.10	-0.03	0.11	-0.10	0.03	-0.19	0.01
a_10_serv	0.01	0.09	-0.04	-0.11	0.08	-0.18	0.06
a_10_ind	0.16	-0.04	0.01	0.06	-0.05	0.11	-0.04
a_11_25k	-0.03	-0.09	-0.10	0.04	0.09	-0.16	0.19
a_11_40k	0.02	0.09	0.09	-0.02	-0.03	0.16	-0.12
a_11_80k	-0.01	0.02	0.04	-0.06	-0.07	-0.01	-0.11
a_11_a80k	0.05	-0.02	0.07	-0.03	-0.03	-0.03	-0.03
a_12	-0.04	0.02	-0.22	0.01	0.05	0.05	0.39
e_1	-0.05	-0.24	-0.07	0.11	-0.11	0.11	0.04
e_2	-0.13	-0.04	-0.05	0.03	-0.03	0.06	0.06
e_3	-0.09	-0.20	-0.07	0.18	-0.06	0.12	-0.03
e_4	-0.11	-0.02	0.01	-0.23	0.02	0.20	-0.10
e_5	0.03	-0.05	0.08	-0.09	0.02	0.18	-0.09
e_6	-0.01	-0.02	0.05	0.19	0.09	0.01	-0.07
e_7	0.01	-0.16	0.03	-0.05	0.07	0.20	0.03
e_8	0.00	0.05	0.00	0.00	0.03	0.06	0.00
e_9	-0.06	0.04	-0.02	-0.03	-0.05	0.09	0.10

Table F.2: Pairwise Correlation test for Multicollinearity (Part-2)

	division_ code_syl	a_5	a_6	a_7	a_8	a_9	a_10_serv
division_ code_syl	1.00						
a_5	-0.05	1.00					
a_6	-0.07	0.06	1.00				
a_7	-0.10	-0.08	-0.07	1.00			

a_8	0.20	-0.05	0.15	-0.13	1.00		
a_9	0.24	-0.02	0.13	-0.03	0.58	1.00	
a_10_serv	-0.02	-0.02	-0.02	0.20	-0.01	-0.03	1.00
a_10_ind	-0.01	0.02	0.03	-0.01	0.00	0.02	-0.50
a_11_25k	0.03	0.05	-0.07	-0.30	-0.12	-0.12	-0.03
a_11_40k	-0.01	-0.06	0.00	0.18	0.07	0.07	0.04
a_11_80k	-0.02	-0.02	0.09	0.19	0.11	0.12	0.06
a_11_a80k	-0.02	-0.02	0.01	0.00	0.02	-0.01	0.01
a_12	-0.03	-0.13	-0.02	0.15	-0.02	0.01	0.08
e_1	0.01	0.02	0.10	0.12	-0.06	-0.06	0.04
e_2	-0.04	0.03	-0.09	0.10	0.00	-0.02	0.08
e_3	-0.05	0.03	-0.01	0.10	-0.02	-0.06	0.03
e_4	0.05	-0.01	-0.07	0.02	0.01	0.04	-0.04
e_5	0.06	0.04	0.01	0.04	0.01	-0.01	-0.08
e_6	-0.04	0.03	-0.08	-0.06	0.02	-0.06	-0.11
e_7	-0.11	0.00	-0.09	0.00	-0.07	-0.08	-0.09
e_8	0.13	-0.01	-0.11	-0.07	0.00	-0.01	0.07
e_9	0.09	0.00	0.00	0.06	-0.02	-0.02	0.04

Table F.3: Pairwise Correlation test for Multicollinearity (Part-3)

	a_10_ind	a_11_25k	a_11_40k	a_11_80k	a_11_a80k	a_12	e_1
a_10_ind	1.00						
a_11_25k	-0.04	1.00					
a_11_40k	0.02	-0.74	1.00				
a_11_80k	0.01	-0.36	-0.28	1.00			
a_11_a80k	0.05	-0.09	-0.07	-0.03	1.00		
a_12	-0.03	-0.04	0.01	0.05	-0.04	1.00	
e_1	-0.01	-0.01	-0.02	0.05	0.01	-0.05	1.00
e_2	-0.07	-0.02	-0.02	0.07	-0.04	0.10	0.22
e_3	-0.05	-0.07	0.02	0.08	-0.06	-0.01	0.47
e_4	-0.02	-0.12	0.10	0.06	-0.06	0.01	0.24
e_5	0.02	-0.12	0.06	0.08	0.01	0.03	0.29
e_6	0.05	0.03	0.00	-0.01	-0.02	0.04	0.02
e_7	-0.01	-0.01	0.04	-0.04	-0.05	0.07	0.14
e_8	-0.10	0.04	0.03	-0.08	-0.04	0.00	0.14

e_9	-0.06	0.01	0.00	-0.02	-0.03	0.04	0.25

Table F.4: Pairwise Correlation test for Multicollinearity (Part-4)

e_2		e_3	e_4	e_5	e_6	e_7	e_8	e_9
e_2	1							
e_3	0.3632	1						
e_4	0.3854	0.2955	1					
e_5	0.1797	0.2581	0.3736	1				
e_6	0.1829	0.1107	0.1249	0.1853	1			
e_7	0.2578	0.2669	0.285	0.2701	0.1703	1		
e_8	0.1831	0.1244	0.1775	0.1496	0.1897	0.0967	1	
e_9	0.2974	0.2011	0.1977	0.3972	0.0969	0.2274	0.2698	1

Table F.5: Breusch-Pagan test for heteroskedasticity

Variables: fitted values pss_elcs			Variables: fitted values pss_fuelsp		
chi2(1)	=	100.01	chi2(1)	=	107.07
Prob > chi2 =		0.0000	Prob > chi2 =		0.0000
Variables: fitted values of pss_elcp			Variables: fitted values of pss_fuelsp		
chi2(1)	=	11.88	chi2(1)	=	35.90
Prob > chi2 =		0.0006	Prob > chi2 =		0.0000
Variables: fitted values of pss_gassp			Variables: fitted values of pss		
chi2(1)	=	81.85	chi2(1)	=	134.97
Prob > chi2 =		0.0000	Prob > chi2 =		0.0000
Variables: fitted values of pss_gaspr					
chi2(1)	=	58.74			
Prob > chi2 =		0.0000			

Appendix G: Results from Ordered Probit Model

Regression Results

Table G.1: Regression Results from Ordered Probit Model

(1) VARIABLES _rng	pss_elcs	(2) pss_elcp _rng	(3) pss_gassp _rng	(4) pss_gaspr _rng	(5) pss_fuelsp _rng	(6) pss_fuelpr _rng	(7) pss_rng
urban	0.735***	0.252***	1.466***	0.750***	0.822***	0.475***	1.145***
(0.108)		(0.0886)	(0.143)	(0.0971)	(0.136)	(0.0939)	(0.133)
division_code_ bar	1.042***	0.0895	0.932***	0.611***	1.237***	0.537***	1.298***

	(0.199)	(0.135)	(0.165)	(0.194)	(0.373)	(0.188)	(0.166)
division_code_ctg	0.792***	-0.0144	0.390***	-0.0182	1.229***	0.674***	0.921***
	(0.127)	(0.110)	(0.143)	(0.121)	(0.209)	(0.108)	(0.121)
division_code_khl	1.082***	0.530***	-0.109	0.412*	0.378	1.025***	1.635***
	(0.223)	(0.193)	(0.190)	(0.212)	(0.231)	(0.219)	(0.247)
division_code_mym	0.635***	-0.203*	-0.0137	-0.234	0.838***	0.439***	0.432**
	(0.153)	(0.123)	(0.209)	(0.149)	(0.223)	(0.138)	(0.200)
division_code_raj	-0.449**	-1.049***	-0.817***	-1.094***	-1.174***	-0.943***	-1.144***
	(0.178)	(0.170)	(0.212)	(0.170)	(0.212)	(0.177)	(0.183)
division_code_rang	1.715***	0.814***	1.334***	0.790***	2.398***	1.023***	2.033***
	(0.186)	(0.174)	(0.193)	(0.185)	(0.336)	(0.224)	(0.215)
division_code_syl	0.871***	-0.175	0.613***	0.0803	0.996***	0.407**	0.833***
(0.210)		(0.175)	(0.222)	(0.179)	(0.287)	(0.200)	(0.263)
a_5	-0.341	-0.413*	-0.619***	-0.390	-0.300	-0.418*	-0.402
(0.268)		(0.237)	(0.188)	(0.270)	(0.333)	(0.225)	(0.297)
a_6	-0.00919*	-0.00574	-0.0115**	-0.00354	-0.0225***	-0.00824*	-0.00759
(0.00473)		(0.00416)	(0.00471)	(0.00437)	(0.00552)	(0.00437)	(0.00576)
a_7	-0.0108	-0.00435	-0.0376***	0.00196	-0.0364***	0.0111	0.00146
(0.00938)		(0.00846)	(0.0113)	(0.00885)	(0.0129)	(0.00956)	(0.0116)
a_8	0.00356	0.0400	-0.0414	0.00588	-0.0115	-0.0110	0.0201
(0.0340)		(0.0307)	(0.0344)	(0.0331)	(0.0462)	(0.0345)	(0.0452)
a_9	-0.0328	-0.0431	0.0158	0.00673	0.0992	0.00743	-0.0255
(0.0546)		(0.0518)	(0.0554)	(0.0551)	(0.0680)	(0.0524)	(0.0686)
a_10_serv	-0.227*	-0.296***	-0.334***	-0.303**	-0.869***	-0.378***	-0.440***
(0.121)		(0.113)	(0.123)	(0.123)	(0.191)	(0.116)	(0.135)
a_10_ind	-0.0325	0.118	0.256	0.0510	-0.344	-0.216	-0.107
(0.196)		(0.167)	(0.218)	(0.176)	(0.302)	(0.169)	(0.195)
a_11_25k	-0.465	0.160	-0.725*	-0.176	-0.627*	-0.0297	-0.170
(0.381)		(0.319)	(0.420)	(0.359)	(0.352)	(0.295)	(0.415)
a_11_40k	-0.243	0.222	-0.484	-0.0399	-0.216	0.121	-0.00946
(0.388)		(0.324)	(0.432)	(0.366)	(0.344)	(0.299)	(0.422)
a_11_80k	-0.612	0.0503	-0.496	-0.421	-0.559	-0.367	-0.380
(0.404)		(0.350)	(0.468)	(0.389)	(0.379)	(0.318)	(0.440)
a_11_a80k	-0.916	0.555	-1.417**	-0.707	0.294	-0.534	-0.922
(0.617)		(0.797)	(0.626)	(0.553)	(0.788)	(0.492)	(0.716)
a_12	0.257**	0.0721	0.179	0.184*	0.914***	0.688***	0.315**
(0.113)		(0.0962)	(0.121)	(0.104)	(0.163)	(0.126)	(0.135)
e_1	-0.172***	-0.0791**	-0.182***	-0.0877**	-0.420***	-0.0664	-0.231***
(0.0531)		(0.0392)	(0.0595)	(0.0435)	(0.0996)	(0.0439)	(0.0498)
e_2	-0.0657	0.133***	-0.0262	0.0746	-0.201***	-0.0421	-0.0470
(0.0499)		(0.0472)	(0.0543)	(0.0461)	(0.0638)	(0.0482)	(0.0558)
e_3	-0.00145	0.0822*	-0.0495	-0.00443	0.00230	-0.0630	-0.0510
(0.0465)		(0.0437)	(0.0593)	(0.0447)	(0.0639)	(0.0457)	(0.0499)
e_4	0.0454	0.179***	-0.0734	-0.0788	0.0525	-0.0222	0.000953
(0.0501)		(0.0522)	(0.0571)	(0.0545)	(0.0602)	(0.0556)	(0.0580)
e_5	0.276***	-0.0141	0.145***	0.181***	0.103*	0.198***	0.375***
(0.0485)		(0.0466)	(0.0514)	(0.0473)	(0.0614)	(0.0556)	(0.0582)
e_6	0.136***	-0.141***	0.175***	0.0578	0.417***	0.144***	0.119**
(0.0478)		(0.0446)	(0.0496)	(0.0454)	(0.0595)	(0.0490)	(0.0491)
e_7	0.129**	0.108**	0.187***	0.210***	0.302***	0.199***	0.339***
(0.0521)		(0.0446)	(0.0565)	(0.0481)	(0.0761)	(0.0470)	(0.0522)
e_8	-0.207***	-0.105**	-0.0310	-0.0629	-0.159***	-0.0976**	-0.112**
(0.0458)		(0.0420)	(0.0486)	(0.0436)	(0.0593)	(0.0410)	(0.0487)
e_9	-0.0948*	-0.157***	-0.223***	-0.146***	-0.272***	-0.121***	-0.257***

(0.0490)		(0.0416)	(0.0517)	(0.0465)	(0.0626)	(0.0429)	(0.0497)
/cut1	-1.533***	-1.490***	-3.118***	-1.235***	-4.016***	-0.863**	-1.238**
(0.524)		(0.425)	(0.585)	(0.462)	(0.585)	(0.418)	(0.610)
/cut2	1.865***	1.333***	0.782	1.853***	1.474**	2.344***	3.311***
(0.526)		(0.428)	(0.579)	(0.468)	(0.577)	(0.418)	(0.628)
Observations	1,000	1,000	1,000	1,000	1,000	1,000	1,000

Robust Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Marginal Effects

Table G.2: Marginal Effects from the Ordered Probit Model (Scenario: Supply of Electricity)

Variables	Prob (pss_elcs_rng = 1)		Prob (pss_elcs_rng = 2)		Prob (pss_elcs_rng = 3)	
	Mg. Eff.	(P-Val.)	Mg. Eff.	(P-Val.)	Mg. Eff.	(P-Val.)
urban	-0.13	0.00	0.06	0.00	0.07	0.00
division_code_bar	-0.18	0.00	0.09	0.00	0.09	0.00
division_code_ctg	-0.14	0.00	0.07	0.00	0.07	0.00
division_code_khl	-0.19	0.00	0.09	0.00	0.10	0.00
division_code_mym	-0.11	0.00	0.06	0.00	0.06	0.00
division_code_raj	0.08	0.01	-0.04	0.01	-0.04	0.01
division_code_rang	-0.30	0.00	0.15	0.00	0.15	0.00
division_code_syl	-0.15	0.00	0.08	0.00	0.08	0.00
a_5	0.06	0.2	-0.03	0.2	-0.03	0.2
a_6	0.001	0.054	0.001	0.06	0.001	0.053
a_7	0.002	0.25	0.001	0.25	0.001	0.252
a_8	0.00	0.92	0.00	0.92	0.00	0.92
a_9	0.01	0.54	0.00	0.55	0.00	0.54
a_10_serv	0.04	0.06	-0.02	0.07	-0.02	0.06
a_10_ind	0.01	0.9	0.002	0.9	0.002	0.87
a_11_25k	0.08	0.221	-0.04	0.225	-0.04	0.223
a_11_40k	0.04	0.531	-0.02	0.532	-0.02	0.532
a_11_80k	0.11	0.129	-0.05	0.132	-0.05	0.134
a_11_a80k	0.16	0.14	-0.08	0.14	-0.08	0.14
a_12	-0.05	0.02	0.02	0.03	0.02	0.023
e_1	0.03	0.00	-0.01	0.00	-0.02	0.00
e_2	0.01	0.20	-0.01	0.20	-0.01	0.20
e_3	0.00	0.98	0.00	0.98	0.00	0.98
e_4	-0.01	0.36	0.00	0.36	0.00	0.37
e_5	-0.05	0.00	0.02	0.00	0.02	0.00
e_6	-0.02	0.00	0.01	0.00	0.01	0.00
e_7	-0.02	0.01	0.01	0.02	0.01	0.01
e_8	0.04	0.00	-0.02	0.00	-0.02	0.00
e_9	0.02	0.05	-0.01	0.05	-0.01	0.05

Table G.3: Marginal Effects from the Ordered Probit Model (Scenario: Price of Electricity)

Variables	Prob (pss_elcp_rng = 1)	Prob (pss_elcp_rng = 2)	Prob (pss_elcp_rng = 3)

	Mg. Eff.	(P-Val.)	Mg. Eff.	(P-Val.)	Mg. Eff.	(P-Val.)
urban	-0.039	0.004	-0.005	0.192	0.044	0.004
division_code_bar	-0.014	0.513	-0.002	0.463	0.016	0.503
division_code_ctg	0.002	0.895	0.000	0.900	-0.003	0.896
division_code_khl	-0.082	0.007	-0.010	0.185	0.092	0.006
division_code_mym	0.031	0.095	0.004	0.329	-0.035	0.107
division_code_raj	0.162	0.000	0.020	0.170	-0.182	0.000
division_code_rang	-0.126	0.000	-0.016	0.132	0.141	0.000
division_code_syl	0.027	0.315	0.003	0.460	-0.030	0.325
a_5	0.064	0.080	0.008	0.257	-0.072	0.080
a_6	0.001	0.169	0.000	0.301	-0.001	0.167
a_7	0.001	0.608	0.000	0.618	-0.001	0.607
a_8	-0.006	0.195	-0.001	0.324	0.007	0.194
a_9	0.007	0.405	0.001	0.469	-0.007	0.405
a_10_serv	0.046	0.009	0.006	0.185	-0.051	0.008
a_10_ind	-0.018	0.479	-0.002	0.534	0.021	0.481
a_11_25k	-0.025	0.615	-0.003	0.634	0.028	0.615
a_11_40k	-0.034	0.493	-0.004	0.535	0.038	0.494
a_11_80k	-0.008	0.886	-0.001	0.887	0.009	0.886
a_11_a80k	-0.086	0.484	-0.011	0.539	0.096	0.486
a_12	-0.011	0.455	-0.001	0.487	0.013	0.452
e_1	0.012	0.048	0.002	0.179	-0.014	0.041
e_2	-0.021	0.004	-0.003	0.205	0.023	0.005
e_3	-0.013	0.061	-0.002	0.232	0.014	0.059
e_4	-0.028	0.001	-0.003	0.175	0.031	0.001
e_5	0.002	0.763	0.000	0.763	-0.002	0.763
e_6	0.022	0.001	0.003	0.207	-0.025	0.002
e_7	-0.017	0.018	-0.002	0.166	0.019	0.014
e_8	0.016	0.014	0.002	0.190	-0.018	0.013
e_9	0.024	0.000	0.003	0.138	-0.027	0.000

Table G.4: Marginal Effects from the Ordered Probit Model (Scenario: Supply of Gas)

Variables	Prob (pss_gassp_rng = 1)		Prob (pss_gassp_rng = 2)		Prob (pss_gassp_rng = 3)	
	Mg. Eff.	(P-Val.)	Mg. Eff.	(P-Val.)	Mg. Eff.	(P-Val.)
urban	-0.239	0.000	0.142	0.000	0.098	0.000
division_code_bar	-0.152	0.000	0.090	0.000	0.062	0.000
division_code_ctg	-0.064	0.006	0.038	0.010	0.026	0.004
division_code_khl	0.018	0.566	-0.011	0.566	-0.007	0.569
division_code_mym	0.002	0.948	-0.001	0.948	-0.001	0.948
division_code_raj	0.133	0.000	-0.079	0.000	-0.054	0.000
division_code_rang	-0.218	0.000	0.129	0.000	0.089	0.000
division_code_syl	-0.100	0.005	0.059	0.007	0.041	0.007
a_5	0.101	0.001	-0.060	0.001	-0.041	0.001
a_6	0.002	0.017	-0.001	0.021	-0.001	0.018
a_7	0.006	0.001	-0.004	0.002	-0.003	0.002

a_8	0.007	0.231	-0.004	0.232	-0.003	0.235
a_9	-0.003	0.776	0.002	0.776	0.001	0.776
a_10_serv	0.054	0.007	-0.032	0.009	-0.022	0.009
a_10_ind	-0.042	0.239	0.025	0.241	0.017	0.244
a_11_25k	0.118	0.084	-0.070	0.086	-0.048	0.090
a_11_40k	0.079	0.260	-0.047	0.261	-0.032	0.266
a_11_80k	0.081	0.288	-0.048	0.290	-0.033	0.289
a_11_a80k	0.231	0.022	-0.137	0.022	-0.094	0.029
a_12	-0.029	0.131	0.017	0.140	0.012	0.127
e_1	0.030	0.002	-0.018	0.003	-0.012	0.002
e_2	0.004	0.630	-0.003	0.632	-0.002	0.628
e_3	0.008	0.402	-0.005	0.400	-0.003	0.407
e_4	0.012	0.200	-0.007	0.206	-0.005	0.197
e_5	-0.024	0.004	0.014	0.005	0.010	0.006
e_6	-0.029	0.000	0.017	0.001	0.012	0.000
e_7	-0.030	0.001	0.018	0.001	0.012	0.001
e_8	0.005	0.523	-0.003	0.523	-0.002	0.523
e_9	0.036	0.000	-0.022	0.000	-0.015	0.000

Table G.5: Marginal Effects from the Ordered Probit Model (Scenario: Price of Gas)

Variables	Prob (pss_gaspr_rng = 1)		Prob (pss_gaspr_rng = 2)		Prob (pss_gaspr_rng = 3)	
	Mg. Eff.	(P-Val.)	Mg. Eff.	(P-Val.)	Mg. Eff.	(P-Val.)
urban	-0.114421	0.000	0.009961	0.282	0.10446	0.000
division_code_bar	-0.093178	0.002	0.008112	0.323	0.085066	0.001
division_code_ctg	0.0027729	0.880	-0.000241	0.875	-0.002532	0.881
division_code_khl	-0.06279	0.052	0.005466	0.344	0.057323	0.051
division_code_mym	0.0357084	0.117	-0.003109	0.342	-0.0326	0.123
division_code_raj	0.1669587	0.000	-0.014535	0.262	-0.152424	0.000
division_code_rang	-0.120586	0.000	0.010498	0.303	0.110089	0.000
division_code_syl	-0.012249	0.654	0.001066	0.703	0.011183	0.651
a_5	0.0595107	0.148	-0.005181	0.383	-0.05433	0.148
a_6	0.0005394	0.420	-0.000047	0.537	-0.000493	0.416
a_7	-0.0003	0.824	2.61E-05	0.827	0.000274	0.825
a_8	-0.000897	0.859	7.81E-05	0.861	0.000819	0.859
a_9	-0.001027	0.903	8.94E-05	0.904	0.000938	0.903
a_10_serv	0.0462093	0.014	-0.004023	0.320	-0.042187	0.014
a_10_ind	-0.007788	0.772	0.000678	0.776	0.00711	0.773
a_11_25k	0.0268296	0.624	-0.002336	0.650	-0.024494	0.625
a_11_40k	0.0060836	0.913	-0.00053	0.914	-0.005554	0.913
a_11_80k	0.0641883	0.280	-0.005588	0.435	-0.0586	0.281
a_11_a80k	0.1078928	0.201	-0.009393	0.392	-0.0985	0.204
a_12	-0.028003	0.078	0.002438	0.361	0.025565	0.076
e_1	0.0133878	0.047	-0.001166	0.357	-0.012222	0.043
e_2	-0.011388	0.103	0.000991	0.317	0.010397	0.112
e_3	0.0006763	0.921	-5.89E-05	0.921	-0.000617	0.921

e_4	0.0120163	0.150	-0.001046	0.381	-0.01097	0.151
e_5	-0.027623	0.000	0.002405	0.280	0.025218	0.000
e_6	-0.008819	0.205	0.000768	0.427	0.008051	0.201
e_7	-0.0321	0.000	0.002795	0.311	0.029305	0.000
e_8	0.0095955	0.151	-0.000835	0.384	-0.00876	0.151
e_9	0.0223214	0.895	-0.001943	0.323	-0.020378	0.001

Table G.6: Marginal Effects from the Ordered Probit Model (Scenario: Supply of Fuel Oil)

Variables	Prob (pss_fuelsp_rng = 1)		Prob (pss_fuelsp_rng = 2)		Prob (pss_fuelsp_rng = 3)	
	Mg. Eff.	(P-Val.)	Mg. Eff.	(P-Val.)	Mg. Eff.	(P-Val.)
urban	-0.113	0.000	0.095	0.000	0.018	0.001
division_code_bar	-0.170	0.000	0.142	0.000	0.027	0.007
division_code_ctg	-0.169	0.000	0.141	0.000	0.027	0.000
division_code_khl	-0.052	0.105	0.043	0.104	0.008	0.140
division_code_mym	-0.115	0.009	0.096	0.000	0.019	0.000
division_code_raj	0.161	0.000	-0.135	0.000	-0.026	0.000
division_code_rang	-0.329	0.000	0.276	0.000	0.053	0.005
division_code_syl	-0.137	0.000	0.115	0.000	0.022	0.005
a_5	0.041	0.364	-0.035	0.369	-0.007	0.349
a_6	0.003	0.000	-0.003	0.000	-0.001	0.002
a_7	0.005	0.005	-0.004	0.005	-0.001	0.026
a_8	0.002	0.803	-0.001	0.803	0.000	0.803
a_9	-0.014	0.147	0.011	0.148	0.002	0.167
a_10_serv	0.119	0.000	-0.100	0.000	-0.019	0.003
a_10_ind	0.047	0.253	-0.040	0.255	-0.008	0.264
a_11_25k	0.086	0.073	-0.072	0.078	-0.014	0.074
a_11_40k	0.030	0.529	-0.025	0.531	-0.005	0.525
a_11_80k	0.077	0.137	-0.064	0.143	-0.012	0.132
a_11_a80k	-0.040	0.709	0.034	0.709	0.007	0.712
a_12	-0.125	0.000	0.105	0.000	0.020	0.000
e_1	0.058	0.000	-0.048	0.000	-0.009	0.002
e_2	0.028	0.001	-0.023	0.001	-0.004	0.007
e_3	0.000	0.971	0.000	0.971	0.000	0.971
e_4	-0.007	0.386	0.006	0.384	0.001	0.408
e_5	-0.014	0.092	0.012	0.092	0.002	0.123
e_6	-0.057	0.000	0.048	0.000	0.009	0.000
e_7	-0.041	0.000	0.035	0.000	0.007	0.001
e_8	0.022	0.007	-0.018	0.006	-0.004	0.032
e_9	0.037	0.000	-0.031	0.000	-0.006	0.001

Table G.7: Marginal Effects from the Ordered Probit Model (Scenario: Price of Fuel Oil)

Variables	Prob (pss_fuelpr_rng = 1)		Prob (pss_fuelpr_rng = 2)		Prob (pss_fuelpr_rng = 3)	
	Mg. Eff.	(P-Val.)	Mg. Eff.	(P-Val.)	Mg. Eff.	(P-Val.)
urban	-0.089446	0	0.0400545	0	0.049392	0

division_code_bar	-0.1011717	0.004	0.0453053	0.008	0.055866	0.003
division_code_ctg	-0.1269441	0	0.0568463	0	0.070098	0
division_code_khl	-0.1930148	0	0.0864331	0	0.106582	0
division_code_mym	-0.0826514	0.001	0.0370118	0.004	0.04564	0.001
division_code_raj	0.1777172	0	-0.0795828	0	-0.098134	0
division_code_rang	-0.1927531	0	0.0863159	0	0.106437	0
division_code_syl	-0.0766597	0.039	0.0343287	0.049	0.042331	0.037
a_5	0.0787047	0.063	-0.0352444	0.067	-0.04346	0.065
a_6	0.0015514	0.059	-0.0006947	0.067	-0.000857	0.059
a_7	-0.0020908	0.248	0.0009363	0.244	0.001155	0.256
a_8	0.002067	0.750	-0.0009256	0.751	-0.001141	0.750
a_9	-0.0014002	0.887	0.000627	0.887	0.000773	0.887
a_10_serv	0.0712218	0.001	-0.0318935	0.002	-0.039328	0.001
a_10_ind	0.040769	0.198	-0.0182566	0.204	-0.022512	0.198
a_11_25k	0.0056012	0.920	-0.0025083	0.920	-0.003093	0.920
a_11_40k	-0.0228424	0.685	0.0102289	0.685	0.012613	0.686
a_11_80k	0.0691679	0.249	-0.0309738	0.253	-0.038194	0.250
a_11_a80k	0.1005535	0.277	-0.0450284	0.280	-0.055525	0.278
a_12	-0.1296086	0.000	0.0580395	0.000	0.071569	0.000
e_1	0.0125153	0.132	-0.0056044	0.144	-0.006911	0.127
e_2	0.007939	0.380	-0.0035551	0.386	-0.004384	0.377
e_3	0.0118755	0.165	-0.0053179	0.169	-0.006558	0.204
e_4	0.0041856	0.689	-0.0018743	0.689	-0.002311	0.689
e_5	-0.0373374	0	0.0167199	0	0.020618	0
e_6	-0.0270647	0.003	0.0121197	0.005	0.014945	0.002
e_7	-0.0375798	0	0.0168284	0	0.020751	0
e_8	0.0183793	0.017	-0.0082303	0.021	-0.010149	0.018
e_9	0.0228306	0.005	-0.0102237	0.009	-0.012607	0.005

Table G.8: Marginal Effect from the Ordered Probit Models (Scenario: Overall Stress Level)

Variables	Prob (pss_rng = 1)		Prob (pss_rng = 2)		Prob (pss_rng = 3)	
	Mg. Eff.	(P-Val.)	Mg. Eff.	(P-Val.)	Mg. Eff.	(P-Val.)
urban	-0.149	0.000	0.088	0.000	0.062	0.000
division_code_bar	-0.169	0.000	0.099	0.000	0.070	0.000
division_code_ctg	-0.120	0.000	0.071	0.000	0.050	0.000
division_code_khl	-0.214	0.000	0.125	0.000	0.088	0.000
division_code_mym	-0.056	0.026	0.033	0.026	0.023	0.033
division_code_raj	0.149	0.000	-0.088	0.000	-0.062	0.000
division_code_rang	-0.265	0.000	0.156	0.000	0.110	0.000
division_code_syl	-0.109	0.001	0.064	0.001	0.045	0.002
a_5	0.052	0.178	-0.031	0.179	-0.022	0.182
a_6	0.001	0.190	-0.001	0.200	0.000	0.183
a_7	0.000	0.899	0.000	0.899	0.000	0.899
a_8	-0.003	0.656	0.002	0.656	0.001	0.656
a_9	0.003	0.710	-0.002	0.709	-0.001	0.710

a_10_serv	0.057	0.001	-0.034	0.003	-0.024	0.001
a_10_ind	0.014	0.585	-0.008	0.587	-0.006	0.583
a_11_25k	0.022	0.682	-0.013	0.682	-0.009	0.683
a_11_40k	0.001	0.982	-0.001	0.982	-0.001	0.982
a_11_80k	0.050	0.387	-0.029	0.387	-0.020	0.391
a_11_a80k	0.120	0.196	-0.071	0.197	-0.050	0.202
a_12	-0.041	0.017	0.024	0.020	0.017	0.018
e_1	0.030	0.000	-0.018	0.000	-0.012	0.000
e_2	0.006	0.399	-0.004	0.403	-0.003	0.396
e_3	0.007	0.304	-0.004	0.304	-0.003	0.308
e_4	0.000	0.987	0.000	0.987	0.000	0.987
e_5	-0.049	0.000	0.029	0.000	0.020	0.000
e_6	-0.015	0.013	0.009	0.017	0.006	0.014
e_7	-0.044	0.000	0.026	0.000	0.018	0.000
e_8	0.015	0.022	-0.009	0.025	-0.006	0.023
e_9	0.034	0.000	-0.020	0.000	-0.014	0.000

The Trade Route to Renewables: Import as a Catalyst for the Diffusion of Renewable Energy Technology

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Abstract

This paper examines the diffusion of renewable energy technologies through international trade, focusing on the role of direct imports from countries with significant renewable energy knowledge. Building on the premise that technological diffusion is facilitated through the importation of goods embedded with advanced technologies, this study proposes that countries importing from partners with a robust renewable energy sector will experience enhanced adoption of these technologies. Our findings demonstrate that trade, particularly imports, plays a crucial role in disseminating renewable technologies across borders, enhancing their adoption in importing nations. Our analyses leverage renewable energy patent data and bilateral import data to construct indices that measure countries' exposure to renewable technologies through imports. We find that imports from technologically advanced countries are strongly associated with higher adoption rates of renewable technologies in the importing countries, underscoring the significant impact of direct trade relationships on technology diffusion. Additionally, the study unfolds the fact that countries with higher educations are significantly capable of utilizing the exposure of renewable energy knowledge stock of the partner country through import and implementing the diffused knowledge in their countries. This study contributes to the understanding of how imports can facilitate diffusion of renewable energy technology, providing important insights for policymakers aiming to enhance their renewable energy sectors.

Keywords: renewable technology diffusion, renewable energy adoption, renewable technology patent, trade and diffusion, import-weighted patent

JEL Classification: F18, O33, Q55, C23

1 Introduction

The global technological progress relies on knowledge "spillovers" through technology diffusion from high innovating countries to receiving countries. Existing literature suggests that several channels facilitate this diffusion across countries, with international trade in goods and foreign direct investment (FDI) being the most frequently studied, alongside immigration, knowledge transfers within multinational firms, trade in services, and cross-border research, technological and scientific collaboration, which are relatively less dominant in the literature (Aller, Ductor, & Herrerias, 2015; Ayerst, et al., 2023; Busse & Groizard, 2007; Coe & Helpman, 1995; Verdolini & Bosetti, 2016; Dechezleprêtre, et al., 2011; Ferrier, Reyes, & Zhu, 2016). This paper delves into the dynamics of global trade in goods to examine how effectively the renewable energy knowledge stock diffuses across borders.

Although increasing trade flows have made the international market more globalized and decentralized over time, driven by the development of middle-strata countries (Kim & Shin, 2002), technological innovations related activities remain concentrated in a relatively small number of advanced economies. The renewable energy technology innovation and R&D activities remains predominantly concentrated in a number of highly-industrialized countries including China (Keller, 2004; Keller, 2010; Xue, et al.,2024). But the adoption of RET remains low despite targeted policy efforts (UNCC, 2023). The diffusion of technology through trade is well-documented across various sectors. Knowledge spillovers are often localized, typically concentrated in specific regions that possess advanced technological capabilities (Keller, 2004). This phenomenon occurs because the nature of technology often requires specific infrastructure or expertise that is not uniformly distributed geographically. Successful technology transfer necessitates interaction between the innovator and the adopter, a process that can be potentially facilitated through trade. Furthermore, Keller (2002) argued that the concentration of trade, driven by transportation costs, further contributes to the localization of knowledge spillovers. Ferrier et al. (2016) illustrates how well-connected countries can not only achieve higher levels of technological sophistication but can also replace obsolete technologies with newer ones through trade. As such trade can facilitate both the spread of advanced technologies new to a recipient country and the phasing out of outdated ones. However, the mechanisms of diffusion vary depending on the type of technology. Given the widespread advancements in renewable energy technology (RET) in recent decades (Chen, Zhao, Li, Zhang, & Li, 2022), this study aims to contribute to the literature by investigating whether renewable energy technology diffuses through trade from countries with higher renewable energy knowledge stock.

The international flow of goods and services through trade and FDI can inform the recipient countries about the existence, uses, and benefits of new technologies. The existing literature on technology diffusion across countries primarily focuses on direct bilateral trade relationships (Coe & Helpman, 1995; Herman & Xiang, 2022; Ayerst et al., 2023). The recent studies have also addressed diffusion through both direct and indirect trade relationships using complex network modelling (Aller, Ductor, & Herrerias, 2015; Ferrier, Reyes, & Zhu, 2016; Herman P. R., 2022). For example, Ayerst et al. (2023) estimates the extent to which trade channels international technology diffusion by investigating the effects of embodied technology imports on innovation, measured by patent data and diffusion outcomes. By leveraging weighted trade networks, Ferrier et al. (2016) illustrated that both direct and indirect network effects of trade significantly contribute to technology diffusion across various technologies. While indirect trade relationships create a broad and significant network for potential spillovers, direct bilateral trade relationships offer a more immediate and impactful conduit for transferring complex technologies (Schiff & Wang, 2006; Martínez-Zarzoso & Chelala, 2021)[1]. In this paper, we mainly focus on renewable energy technology diffusion through direct trade, highlighting how these direct exchanges drive innovation across borders.

Empirical results regarding technology diffusion through trade have varied, perhaps due to different measurements of trade relationships. For instance, Coe and Helpman (1995) found a significant relationship between import-weighted foreign R&D expenditures and domestic total factor productivity, suggesting technology diffusion through trade. In contrast, Keller (1998), using a different approach of trade measurement, suggested that knowledge spillovers are independent of trade. In our research, the outcome variable is electricity consumption from renewable energy sources, normalized by population.

The broad literature on renewable energy transfer extensively discusses the relationships between the diffusion and adoption of renewable energy technology and various channels through which this occurs. It emphasizes several key domestic and international factors influencing adoption, including shared socio-economic, political, and geographic factors across the countries (Marques, Fuinhas, & Manso, 2010; Berry & Baybeck, 2005; Matisoff & Edwards, 2014; Stadelmann & Castro, 2014; Massey, Biesbroek, Huitema, & Jordan, 2014; Shipan & Volden, 2008) along with income level, imported oil prices, natural resource endowment, trade openness, renewable energy policies, intra-regional trade integration, domestic energy consumption (Murshed, 2021; Carley, 2009; Li, et al., 2023; Pfeiffer & Mulder, 2013; Chandler, 2009; Popp, Hascic, & Medhi, 2011). Fadly and Fontes (2019) explores the connection between geographic proximity, trade, and the intensity of renewable energy technology adoption. The adoption in RET in neighboring countries is strongly associated with the domestic adoption, and this effect tends to intensify when major trade partners are also robust adopters of renewable energy technologies (Fadly & Fontes, 2019).

[1] In the original paper, Schiff & Wang (2006) argued that while both direct and indirect North-South diffusion positively influence TFP, diffusion through direct trade has a more substantial and faster impact. Indirect effects, although significant, are smaller in magnitude and slower in impacting TFP. The analysis also shows that the diffusion process through direct trade routes is more efficient, suggesting that policies focusing on enhancing direct trade connections might be more effective in fostering technology transfer in less developed regions.

While Fadly and Fontes (2019) use the renewable energy adoption rates of neighboring countries as indicators of technology receipt in the reporting country, this does not necessarily measure whether knowledge spillover has occurred from the partner country. In our study, we utilize the patent data for renewable energy technology from the partner country to measure whether the knowledge stock of the partner country is influencing the technology diffusion in the reporting country. This distinction is crucial because it allows us to directly connect the diffusion of technology to aggregate renewable energy innovations, providing a more precise analysis of this technology spread, thus enhancing the policy relevance by pinpointing specific channels of renewable technological knowledge transfer.

In contrast to Fadly and Fontes' (2019) use of total trade, we use imports as the measure of trade channel to strengthen the directional aspect of trade in the role of technology diffusion through knowledge spillover (Fadly & Fontes, 2019). This methodological choice is underscored by the clear distinction imports make in revealing the pathways of technology transmission, which is otherwise ambiguous if we use total trade, by focusing on the role of imported goods as implicit carriers of new technologies.[2] The mechanism of importing allows recipient countries a more proactive role in selecting their trade partners, particularly those with higher renewable energy knowledge stocks. This agency enhances the strategic aspect of technology transfer, contrasting with exports where the choice of destination is often driven by external demand and may be less targeted. For our analysis, this means that reporting countries are not passively receiving technologies but actively seeking out and choosing to import from nations that are leaders in renewable energy. This selective approach enables them to directly tap into advanced technological ecosystems, facilitating more deliberate and effective integration of new energy technologies. Hence, we think focusing on import, rather than total trade volume or export should be the first tale.

Incorporating insights from Peri (2005) and MacGarvie (2005) who quantified the effects of distance and language on knowledge flows, it can be observed that Peri (2005) estimated that geographic distance reduces knowledge flows by 3% for each thousand kilometers traveled, and that a language difference results in a 19% loss in knowledge flow. However, sector-specific knowledge and technological leadership often transcend these barriers, traveling further and having significant impacts (MacGarvie, 2005; Peri, 2005). Additionally, recent developments in machine translation tools have further mitigated the overall impact of language barriers (Steigerwald, et al., 2022), enhancing the potential for global knowledge spillover. This demonstrates that while traditional barriers still play a

[2] This distinction does not challenge the validity of using total trade as a measure but emphasizes that understanding the specifics of trade directionality can provide more precise insights into how technology transfer is facilitated through economic interactions (Martínez-Zarzoso & Chelala , 2021). Importantly, boosting total trade may not always be feasible for a country due to economic or political constraints, making the focus on, specific trade channels, in our case, imports particularly relevant for assessing the direct impacts of trade on technology diffusion (Busse & Groizard, 2007).

role, their effects can be offset by advancements in technology and the specific nature of the knowledge being transferred. This insight justifies the motivation behind our research.

To measure diffusion through direct trade, we utilize an import-weighted patent index. Our analysis indicates that countries with higher exposure to these technologies, as measured by the import-weighted patent index, experience significantly increased adoption rates of renewable energy, affirming the substantial impact of direct imports on renewable technology diffusion. Our findings are robust to alternative measurement of exposure such as a patent index from each partner country, adjusted for the total bilateral imports of the reporting country and normalized against its GDP. Our analyses also include several covariates such as the adoption of renewable energy policies, per capita CO_2 emissions, population size, and GDP per capita of the reporting countries. Moreover, to tackle potential endogeneity and omitted variable biases, we'll consider the educational attainment levels in the reporting countries, drawing on the well-documented relationship between education and the diffusion of technology through trade as described in the literature (Ferrier, Reyes, & Zhu, 2016; Nelson & Phelps, 1966; Akhvlediani & Cieślik, 2020).

Notably, the import-share weighted patent index proves to be a more effective predictor of renewable energy adoption than the import-GDP weighted patent index. Our study also highlights that non-innovator countries benefit substantially from these trade-induced spillovers, suggesting that enhancing trade connections with technologically advanced countries can lead to higher adoption rates of renewable technologies in less innovative regions. These results offer new insights into the mechanisms of technology diffusion through international trade and the strategic role of imports in advancing a country's renewable energy agenda.

The rest of the paper is organized as follows: Section 2 details the methods and materials, covering the data sources, conceptual framework, and empirical strategy. Section 3 presents the main results and discussions, including robustness checks to validate the findings. Section 4 outlines policy implications and concludes the paper, offering insights into the diffusion of renewable energy technologies through trade and suggesting directions for future research.

2 Methods and Materials

2.1 *Data*

Our analysis employs an unbalanced panel dataset that spans from 2001 to 2022 for 196 countries, sourced from various global databases. Due to limitations associated with the outcome and primary explanatory variables, our primary models are based on this comprehensive global sample. The details associated with large definitions of the variables, sample processing, dataset selection and sampling can be found in Appendix B.

In our analysis, we have sourced data on bilateral import volume reported from the ITC Trade Map for 196 countries from 2001 to 2022, expressed in thousands of US dollars (ITC, 2022). Despite some limitations[3], we have used mirror import data as a substitute for original import data which consists of a lot of missing observations. Mirror import data, which is derived from export reports by partner countries, serves as a substitute and a more accurate solution for missing import data from countries that do not report to UN COMTRADE (Carrère & Grigoriou, 2015).

There are several drawbacks to using patent data as a proxy for technology transfer, such as the fact that not all innovations are patented, patented innovations vary widely in value and distribution, and filing a patent does not guarantee the technology's use in the filing country (Griliches, 1990). However, patent applications are still widely adopted as measures of knowledge stock in empirical literature as a parameter of knowledge stock since they represent output measures of technology (Ferrier, Reyes, & Zhu, 2016; Dechezleprêtre, et al., 2011; Ayerst, et al., 2023). Moreover, to measure the renewable knowledge stock of a country, the best available data to the authors is the number of patents filed yearly across countries. The data has been sourced from IRENA (2024) - INSPIRE Platform - with major processing by Our World in Data (OWID, 2023)[4]. The patent data exclusively covers energy source technologies, excluding technologies related to energy storage or transport.

Two types of renewable energy variables are used to measure renewable technology adoption: annual electricity generation (Tw-H) from renewable energy sources, normalized by total population, and the share of electricity production from renewable energy sources (%). These data have been sourced from Ember (2024); Energy Institute - Statistical Review of World Energy (2024) – with major processing by Our World in Data (Ritchie, Rosado, & Roser, 2024). In this case, renewable energy encompasses electricity production from hydropower, solar, wind, biomass and waste, geothermal, wave, and tidal sources[5].

Yearly data on number of domestic renewable energy policies has been sourced from the IEA Policy Database (IEA, 2024). Number of country-wise renewable energy policies that were in effect during the respective study period have been taken into consideration. However, it is important to note that the authors have decided to leave out the policies which are currently in the announced and planned status to avoid complications. Moreover, policies taken at a regional level, such as the European Union, are also left out due to our intention of focusing on national-level policies of the reporting countries to

[3] The limitations of the mirror data can be found in details in Table B.1 from Appendix B (Carrère & Grigoriou, 2015; Markowicz & Baran, 2020; Meshcheryakova & Shvydun , 2024).

[4] The details source description of this data can be found in Table B.1 from Appendix B (IRENA, 2024).

[5] In Ritchie, Rosado, & Roser (2024), electricity generation (Tw-H) from renewable energy sources is the simplified terminology of modern renewable energy generation by source. The other renewables including bioenergy encompasses geothermal, tidal and wave generation, whereas the same disaggregation has been outlined in the case of share of electricity production from renewable energy sources (Ember, 2024). The details can be found in Table B.1 from Appendix B.

ensure clarity in assessing the direct impact of specific policy actions on the renewable energy sector within individual countries.

Data on real GDP (constant 2015 US$), per capita real GDP (constant 2015 US$), and nominal GDP (current 2015 US$) have been sourced from World Development Indicators (World Bank, 2024). Majority of the data on total population of a country has been sourced from both World Development Indicators, while Our World in Data has been utilized as a data source when the data is unavailable in WDI (World Bank, 2024; Ritchie, et al., 2023). Lastly, CO_2 emissions, average years of schooling, electricity generation from fossil fuel and gross enrollment ratio in primary energy are sourced from Our World in Data as well (OWID, 2024; Ritchie & Roser, 2024; UNDP, 2024; UNESCO Institute for Statistics, 2024).

2.2 Conceptual Framework

Our core hypothesis suggests that renewable energy knowledge, as reflected in the patents filed by exporting countries, spreads across international borders, primarily from countries with a significant knowledge base to those with lesser knowledge, through the mechanism of imports. This process of knowledge transfer is theorized to boost the adoption rates of renewable energy technologies in the importing countries. Specifically, the study aims to examine whether there is an association between the level of exposure to foreign renewable energy technologies - as gauged by the patent activities of trade partners - and the extent of renewable energy adoption within a given country. Essentially, we hypothesize that increased exposure to advanced renewable technologies, via imports from technologically advanced countries, directly contributes to a higher rate of adoption and integration of these technologies within the domestic framework of the reporting countries. This effect would manifest as a noticeable increase in the deployment of renewable energy solutions, driven by enhanced access through import to and familiarity with cutting-edge technologies and practices from abroad.

First, understanding the directionality of trade flows, through import, is crucial to accurately assess the pathways of technology diffusion. Total trade, which aggregates imports and exports, can obscure the distinct impacts each has on technology transfer. This aggregation makes it challenging to discern whether it is the inflow of technology through imports or the outflow through exports that drives technology diffusion. In theoretical terms, technology diffusion can occur both ways; however, empirical evidence, as discussed extensively by Keller (2004, 2010), predominantly supports import as a more potent channel for diffusion, while the exporting channel presents more complexities and is harder to establish. Focusing on imports is particularly valuable because it allows for a clear, direct observation of how technologies enter a country. When countries import goods from nations with advanced renewable energy technologies, they gain access to the latest innovations embedded within these products. This direct exposure is critical for facilitating the adoption and integration of new technologies within the importing country's economy (Ayerst, et al., 2023). Therefore, we specifically prioritize the study of imports as a channel from the frontier to potentially recipient countries before considering the role of exports and then potentially examining the cumulative effects within total trade.

We concentrate on the role of direct trade as the primary channel for technology diffusion, given its pivotal role in transferring technology between countries directly involved in trade transactions. In the context of trade, a direct network refers to the immediate, bilateral trade relationships between countries. This direct connection is essential for the initial transfer of technology and knowledge. An indirect network, however, involves countries that may not trade directly but are linked through intermediate countries. For instance, as Ferrier, Reyes, & Zhu (2016) outlined and using Coe and Helpman's (1995) model, if Country A trades with Country B, Country B trades with Country C and Country A does not trade Country C, technology from Country A can indirectly reach Country C through B. This example highlights the contagion effect in trade networks. Lumenga-Neso, Olarreaga, & Schiff (2005) delineate two types of R&D: "produced" R&D and "available" R&D. "Produced" R&D is generated and housed within the country of origin but can be transmitted to other nations via direct trade. After being transferred to another country, this R&D is integrated into the importer's "available" knowledge pool. It can then easily spread to additional countries by allowing for knowledge to become indirectly available to other nations beyond the initial direct trade links. In our study, this conceptual framework underpins the investigation into whether the renewable energy knowledge stock, initially part of the "produced" category, has successfully diffused to another country (referred to as country B) and has been adopted there as part of the country's renewable energy strategies. This exploration starts with the premise that direct trade is a primary conduit and pre-condition for such knowledge transfer and without establishing direct trade as an effective channel, it is not possible to assess the impact of indirect trade. We hypothesize that if country B has imported from country A (the producer of renewable energy knowledge stock), it could lead to an increase in country B's adoption of these technologies. Thus, our focus on direct trade serves as a critical first step in identifying and quantifying the impact of "produced" R&D on renewable energy adoption in country B, before considering the broader, more complex dynamics of indirect trade effects.

2.2.1 Measuring Exposures

Drawing inspiration from Ayerst, et al. (2023) and Zhu & Jeon (2007), to analyze the impact of renewable energy technology diffusion through imports, we first construct an index to measure renewable energy exposure via imports for reporter countries for each year. We call it import share-weighted RE patent for reporter country 'i' for a given year 't' and it can be expressed as[6]

[6] Following Ferrier, Reyes, & Zhu (2016), we treat the geographically largest economy as the sole predecessor or successor when countries split or merge to maintain methodological consistency with technology data and account for historical changes in national boundaries. Serbia is considered the sole successor of Serbia and Montenegro, with Montenegro treated as a new entity after 2004 post-dissolution.

$$trp_{i,t} = \sum_{j \neq i} \left[\frac{(imp_{i,j,t} \times p_{j,t})}{imp_{i,t}} \right] = \sum_{j \neq i} \left[\frac{(imp_{i,j,t} \times p_{j,t})}{\sum_{j \neq i} imp_{i,j,t}} \right] \quad (1)$$

where *'j'* represents the partner country from which the reporter countries import, and bilateral import from partner country *'j'* to reporter country *'i'* is represented by $imp_{i,j,t}$ for year *'t'*. In this index, total import volume of reporter country *'i'* is expressed by $imp_{i,t} = \sum_{j \neq 1} imp_{i,j,t}$ for a given year *'t'*. To ensure that re-exports or re-imports are not considered, we apply a condition in the summation rule, namely $j \neq i$, ensuring that the reporter country and partner country are not the same. The annual number of patent applications filed by partner country *'j'* is expressed by $p_{j,t}$ for a given year *'t'*.

This approach allows us to assess how the inflow of goods, embedded with new technologies, from a country with a higher concentration of renewable energy patents can influence the renewable energy landscape of the importing country. The higher the value of the constructed index, the greater the exposure of the reporting country to the renewable energy knowledge stock of its partner countries through imports. Essentially, this measure reflects the potential for technology transfer and adoption based purely on the volume and value of imported goods carrying new innovations. Additionally, for robustness, we create an alternative index using the nominal GDP of the reporting country, rather than its total bilateral imports.

$$ngrp_{i,t} = \sum_{j \neq i} \left[\frac{(imp_{i,j,t} \times p_{j,t})}{ngdp_{i,t}} \right] \quad (2)$$

where $ngdp_{i,t}$ is the nominal GDP of reporter country for a given year. This formulation integrates the economic context by normalizing the influence of patents by the economic size (nominal GDP) of the reporting country, which can provide more insights into how significant the imported renewable energy technology is relative to the country's overall economic capacity. Similar to the previous index, a higher value of this index indicates greater exposure of the reporting country to the renewable energy knowledge stock through trade. Additionally, because the bilateral import data is reported in current USD, using nominal GDP instead of real GDP is more appropriate. This method is particularly useful for understanding the relative weight of renewable energy technology transfer in relation to the country's economic scale. To ensure consistency and comparability, both indices are standardized across various times and countries.

2.2.2 Measuring Outcome Variable

For our outcome variable, we measure electricity generation from renewable energy sources, normalized by the total population. For a given year *'t'*, it can be expressed as[7]

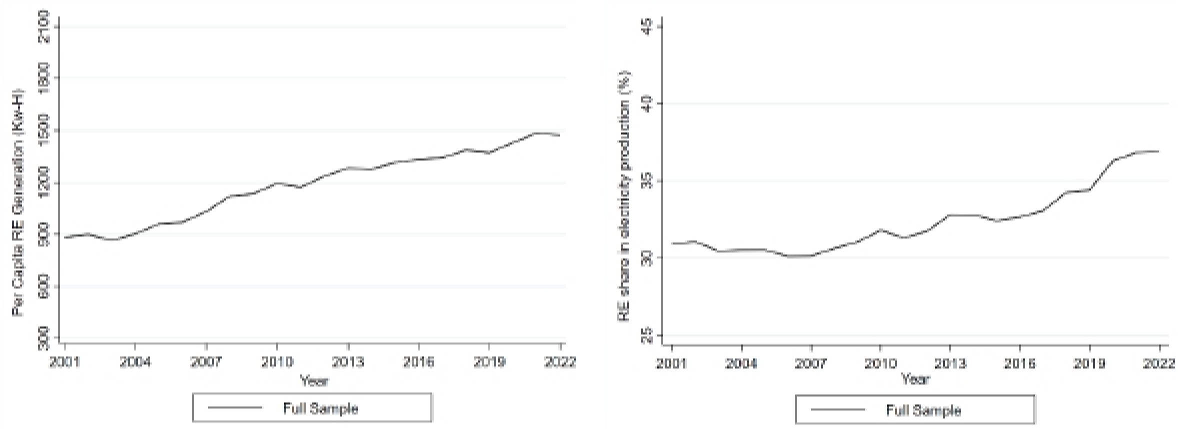
[7] The unit of the normalized variable, originally measured in Tw-H for electricity generation from renewable energy, has been converted to Kw-H per capita for analysis.

$$re\_elc\_pop_{i,t} = \frac{re\_elc_{i,t} \times 10^9}{pop_{i,t}} \tag{3}$$

where $re_elc_{i,t}$ represents electricity generation from renewable energy source for country *‘i’* for a given year *‘t’* and $pop_{i,t}$ represents total population of a country for a given year.

Normalizing by population is crucial because it allows us to assess the per capita availability and use of renewable energy, providing a clearer picture of energy accessibility and sustainability for the average individual in a country. This normalization helps us understand the extent to which renewable energy meets the energy needs of the population, regardless of total population size, making comparisons between countries with differing population scales more meaningful. For robustness, we also measure electricity consumption from renewable sources, normalized by real GDP[7]. This approach adjusts the consumption figures for the economic size of the country, allowing us to analyze how economically significant renewable energy consumption is relative to the country's overall economic activity.

Figure 1: Trends in Renewable Energy Utilization.



(a) Per Capita RE Generation (Kw-H) (b) RE Share in Total Electricity Production (%)

Note: Panel (a) displays the per capita renewable energy generation measured in kilowatt-hours (Kw-H), while panel (b) shows the percentage share of renewable energy in total electricity production. Both panels present unweighted averages for countries included in a balanced sample, illustrating the evolution of renewable energy adoption over the observed period.

Additionally, we have considered using the share of electricity generation from renewable sources ($reshare\_elc_{i,t}$) as another outcome variable to gauge the relative change in total electricity generation.

This metric is important because it indicates the proportion of renewable energy generation in the total energy mix, offering insights into the energy transition dynamics within the country. However, cross-sectional trend analysis, as illustrated in Figure 1, demonstrates a consistent increase over time in both the average per capita renewable energy generation and the average share of renewable energy (%) in total electricity production. The growth in per capita renewable energy generation has seen a substantial increase of approximately 66%, while the share of renewable energy in total electricity production has experienced a more modest rise of around 15% over the years.

2.2.3 Other control variables

In our study, including domestic renewable energy policies allows us to control for the domestic political ecosystem that might significantly influence technology adoption, thereby isolating the impact of imports as a channel for renewable energy diffusion. Verdolini & Bosetti (2016) raises several concerns regarding the use of policy variables in assessing renewable energy initiatives. Firstly, these variables often only indicate whether a specific policy instrument has been adopted, without reflecting the actual stringency of the policy. Secondly, they tend to aggregate different policy instruments without accounting for the specific design parameters that dictate their stringency, such as the tariff levels for feed-in tariffs (FITs) or subsidies for solar energy. Moreover, merely counting these instruments overlooks the variations in their enforcement. To address these issues, Verdolini & Bosetti (2016) recommends integrating a measure that reflects a country's general propensity to enforce laws as a proxy for the effective enforcement of environmental policies.

By examining both the absolute figures normalized by population and the relative share within the total energy mix, we can obtain a comprehensive view of how renewable energy is being integrated and scaled up in relation to other energy sources. This dual approach allows us to address two different dimensions of renewable energy adoption: one focusing on individual or economic scale impact and the other on sectoral shift within the power industry.

Previous literatures emphasize the significance of economic factors, such as income level and market size, in adopting alternative energy sources. Studies by Aguirre & Ibikunlem (2014) and Pfeiffer and Mulder (2013) specifically highlight GDP per capita and population size as proxies for these factors, illustrating their pivotal role in influencing energy adoption trends. This measure controls for the market size of the recipient country, which is likely to attract foreign technologies, and also accounts for the greater incentive of energy-intensive countries to source cleaner and more efficient technologies from abroad. Furthermore, we account for CO_2 emission levels, which, according to studies such as Aguirre and Ibikunle (2014), Fadly and Fontes (2019) and Marques et al. (2011) can either positively or negatively affect the adoption of renewable energies, depending on the extent to which policymakers prioritize environmental concerns. As noted by Ferrier, et al. (2016), and Fadly and Fontes (2019), including these variables helps address endogeneity concerns, ensuring that the adoption of renewable energy technologies as a dependent variable does not reversely affect our control variables - population, per capita GDP, and per capita CO_2 emission- thereby offering a clearer understanding of the drivers of technology transfer (Alam & Murad, 2020; Ghazouani, Boukhatem, & Sam, 2020; Wang, et al., 2023;

Han, et al., 2022; Rahman, Sultana, & Velayutham, 2022; Muhammad, et al., 2022)[8]. Lastly, to ensure robustness and to enhance our analysis of technology adoption, specifically renewable energy technologies, we calculate the energy intensity[9] of the economy, defined as primary energy use divided by GDP.[10]

2.3 Empirical Strategy

Our empirical analysis aims to assess the impact of exposure to renewable energy knowledge stock through import on the adoption of renewable energy technologies by constructing two primary models using panel data regression with country and year fixed effects. For country *'i'* and year *'t'*:

Main Model (Per capita electricity generation from renewable energy sources):

$$re\_elc\_pop_{i,t} = \beta_0 + \beta_{i,t}T + \beta_{i,t}T^2 + \beta_1 trp_{i,t} + \beta_2 population_{i,t} + \beta_3 gdp\_pc_{i,t} + \beta_4 co2pc_{i,t} + \mu_i + \gamma_t + \varepsilon_{i,t} \tag{4}$$

where *'i'* denotes countries, *'t'* indexes time (year), '$gdp\_pc_{i,t}$' measures per capita real GDP, '$co2pc_{i,t}$' quantifies the per capita CO_2 emissions, 'μ_i' and 'γ_t' denote country and year fixed effects, respectively, capturing inherent time-invariant national characteristics and common temporal shocks. In the model, $\beta_{i,t}T$ and $\beta_{i,t}T^2$ represent the country-specific linear time trend and its quadratic form, respectively. Coefficient for the linear and quadratic time trend for country *'i'* at time *'t'*, capturing the general trend and effect of country specific policies, and acceleration or deceleration in the trend of renewable energy adoption over time within each country. $\varepsilon_{i,t}$ denotes a stochastic error term. As suggested by Fadly and Fontes (2019), these terms are included to account for country-specific quadratic trends in the adoption of renewable energies, such as those driven by technical progress, environmental policies or any other shocks, which may vary across countries.

For ensuring robustness to the main explanatory variable, we use the index created in equation (2) instead of import share-weighted RE patent, as the main explanatory variable. The model can be specified as:

[8] While there are literatures outlining the bidirectional causal relationship between trade openness and renewable energy consumption, to our best knowledge, we found that most empirical researches are supporting a unidirectional relationship from trade openness and renewable energy consumption. However, in the presence of real GDP or per capita GDP, the trade openness act as the determinant. (Ghazouani, Boukhatem, & Sam, 2020)

[9] The details of energy intensity can be found in Table B.1 from Appendix B.

[10] As a substitution of energy intensity, we can incorporate per capita GDP as a control variable to account for the economic development level of the country, which can significantly influence the capacity and readiness to adopt new technologies. From the previous literature, it can be noted that there exists a unidirectional causal relationship from per capita GDP to renewable energy consumption, although bidirectional relationship exists between real GDP and renewable energy consumption.

$$re\_elc\_pop_{i,t} = \alpha_0 + \alpha_{i,t}T + \alpha_{i,t}T^2 + \alpha_1 ngrp_{i,t} + \alpha_2 population_{i,t} + \alpha_3 gdp\_pc_{i,t} + \alpha_4 co2pc_{i,t} + \theta_i + \delta_t + \omega_{i,t} \quad (5)$$

where θ_i and δ_t denote the country and year-fixed effect respectively, and $\omega_{i,t}$ indicates the stochastic error term.

For robustness, we enhance our analysis by conducting Principal Component Analysis (PCA)[11] on the standardized counts of renewable energy policies and average Worldwide Governance Indicators[12]. This allows us to create a composite index (*re_imp*$_{i,t}$), which we name the 'Renewable Energy Implementation Index.' This index provides a more realistic representation of a country's overall readiness and effectiveness in implementing and enforcing renewable energy initiatives, taking into account both the presence of policies and the broader governance environment. We incorporate this variable, along with gross enrollment ratio in primary education (% share)[13] and energy generation from fossil fuel per capita (Kw-H per person)[14] into equations (4) and (5) alongside country-specific trends. This inclusion allows us to isolate the specific impact of renewable energy policies within the reporting countries and distinguish it from the effects of technological progress or other country-specific factors.

To capture the time-lagged effects of diffusion, we have incorporated one and two-year lagged versions of the main explanatory variables into our analysis, utilizing the same model framework. Additionally, to address potential issues of heteroskedasticity and within-panel serial correlation, our models are estimated using robust standard errors (Arellano, 2003; Wooldridge, 2019). By segmenting countries based on higher and lower education levels, this analysis provides insights into how the relationship between renewable energy adoption and the index measuring exposure to partners' renewable energy knowledge stock through imports varies across different tiers of educational attainment across countries. Lastly, we have estimated the same models across the innovator and non-innovator strata.

Our hypothesis posits a positive correlation between the import share-weighted exposure to renewable energy knowledge stock and per capita electricity generation from renewable sources. This suggests that countries with greater exposure to renewable energy knowledge through imports are more likely to adopt renewable energy technologies. Similarly, we anticipate that an alternative index measuring

[11] PCA provides a statistically grounded method of reducing dimensionality and can indicate the most variance-explaining combination of these variables.

[12] The details of the data regarding average World Governance Indicators are sourced from the World Bank and the construction of this governance indicator has been inspired from NLiS averaged aggregate governance indicators (WHO, 2024). The details can be found in Table B.1 from Appendix B.

[13] Common proxies for education typically involve measures like primary and secondary school enrollment rates (Ferrier, Reyes, & Zhu, 2016). However, due to the greater availability of data, we have opted to use the gross enrollment rate in primary education as a substitute for secondary school enrollment rates in our analysis. The details can be found in Table B.1 from Appendix B.

[14] The details of this variable can be found in Table B.1 from Appendix B.

exposure to renewable energy knowledge through imports will show a comparable positive relationship with renewable energy adoption in the partner countries.

Furthermore, we anticipate that these associations will remain largely consistent in sensitivity analyses that control for additional factors beyond the control variables included in the main model. In the stratification analyses, we anticipate that the relationship between the main explanatory variable and renewable energy diffusion will exhibit a stronger and positive coefficient in non-innovator and higher-education countries compared to their counterparts. Here, a "stronger" coefficient refers to a larger magnitude when coefficients from both groups within a stratum are significant, or the presence of a significant coefficient when the counterpart shows an insignificant one. This consistency would underscore the robustness of the import exposure's impact on renewable energy uptake, reinforcing the significance of international knowledge transfer in fostering sustainable energy solutions.

3 Findings

3.1 Main Results

Table 1 presents the regression results from the main model. Table 1 presents six models analyzing per capita renewable energy generation in logarithmic form, with the import-weighted patent index as the main explanatory variable. Model (1) includes only the import-weighted patent index with country-fixed effects. Model (2) incorporates country-fixed effects, and country-specific trends alongside the main explanatory variable. Model (3) adds year-fixed effects to the settings of Model (2). Model (4) includes the main explanatory variable with additional covariates and country-fixed effects. Model (5) replicates the settings of model (2) with covariates. Finally, model (6) from Table 1 combines all covariates, country-fixed effects, year-fixed effects, and country-specific trends, representing our main model specification. Following arguments of de Chaisemartin & D'Haultfœuille (2020), we have structured the regression results in a sequential and hierarchical manner to ensure that each model progressively includes more controls and complexities. By incrementally adjusting for country and year-specific trends and incorporating various covariates, we aim to mitigate any potential biases that could arise from omitted variables or heterogeneous treatment effects (de Chaisemartin & D'Haultfœuille, 2020).

Table 1: Main regression results – renewable energy generation per capita and import share-weighted patent index

Dependent Variable: Log of per capita renewable energy generation						
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Import share-weighted	0.203***	0.012	0.021	0.196***	0.019*	0.041***
patent index (Std.)	(0.011)	(0.009)	(0.014)	(0.013)	(0.010)	(0.015)
GDP pc (Std.)				0.754***	-0.015	-0.003
(0.067)					(0.066)	(0.064)

Population (Std.)				0.427***	-0.274	-0.201
(0.130)					(1.837)	(3.055)
CO_2 Emissions pc				-0.064***	-0.03***	-0.034**
(0.009)					(0.009)	(0.013)
Observations	3,352	3,352	3,352	3,258	3,258	3,258
R-squared (Within)	0.095	0.863	0.865	0.167	0.864	0.866
Number of countries	179	179	179	172	172	172
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Country-specific trend	No	Yes	Yes	No	Yes	Yes
Year-fixed effect	No	No	Yes	No	No	Yes

Here, *** p<0.01, ** p<0.05, * p<0.1 and standard errors are presented in parentheses. All figures in the table are rounded to three decimal points. In all specifications that feature country-specific trends, a quadratic trend is incorporated along with the linear trend. The inclusion of covariates in the sample resulted in the loss of seven countries from the analysis. While the constant term is included in the model specification, it is not reported in the table, as it holds no significant implication in the context of a multivariate model.

In Table 1, we observe positive coefficients between the import share-weighted patent index and per capita renewable energy generation in three specifications: models (1), (4), and (6), with coefficients of 0.203, 0.196, and 0.041 respectively. Conversely, models (2), and (3) show insignificant coefficients, while model (5) shows a weaker coefficient (at 10% significance level). Our proposed specification, as outlined in model (6), reveals a relatively weaker positive coefficient compared to models (1) and (4). Our proposed model indicates that a one standard deviation increase in exposure to renewable energy knowledge stock through imports leads to a 4.1% (p value < 0.05) increase in per capita renewable energy adoption. Across models with significant coefficients, this increase ranges from 4% to 20.3% (p value < 0.05). This suggests that our hypothesis regarding the diffusion of renewable energy knowledge stock through imports is viable, as the exposure to renewable energy knowledge stock through imports is positively associated with per capita renewable energy generation. Introduction of covariates even within the same fixed effect framework in models (4) and (5)[15] shifts this coefficient to insignificance, suggesting that it may be attributable to factors unaccounted for in simpler models but captured by the additional covariates, at 5% significance level. Lastly, model (6) shows a significant coefficient compared to model (3), highlighting the importance of covariates even though the incremental R-squared values from model (3) to Model (6) are small under country fixed effects, year fixed effects, and country-specific trends. Similarly, the comparison between model (5) and model (6) reveals that including year-fixed effects alongside country-fixed effects, country-specific trends, and covariates results in a notably significant coefficient.

In the case of the control variables, observations from models (4) to (6) demonstrate that per capita CO_2 emissions consistently exhibit a significant negative association with per capita renewable energy

[15] The coefficient is significant at 10% significance level.

generation, confirming findings from recent studies (Justice, Nyantakyi, & Isaac, 2024; Perone, 2024). Furthermore, higher GDP per capita, indicative of a country's economic strength, is significantly linked to increased adoption of renewable energy sources, as evidenced in models (4) and (5) and supported by previous research (Fadly & Fontes, 2019; Aguirre & Ibikunle, 2014). However, per capita GDP appears insignificant in the model that includes country-specific trends alongside the two fixed effects. This could happen because: country-specific trends could be capturing long-term economic growth patterns that are closely related to changes in GDP per capita. When these trends are included, they might absorb much of the variability that per capita GDP would otherwise explain, rendering the GDP variable statistically insignificant (Kleiber & Zeileis, 2008). Conversely, the proxy for domestic market size, population, shows no significant impact on per capita renewable energy generation across most models, except when only country-fixed effects are considered. This finding aligns with the literature, which often downplays the significance of market size in influencing renewable energy adoption (Fadly & Fontes, 2019; Eyraud, et al., 2011).

The explanatory power of our models significantly improves from simpler configurations, such as Model 1 (R-squared of 0.095), to more complex ones like Model 3 (R-squared of 0.865), highlighting the importance of adding country-specific trends. However, adding further covariates in Model 6 marginally increases the R-squared to 0.866, indicating that while these variables are significant, their additional explanatory power is limited.

Regarding the validity of our results, considering the import share-weighted patent index as a key variable, it is crucial to acknowledge that this measure could be conflated with other unobserved variables influencing renewable energy generation. Incorporating the fixed effects help partially mitigate the confounding influences of both observable and unobservable country-specific and time-specific variables as indicated by the highly increased R-squared value in model (2), (3), (5) and model (6), compared to the other models. This approach aligns with methodologies seen in the literature, such as those discussed by Comin et al. (2012) and Fadly and Fontes (2019), which emphasize the importance of accounting for endogeneity in variables that might be influenced by omitted or unobserved factors.

Although we have included country-fixed effects, year-fixed effects and country specific linear and quadratic trend in the model, the possibility of omitted variable bias remains. The inclusion of GDP per capita, population, and CO_2 emissions as control variables strengthens the model by addressing some key economic and demographic factors known to influence renewable energy adoption. Yet, there could still be other unmeasured factors impacting our dependent variable. We address this issue by testing the robustness of our results against the inclusion of additional variables, as shown in the appendix. While these tests reinforce the stability of our findings, they cannot definitively eliminate all concerns regarding omitted variables.

3.2 *Robustness Check*

First, we aim to evaluate the alternative index, as defined in equation (2), to assess the consistency of its relationship with renewable energy generation compared to the original index. This involves testing whether the alternative index, which measures renewable energy exposure through trade, offers a better fit compared to our original specification. Results are detailed in Table C.1 from Appendix C. A key observation from this table is that the relationship between the alternative index and renewable energy adoption is predominantly positive but insignificant across various model settings, except when only country-fixed effects are included. Notably, models incorporating country-specific trends account for more than double the variance compared to other models, suggesting a deeper explanatory power but also highlighting the instability of the alternative index under these conditions. This discrepancy suggests that normalizing by nominal GDP might not be the most effective method for constructing this index. Despite these concerns, it is significant that the coefficients remain positive where they are significant, indicating a generally positive influence of the alternative index, a representation of exposure of renewable energy knowledge stock through import, on renewable energy adoption.

Second, we addressed potential issues of heteroscedasticity and within cross-section serial autocorrelation in our regression models, as detailed in section 2.3, with results presented in Table 2. While the robust error adjustments altered the significance of some covariates in specific settings, the overall magnitude and significance of the coefficients linking the main explanatory variable to the dependent variable remained largely consistent with those in Table 1, which were estimated without robust error adjustments. Furthermore, the overall model fitness shows minimal variation between the two analytical approaches, and our proposed specification yields nearly identical results in terms of magnitude, direction, and significance ($p < 0.05$) of the coefficient between the dependent variable and the exposure to renewable energy knowledge stock of partner countries through import. This consistency reinforces the robustness and parsimony of our proposed model[16], confirming its reliability in analyzing the impact of renewable energy knowledge stock exposure on renewable energy adoption. Additionally, we estimated the regression models for the alternative index using robust errors, with results presented in Table C.2 from Appendix C. These findings were consistent with those of the models that employed standard errors, indicating stability across different error specifications and misrepresentation of the alternative index.

Table 2: Main regression results – renewable energy generation per capita and import share-weighted patent index, with robust standard errors

Dependent Variable: Log of per capita renewable energy generation						
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)

[16] Specification (6) from Table 1.

Import share-weighted patent index (Std.)	0.203*** (0.041)	0.012 (0.011)	0.021 (0.018)	0.196*** (0.038)	0.019* (0.011)	0.041*** (0.015)
GDP pc (Std.)				0.754**	-0.015	-0.003
(0.312)					(0.052)	(0.064)
Population (Std.)				0.427	-0.274	-0.201
(0.285)					(2.964)	(3.055)
CO_2 Emissions pc				-0.064**	-0.031**	-0.034**
(0.026)					(0.013)	(0.013)
Observations	3,352	3,352	3,352	3,258	3,258	3,258
R-squared (Within)	0.095	0.863	0.865	0.167	0.864	0.866
Number of countries	179	179	179	172	172	172
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Country-specific trend	No	Yes	Yes	No	Yes	Yes
Year-fixed effect	No	No	Yes	No	No	Yes

Here, *** p<0.01, ** p<0.05, * p<0.1 and robust standard errors are presented in parentheses. All figures in the table are rounded to three decimal points. In all specifications that feature country-specific trends, a quadratic trend is incorporated along with the linear trend. The inclusion of covariates in the sample resulted in the loss of seven countries from the analysis. While the constant term is included in the model specification, it is not reported in the table, as it holds no significant implication in the context of a multivariate model.

Third, we incorporate renewable energy policy implementation, gross enrollment ratio in primary education (% share) and per capita electricity generation from fossil fuel as additional control variables in the same model. This is designed to specifically reflect how conducive the domestic environment is to facilitating the adoption and diffusion of renewable energy and in accordance with extensive usage of these variables in the previous literature. The outcomes of this test are detailed in Table C.3 of Appendix C. The inclusion of the additional control variable leads to a significant positive coefficient between the main explanatory variable and the dependent variable in models with country fixed effects, year fixed effects, and country-specific trends, observed under both standard error and robust standard error settings. Similar results were obtained with only country-fixed effects. However, the combination of country-fixed effects and country-specific trend results in a significant coefficient at 10% significance level for the main explanatory variable. In the case of robust standard errors, most covariates, with the exception of CO_2 emissions per capita, are found to be insignificant. Additionally, the inclusion of the additional control variables does not significantly alter the R-squared value compared to our original proposed specification.

Fourth, following Fadly and Fontes (2019), who noted that countries do not immediately respond to new technology adoption patterns due to typical time lags, we have conducted sensitivity tests on our results. These tests involve including one-year and two-year lags of our import share-weighted renewable energy patent index in our regression models. The outcomes of these analyses are detailed in Table C.4. Our analysis demonstrates that incorporating one and two-year lags of the main explanatory variable—under settings with country fixed effects, year fixed effects, and country-specific trends—yields positive significant coefficients between the main explanatory variable and the dependent variable. However, in other settings without these specific trends, the contemporaneous value shows no significant coefficients. Overall fitness of the model and the consistency of results with our original proposed specification indicate that the additional lags do not significantly alter the outcome, suggesting that our model effectively captures the dynamics without them. Moreover, Positive significant coefficients emerge under country-fixed effects and country-specific trends when covariates are included; however, these coefficients become insignificant in the absence of covariates. Interestingly, significant positive coefficients are observed in the additional lags under models with only country fixed effects. This suggests that while the extended lag structure can reveal delayed effects in some settings, our streamlined proposed specification, which does not include these additional lags, remains parsimonious and adequately robust for our analysis purposes. The same exercise has been carried out using robust standard errors and similar outcomes[17], illustrated in Table C.5, are observed.

Fifth, in the analysis stratified by innovation status, outlined in Table C.6, we observe distinct patterns between innovator and non-innovator countries. For non-innovator countries, both the standard model and the robust error model reveal positive significant coefficients for the import share-weighted patent index. This indicates that non-innovator countries significantly benefit from their exposure to the renewable energy knowledge stock of their trading partners. Specifically, the positive coefficients suggest that an increase in the importation of goods from countries rich in renewable energy knowledge stock correlates with enhanced renewable energy generation within these non-innovating nations. This reflects a successful transfer of technology through import. In contrast, innovator countries do not show significant coefficients, implying that the diffusion of renewable energy technology within these countries is not primarily driven by imports. This could reflect a higher internal generation of such technologies or a different mechanism of technology adoption that does not rely heavily on importation. The R-squared values, exceeding 80% for models across both groups, indicate a robust model fit, suggesting that the models effectively capture the dynamics of renewable energy generation across different country innovation statuses. This stratification further reinforces the robustness of our proposed specification, enhancing its validity once more.

Sixth, in the regression analyses presented in Table C.7, stratified by educational attainment levels, it is evident that countries with higher education levels exhibit a positive and statistically significant relationship between the exposure to renewable energy knowledge through imports and the adoption of renewable technologies, confirmed at a 5% significance level under both standard and robust error models. On the contrary, for countries that fall below the median education threshold, the association between the import-share weighted patent index and renewable energy adoption emerges as statistically

[17] When using robust standard errors with covariates, country-fixed effects and country-specific trends, the main coefficient is significant at the 10% level [specification (5) in Table C.5]; however, with standard errors, it reaches significance at the 5% level [specification (5) in Table C.5].

insignificant[18]. This pattern highlights the critical role of education in facilitating the effective assimilation and implementation of imported renewable energy technologies. It suggests that enhancing educational standards could serve as a strategic policy lever to bolster a country's capability to harness and capitalize on renewable energy innovations through import, potentially accelerating the transition towards sustainable energy solutions. The consistently high R-squared values, which exceed 80%, underscore the robustness of these findings across educational divides, affirming the substantial impact of educational factors on the diffusion and adoption of advanced technologies. Lastly, the coefficient values of the stratified analysis are relatively close in magnitude to those observed in our parsimonious proposed specification.

4 Conclusion

This paper has explored how renewable energy technology diffusion is influenced by trade relations focusing on the role of direct trade in transferring technology from countries with advanced renewable energy knowledge to those with less. Our findings underscore the importance of direct trade, especially import, interactions for renewable energy technology diffusion, suggesting that imports from countries rich in renewable energy knowledge stock can significantly impact the adoption of renewable technologies in importing nations.

Empirically, we developed indices to assess exposure to renewable energy technologies through imports from countries that are leaders in this field. Our proposed model specification is parsimonious and robust, and our findings indicate a clear positive correlation between these indexes and the adoption of renewable energy in importing nations, suggesting that enhanced access to cutting-edge technologies through imports is linked to increased adoption levels. This reinforces the idea that direct imports from technologically advanced countries can significantly improve a country's renewable energy capabilities. Between the indices tested, the import-share weighted patent index proved more effective than the import-GDP weighted patent index in predicting renewable energy adoption. While this study focuses primarily on direct import channels, it does not encompass indirect trade paths, exports, or aggregate trade measurements, highlighting important avenues for future research to further explore the dynamics of technology diffusion across different trading relationships (Ferrier, Reyes, & Zhu, 2016; Fadly & Fontes, 2019; Ayerst, et al., 2023; Fagiolo, 2010).

The findings of this study underscore significant policy implications, particularly in the context of renewable energy technology diffusion through trade. First, the results demonstrate that non-innovator countries are more likely to adopt renewable energy technologies through increased trade exposure, particularly imports from countries with advanced renewable technology sectors. Second, our analyses

[18] When using robust standard errors with covariates, country-fixed effects and country-specific trends, the main coefficient is significant at the 10% level [specification (5) in Table C.7]; however, with standard errors, it reaches significance at the 5% level [specification (3) and (4) in Table C.7].

suggest that policies aimed at reducing trade (import) barriers and fostering stronger trade relations with technologically advanced nations can significantly enhance the adoption of renewable energies in these non-innovator countries. Third, our analysis highlights the importance of educational development alongside trade liberalization. In lower education countries, the capacity to utilize technology spillovers from import effectively is often hindered by inadequate educational infrastructure and a lack of technical skills. Fourth, economic, trade and foreign policies should not only focus on lowering physical and economic barriers to trade but also on strategically building partnerships with countries that have a successful track record of implementing and supporting renewable energy technologies. Such strategic alliances could accelerate the diffusion process, making it more widespread and effective, particularly in regions where technological uptake has been slow due to various constraints such as capital limitations, inadequate policy support, or simply a lack of technology-specific knowledge.

The future of research in renewable energy technology diffusion should aim to explore several areas that this study has identified as vital for a more comprehensive understanding. Future studies could expand on the indirect trade paths and the roles of exports and total trade, which this study did not fully address. Investigating these aspects could provide insights into how different forms of trade contribute to technology diffusion and whether indirect relationships through third countries play a significant role in spreading renewable energy technologies. Additionally, examining the differential impacts of various types of renewable energies could also be valuable, as the adoption patterns and diffusion dynamics might vary significantly between technologies like solar, wind, and bioenergy.

In conclusion, this study has illuminated the pivotal role of trade, particularly imports, in facilitating the diffusion of renewable energy technologies across borders. By highlighting how non-innovator countries significantly benefit from import-induced technology spillovers, it emphasizes the need for targeted policies that encourage not only the reduction of trade barriers but also substantial investments in education and infrastructure to optimize these benefits. As the world moves towards a more sustainable and energy-efficient future, understanding and harnessing the dynamics of renewable energy technology diffusion through international trade will be crucial in shaping effective and inclusive environmental and economic policies.

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Appendix A

Table A.1: List of countries with the total number of renewable energy patents accumulated from 2000 to 2021

Sl.	Country	Patent	Sl.	Country	Patent	Sl.	Country	Patent
1	Algeria	8	28	Greece	875	55	Panama	14
2	Argentina	1774	29	Guatemala	62	56	Peru	535
3	Australia	19984	30	Honduras	13	57	Philippines	999
4	Austria	4780	31	Hong Kong	1552	58	Poland	5625
5	Belarus	1	32	Hungary	1273	59	Portugal	3239
6	Belgium	482	33	Iceland	42	60	Romania	901
7	Brazil	12576	34	India	1205	61	Russia	13123
8	Bulgaria	293	35	Indonesia	6	62	San Marino	44
9	Canada	19576	36	Ireland	169	63	Saudi Arabia	241
10	Chile	2096	37	Israel	3082	64	Serbia	415
11	China	440406	38	Italy	3730	65	Singapore	2627
12	Colombia	599	39	Japan	98681	66	Slovakia	395
13	Costa Rica	166	40	Jordan	58	67	Somalia	3867
14	Croatia	960	41	Kazakhstan	6	68	South Africa	3867
15	Cuba	164	42	Korea, Rep.	83939	69	Spain	15154
16	Cyprus	549	43	Latvia	128	70	Sweden	983
17	Czechia	1045	44	Lithuania	446	71	Switzerland	871
18	Denmark	8476	45	Luxembourg	104	72	Taiwan	21406
19	Dominican Republic	76	46	Malaysia	984	73	Tajikistan	4
20	Ecuador	194	47	Mexico	6024	74	Tunisia	531
21	Egypt	235	48	Moldova	302	75	Turkey	950
22	El Salvador	20	49	Montenegro	56	76	Ukraine	2534
23	Estonia	74	50	Morocco	1519	77	United Kingdom	8984
24	Finland	915	51	Netherlands	1966	78	USA	135927
25	France	8052	52	New Zealand	2539	79	Uruguay	232
26	Georgia	106	53	Nicaragua	50	80	Vietnam	2
27	Germany	39261	54	Norway	1731			

Source: Authors' calculation based on the data found in Our World in Data

Appendix B: Details of Data Description

Variables	Description	Unit	Source
Bilateral import volume	The import data has been taken into the mirror format despite some limitations of mirror data. Although better than having no data (Carrère & Grigoriou, 2015), mirror data has several limitations: it does not capture trade between non-reporting countries, thus inaccurately representing intra-African trade. Additionally, issues like transshipment can obscure the true origin of goods. Mirror data also inverts reporting standards by valuing exports on a CIF basis (including transportation and insurance) and imports on an FOB basis (excluding these costs). Furthermore, the varying number of reporting countries year-to-year complicates temporal comparisons, requiring cautious interpretation of trends (Markowicz & Baran, 2020; Meshcheryakova & Shvydun , 2024).	USD Thousand	ITC-Trade Map (ITC, 2022)

Number of patents filed on renewable energy technology	The data pertains solely to patents filed on renewable energy technologies, excluding those related to energy storage or transport. From the original data source, it can be found that data for the two most recent years are incomplete due to a lag between the filing date and the official publication of patents. Therefore, data for the past two years are not fully available. The original data is sourced from the EPO PATSTAT 2023 Autumn edition and classified under the Climate Change Mitigation Technologies (Y02) category (IRENA, 2024).	Patents number	Our World in Data (OWID, 2023) and IRENA – INSPIRE Platform (IRENA, 2024)
Electricity generation from renewable energy sources	Renewable energy encompasses electricity production from hydropower, solar, wind, biomass and waste, geothermal, wave, and tidal sources. Electricity production for each renewable source has been added for a year to determine the total electricity generation for a country in a particular year. OWID primarily uses electricity data from Ember. Although the Energy Institute (EI) offers primary energy consumption data with a longer time series dating back to 1965, compared to Ember's data starting in 1990, EI does not cover all countries or all sources of electricity (e.g., electricity from bioenergy is only available from Ember). Therefore, OWID relies on Ember as the primary source of electricity data whenever it is available for a given country and year, and supplements it with data from EI when Ember's data is not available (Ritchie, Rosado, & Roser, 2024).	Tw-H	Our World in Data (Ritchie, Rosado, & Roser, Renewable Energy, 2024)
Share of electricity from renewable energy sources	Renewable energy encompasses electricity production from hydropower, solar, wind, biomass and waste, geothermal, wave, and tidal sources. The aforementioned methodology of interchangeably using Ember and EI, outlined for measuring electricity generation from renewable energy sources, is applied to this case as well (Ritchie, Rosado, & Roser, 2024).	Percentage of total electricity	Our World in Data (Ritchie, Rosado, & Roser, Renewable Energy, 2024)
Yearly count of domestic and national level renewable energy policy	The renewable energy policy database covers the following broad sectors: Power, heat and utilities, electricity and heat generation, power generation, economy-wide (multi-sector), transport, heating and cooling, buildings, industry, fuel processing and transformation, and combined heat and power. It also covers the following technologies: Solar PV, solar, wind, electricity generation and combined heat and power technologies, hydropower (excluding pumped hydro), solar thermal heaters, transport technologies, geothermal electricity (IEA, 2024).	Yearly number of renewable energy policies	International Energy Agency (IEA, 2024)
Real GDP	Gross Domestic Product (GDP) at purchaser's prices is calculated as the sum of the gross value added by all resident producers in the economy, plus any product taxes and minus any subsidies not included in the value of the products. The data are expressed in constant 2015 U.S. dollars, with dollar figures for	USD	WDI (World Bank, 2024)

	GDP converted from domestic currencies using the 2015 official exchange rates (World Bank, 2024).		
GDP Per capita	GDP per capita is simply the ratio of real GDP (expressed in constant 2015 U.S. dollars) and total population.	USD	WDI (World Bank, 2024)
Total population	For Taiwan, Palestine, and Montserrat, where data on total population were missing in WDI, we sourced the population data from OWID, where data for these countries are available (Ritchie, et al., 2023).	Number of populations	WDI (World Bank, 2024) and OWID (Ritchie, et al., 2023)
Average Worldwide Governance Indicator	The World Bank Institute defines governance as the traditions and institutions through which authority is exercised within a country. This concept is comprehensively measured by the Worldwide Governance Indicators, which assess six key dimensions: voice and accountability, political stability and absence of violence or terrorism, government effectiveness, regulatory quality, rule of law, and control of corruption. Following the methodology employed by the NLiS averaged aggregate governance indicators from WHO (2024), we simplify the indicator to an average score for these six dimensions, each represented by its percentile rank, to provide a nuanced and broad assessment of governance.	Percentile rank	World Bank (Raina, 2024)
CO_2 Emissions and Per Capita CO_2 Emissions	Annual CO_2 emissions represent the total emissions of carbon dioxide (CO_2) for a year, excluding those from land-use change. We create the per capita version of the variable by normalizing the CO_2 emissions with population. OWID has sourced annual CO_2 emissions data from the Global Carbon Project. It is measured by million tonnes per capita.	Million tonnes	Our World in Data (Ritchie & Roser, CO_2 emissions, 2024)
Gross Enrollment Ratio in Primary Education	The number of children enrolled in primary education, expressed as a percentage of the total population of the official primary school age, encompasses children of any age group (UNESCO Institute for Statistics, 2024).	%	UNESCO Institute for Statistics and OWID (UNESCO Institute for Statistics, 2024)
Electricity generation from fossil fuels per person	The data has been sourced from Our World in Data (OWID), which primarily processes information from original sources. When available, data for a specific country and year is primarily sourced from Ember; otherwise, it is supplemented with data from the Energy Institute where Ember's data is lacking.	Kw-H per capita	Our World in Data (OWID, 2024)
Average years of schooling	The average number of years of formal education is a statistical measure indicating the total years of schooling that an adult over the age of 25 has received. This includes all forms of structured educational programs that adhere to a standard curriculum, ranging from primary and secondary schooling to tertiary education, but does not include informal or self-directed learning experiences.	Years	Our World in Data and UNDP (UNDP, 2024)

Education classification group (median based)	The education classification has been categorized into two segments: higher education group and lower education group. This categorization is anchored on the median value of average years of schooling across all countries in 2021, which is 7.45818 years.	Years	Authors' calculation based on the data from average years of schooling

Appendix C: Robustness tests

Table C.1: Regression results – renewable energy generation per capita and import-GDP weighted patent index

Dependent Variable: Log of per capita renewable energy generation

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Import-GDP weighted	3.001***	0.121	0.100	2.517***	0.0873	0.09
patent index (Std.)	(0.207)	(0.169)	(0.192)	(0.203)	(0.194)	(0.194)
GDP pc (Std.)				0.861***	0.362***	0.004
(0.067)					(0.066)	(0.067)
Population (Std.)				0.859***	0.000879	-0.424
(0.127)					(0.123)	(1.845)
CO_2 Emissions pc				-0.066***	-0.029***	-0.033***
(0.009)					(0.009)	(0.009)
Observations	3,352	3,352	3,352	3,258	3,258	3,258
R-squared (Within)	0.062	0.863	0.865	0.143	0.275	0.866
Number of countries	179	179	179	172	172	172
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Country-specific trend	No	Yes	Yes	No	No	Yes
Year-fixed effect	No	No	Yes	No	Yes	Yes

Here, *** $p<0.01$, ** $p<0.05$, * $p<0.1$ and standard errors are presented in parentheses. All figures in the table are rounded to three decimal points. In all specifications that feature country-specific trends, a quadratic trend is incorporated along with the linear trend. The inclusion of covariates in the sample resulted in the loss of seven countries from the analysis. While the constant term is included in the model specification, it is not reported in the table, as it holds no significant implication in the context of a multivariate model.

Table C.2: Regression results – renewable energy generation per capita and import-GDP weighted patent index

Dependent Variable: Log of per capita renewable energy generation						
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Import-GDP weighted	3.001***	0.121	0.100	2.517**	0.111	0.087
patent index (Std.)	(1.125)	(0.172)	(0.184)	(1.044)	(0.171)	(0.182)
GDP pc (Std.)				0.861***	-0.0171	0.004
(0.325)					(0.051)	(0.065)
Population (Std.)				0.859**	-0.137	-0.424
(0.338)					(2.913)	(3.027)
CO_2 Emissions pc				-0.0657**	-0.032**	-0.033**
(0.0262)					(0.013)	(0.013)
Observations	3,352	3,352	3,352	3,258	3,258	3,258
R-squared (Within)	0.062	0.863	0.865	0.143	0.864	0.866
Number of countries	179	179	179	172	172	172
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Country-specific trend	No	Yes	Yes	No	No	Yes
Year-fixed effect	No	No	Yes	No	Yes	Yes

Here, *** p<0.01, ** p<0.05, * p<0.1 and robust standard errors are presented in parentheses. All figures in the table are rounded to three decimal points. In all specifications that feature country-specific trends, a quadratic trend is incorporated along with the linear trend. The inclusion of covariates in the sample resulted in the loss of seven countries from the analysis. While the constant term is included in the model specification, it is not reported in the table, as it holds no significant implication in the context of a multivariate model.

Table C.3: Regression results – renewable energy generation per capita and import share-weighted patent index, with RE policy implementation index, electricity generation from fossil fuel and gross enrolment ratio in primary education as added covariate

Dependent Variable: Log of per capita renewable energy generation						
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Import share-weighted	0.211***	0.018*	0.036**	0.211***	0.018	0.036**
patent index (Std.)	(0.013)	(0.010)	(0.016)	(0.041)	(0.011)	(0.016)
RE Policy Imp.	0.102*	0.108**	0.113***	0.102	0.108	0.113
Index (Std.)	(0.056)	(0.043)	(0.043)	(0.126)	(0.066)	(0.070)
GDP pc (Std.)	0.881***	-0.041**	-0.007	0.881**	-0.041	-0.007
(0.071)		(0.018)	(0.068)	(0.401)	(0.032)	(0.090)
Population (Std.)	0.307**	-0.411***	-1.160	0.307	-0.411***	-1.160
(0.138)		(0.066)	(1.896)	(0.239)	(0.142)	(1.481)
CO_2 Emissions pc	-0.106***	-0.016	0.005	-0.106**	-0.016	0.005
(0.013)		(0.066)	(0.011)	(0.053)	(0.070)	(0.013)
Electricity Generation	0.292***	-1.235	-0.406***	0.292	-1.235	-0.406***
- Fossil Fuel pc (Std.)	(0.082)	(1.879)	(0.066)	(0.332)	(1.355)	(0.140)
Enrollment, primary	-0.108***	0.007	-0.039**	-0.108	0.007	-0.039
- % gross (Std.)	(0.019)	(0.011)	(0.018)	(0.068)	(0.013)	(0.031)
Observations	2,873	2,873	2,873	2,873	2,873	2,873
R-squared (Within)	0.214	0.881	0.884	0.214	0.881	0.884
Number of countries	167	167	167	167	167	167
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Country-specific trend	No	Yes	Yes	No	Yes	Yes
Year-fixed effect	No	No	Yes	No	No	Yes
Error type	Standard	Standard	Standard	Robust	Robust	Robust

Here, *** p<0.01, ** p<0.05, * p<0.1 and standard errors for model (1), (2) and (3), and robust standard errors for model (4), (5) and (6) are presented in parentheses. All figures in the table are rounded to three decimal points. In all specifications that feature country-specific trends, a quadratic trend is incorporated along with the linear trend. The inclusion of covariates in the sample resulted in the loss of seven countries from the analysis. While the constant term is included in the model specification, it is not reported in the table, as it holds no significant implication in the context of a multivariate model.

Table C.4: Regression results - renewable energy generation per capita and import-share weighted patent index, with additional lags

Dependent Variable: Log of per capita renewable energy generation						
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Import share-weighted patent index (Std.)						
t	-0.002	0.012	0.031**	0.007	0.021**	0.050***
(0.019)		(0.009)	(0.014)	(0.020)	(0.010)	(0.016)
t – 1	0.124***	0.008	-0.016	0.132***	0.015	-0.013
(0.042)		(0.023)	(0.027)	(0.043)	(0.024)	(0.028)
t -2	0.115**	0.028	-0.011	0.112**	0.029	-0.013
(0.046)		(0.025)	(0.030)	(0.048)	(0.027)	(0.032)
GDP pc (Std.)				0.603***	0.061	0.083
(0.071)					(0.069)	(0.071)
Population (Std.)				0.113	0.444	0.566
(0.147)					(1.820)	(1.824)
CO_2 Emissions pc				-0.064***	-0.031***	-0.031***
(0.009)					(0.009)	(0.009)
Observations	3,057	3,057	3,057	2,972	2,972	2,972
R-squared (Within)	0.131	0.865	0.868	0.192	0.866	0.869
Number of countries	179	179	179	172	172	172
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Country-specific trend	No	Yes	Yes	No	Yes	Yes
Year-fixed effect	No	No	Yes	No	No	Yes

Here, *** p<0.01, ** p<0.05, * p<0.1 and standard errors are presented in the parentheses. All figures in the table are rounded to three decimal points. In all specifications that feature country-specific trends, a quadratic trend is incorporated along with the linear trend. The inclusion of covariates in the sample resulted in the loss of seven countries from the analysis. While the constant term is included in the model specification, it is not reported in the table, as it holds no significant implication in the context of a multivariate model.

Table C.5: Regression results - renewable energy generation per capita and import-share weighted patent index, with additional lags and robust standard errors

Dependent Variable: Log of per capita renewable energy generation						
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Import share-weighted patent index (Std.)						
t	-0.002	0.012	0.031*	0.007	0.0205*	0.050***
(0.017)		(0.012)	(0.018)	(0.020)	(0.0113)	(0.015)
t-1	0.124***	0.008	-0.016	0.132***	0.0148	-0.013
(0.039)		(0.020)	(0.025)	(0.043)	(0.0220)	(0.026)
t-2	0.115**	0.028	-0.011	0.112**	0.0293	-0.013
(0.048)		(0.027)	(0.027)	(0.054)	(0.0297)	(0.030)
GDP pc (Std.)				0.603**	0.0613	0.083
(0.280)					(0.0544)	(0.058)
Population (Std.)				0.113	0.444	0.566
(0.346)					(2.867)	(2.979)
CO_2 Emissions pc				-0.064**	-0.0306**	-0.031**
(0.026)					(0.013)	(0.014)
Observations	3,057	3,057	3,057	2,972	2,972	2,972
R-squared (Within)	0.131	0.865	0.868	0.192	0.866	0.869
Number of countries	179	179	179	172	172	172
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	No	No	Yes	No	No	Yes
Country-specific trend	No	Yes	Yes	No	Yes	Yes

Here, *** p<0.01, ** p<0.05, * p<0.1 and robust standard errors are presented in the parentheses. All figures in the table are rounded to three decimal points. In all specifications that feature country-specific trends, a quadratic trend is incorporated along with the linear trend. The inclusion of covariates in the sample resulted in the loss of seven countries from the analysis. While the constant term is included in the model specification, it is not reported in the table, as it holds no significant implication in the context of a multivariate model.

Table C.6: Regression results - renewable energy generation per capita and import-GDP weighted patent index, stratified by innovator and non-innovator group

Dependent Variable: Log of per capita renewable energy generation				
	(1)	(2)	(3)	(4)
VARIABLES	Non-innovators	Non-innovators	Innovators	Innovators
Import share-weighted	0.045**	0.045**	0.033	0.033
patent index (Std.)	(0.023)	(0.019)	(0.023)	(0.023)
GDP pc (Std.)	-0.058	-0.058	0.175	0.175
	(0.088)	(0.057)	(0.120)	(0.160)
Population (Std.)	-2.504	-2.504	0.434	0.434
	(4.167)	(12.05)	(1.805)	(1.244)
CO_2 Emissions pc	-0.032**	-0.032*	-0.039***	-0.039*
	(0.013)	(0.017)	(0.013)	(0.020)
Observations	1,665	1,665	1,593	1,593
R-squared (Within)	0.817	0.817	0.913	0.913
Number of countries	94	94	78	78
Country-fixed effect	Yes	Yes	Yes	Yes
Country-specific trend	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes
Error type	Standard	Robust	Standard	Robust

Here, *** p<0.01, ** p<0.05, * p<0.1 and standard errors for model (1) and (3), and robust standard errors for model (2) and (4) are presented in parentheses. The table only contains regression estimates from our proposed specification, under standard error and robust error settings. All figures in the table are rounded to three decimal points. In all specifications that feature country-specific trends, a quadratic trend is incorporated along with the linear trend. The inclusion of covariates in the sample resulted in the loss of seven countries from the analysis. While the constant term is included in the model specification, it is not reported in the table, as it holds no significant implication in the context of a multivariate model.

Table C.7: Regression results - renewable energy generation per capita and import-GDP weighted patent index, stratified by high and low education group of countries

Dependent Variable: Log of per capita renewable energy generation				
(1)		(2)	(3)	(4)
VARIABLES	High education	High education	Low education	Low education
Import share-weighted	0.044**	0.044**	0.0416	0.0416*
patent index (Std.)	(0.019)	(0.020)	(0.0311)	(0.0217)
GDP pc (Std.)	0.141	0.141	-0.640	-0.640
(0.120)		(0.171)	(1.955)	(2.798)
Population (Std.)	-0.631	-0.631	3.210	3.210
(2.035)		(1.853)	(4.046)	(8.685)
CO_2 Emissions pc	-0.032***	-0.032**	-0.157***	-0.157
(0.010)		(0.015)	(0.0522)	(0.135)
Observations	2,169	2,169	975	975
R-squared (Within)	0.893	0.893	0.817	0.817
Number of countries	114	114	52	52
Country-fixed effect	Yes	Yes	Yes	Yes
Country-specific trend	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes
Error type	Standard	Robust	Standard	Robust

Here, *** $p<0.01$, ** $p<0.05$, * $p<0.1$ and standard errors for model (1) and (3), and robust standard errors for model (2) and (4) are presented in parentheses. The table only contains regression estimates from our proposed specification, under standard error and robust error settings. All figures in the table are rounded to three decimal points. In all specifications that feature country-specific trends, a quadratic trend is incorporated along with the linear trend. The inclusion of covariates in the sample resulted in the loss of seven countries from the analysis. While the constant term is included in the model specification, it is not reported in the table, as it holds no significant implication in the context of a multivariate model.

Climate-Driven Temporal Analysis of Global Agricultural Trade Networks: Past and Predictive Insights on Essential Crops

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1 Introduction

Global agricultural trade is crucial for the economic stability and growth of developing countries. These nations have increasingly relied on international trade to obtain essential goods, benefiting both from the income it generates and the stabilizing effect on their economies [Kummu et al., 2020]. This strategic emphasis on agriculture is partly due to the effectiveness of agricultural exports in driving economic growth, often more significantly than the expansion of domestic market demand [Aksoy and Beghin, 2005]. As of 2014, the global agricultural trade was valued at approximately one trillion dollars and has been growing steadily at about 3.6 percent per year over the last two decades [Beckman et al., 2017].

However, this vital economic pillar is under significant threat from climate change, which poses numerous chal- lenges to food systems worldwide. Climate change impacts agricultural trade directly through effects on crop produc- tion, as temperature changes affect the length of growing seasons and thus significantly alter crop yields [Gregory et al.]. As a result, developing countries face heightened risks of economic instability and food insecurity [Dasgupta and Robinson, 2022], a condition defined by the Food and Agriculture Organization (FAO) as a lack of regular ac- cess to enough safe and nutritious food for normal growth and development and an active and healthy life [Food and Agriculture Organization of the United Nations, 2023].

The increasing effects of climate change are felt not just by developing countries but also by developed ones, making this a global threat. This necessitates a critical analysis of the trade dynamics between major trading coun- tries for essential crops. This study specifically focuses on some of the most traded and indispensable crops, such as wheat, beans, and potatoes. The strength of these countries' ties in agricultural trade will largely determine their resilience in the face of climate change. The network model, with its inherent architecture, allows us to look closer at the dynamics of such trade ties and corresponding resilience under climate threats. With these ever- evolving connections, it becomes crucial to employ predictive data analysis to better understand future trends in agricultural outputs and trade dynamics. This method allows for proactive planning, shifting away from merely re- active responses to changes. Effective prediction models can help create strategies that could have the potential to strengthen the agricultural trade network and reduce the risk of food insecurity globally.

2 Literature Review

Existing literature has already demonstrated the usefulness of sophisticated modeling techniques such as Agent Based Modeling (ABM) and Complex Network Analysis (CNA) in dissecting the changes in agricultural trade and its susceptibility to various stressors. ABM, for instance, has proven effective in simulating the decisions and behaviors of individual agents, such as farmers, under diverse scenarios; this offers information about behavioral adaptations in response to external pressures [Namany et al., 2020]. Similarly, CNA has been utilized to look at both the stream flow and the strength of agri-food exchange systems against shocks, explaining the structural vulnerabilities within global food trade systems [Gutiérrez-Moya et al., 2020].

Yet, current research in agricultural production forecasting reveals a significant lack of models that specifically focus on temperature changes, a major effect of climate change, and their global impacts on crop yields. Most studies are region-specific and do not address the broader global context needed for comprehensive analysis. For example, research by [Adhikari et al., 2015] specifically addresses predictions of crop yields in Africa. This focus on localized studies, while valuable, limits the understanding required to formulate global agricultural strategies and policies.

In contrast, this study takes a different approach by adopting a wider lens in relation to the impacts of temperature changes on different countries' crop yields. It also expands the focus from regional to global scales, incorporating historical data as well as predictive analysis to give a comprehensive outlook on agricultural trends over time. By doing so, the study seeks to bridge the critical gaps left by prior research and aid in the crafting of effective agricultural policies aimed at decreasing the impacts of climate change.

3 Research Objective

The main aim of this study is to comprehensively assess how different major agricultural products respond to global climate change. Given the rate of climate change, it is crucial to be able to understand the overall effects of climate variability on specific staple crops and their trade dynamics. Specifically, the global trade patterns of crops critical for food security and highly sensitive to climatic conditions are considered, including beans (dry), wheat, and potatoes.

- Beans (dry): Beans are a vital source of protein, particularly in developing countries. The cultivation of beans is greatly affected by specific temperature and moisture conditions. Their susceptibility to drought and excessive rainfall can drastically affect global trade flows.
- Wheat: Essential for global food security, wheat is primarily vulnerable to heat stress during key growth phases. Temperature fluctuations and water scarcity can lead to reduced yields, which can impact the crop's availability.
- Potatoes: Potatoes are a major staple diet worldwide and require precise climate conditions for growth. They are affected by heat stress and water shortages, which can lead to decreased quality and yields.

Firstly, the study aims to unveil the recent trends (2022) in the trading dynamics of essential crops. The key nodes in this year are identified in each agricultural trade network focusing specifically on their exports and imports. By utilizing the Louvain Community Detection Algorithm on the key nodes, the research aims to highlight the strongest communities within these networks as well as the immediate and long-term effects of climate fluctuations on global agricultural trade. Secondly, the study has developed specialized visualizations that portray centrality measures across different countries for specific crops from the past 37 years. These visualizations mark peak values to clarify long-term trade dynamics and illustrate the considerable differences in trade impacts among crops and within the same country. Thirdly, to aid policymakers and economists in strategic planning for future events, the research will predict agricultural trade volumes for the crops from 2022 to 2040. This is achieved by testing various forecasting models such as Auto ARIMA, Linear Regression, Polynomial Regression, and Gaussian Processes. This approach provides a spectrum of perspectives on future trade dynamics and helps determine the most comprehensive forecasting model by comparing their effectiveness side by side. Furthermore, using the most well-rounded model, the study makes a comparative analysis of the trade quantities from past data (2006) and projected future data (2038), framed as sixteen-year trend markers before and after 2022. By applying community detection methods to both datasets, the research will assess how trade communities are restructuring in response to changing climate conditions. Finally, the study will outline strategic interventions aimed at bolstering resilience within global agricultural trade networks in response to climate change. These strategies will focus on key areas such as enhancing cooperative trade practices, developing regional hubs for agricultural innovation, and strengthening key trade nodes to improve overall network stability. By leveraging mutual support between nations and integrating advanced agricultural technologies, the research intends to facilitate responses to environmental challenges and enhance global food security.

4 Methodology

4.1 FAO Data Filtering

The specific data on global production and trade for the crops considered in this study were obtained from the Food and Agriculture Organization of the United Nations (FAO) using their FAOSTAT platform. This source provided comprehensive statistics crucial for understanding the overall landscape of agricultural trade [Food and Agriculture Organization of the United Nations, 2024].
To ensure the effectiveness of the analysis of global agricultural trade for key crops of wheat, beans, and potatoes, this data underwent a preprocessing routine tailored to the needs of this study. This included selectively filtering the dataset to retain only those crops and countries directly relevant to the study's objectives for more precise analysis. In terms of specific variables, the dataset initially contained a wide array of attributes. To streamline the analysis, non-essential columns were removed, focusing on key attributes necessary for the research. The retained attributes included the 'Reporter Country', whose role as exporter or importer depends on the 'Element', and the 'Partner Country', which is the corresponding importer or exporter. The 'Item' column identifies the crop type, the 'Element' differentiates between export and import quantities, and the 'Trade Quantity (tons)' standardizes all trade measurements to tons for uniformity.

4.2 Introduction to Network Analysis

Network analysis is a methodology in which the corresponding dataset is examined as the structure of a system containing various nodes and edges. Although it is widely adopted in various subjects such as biology, physical sciences, transportation, and social networks, it is a revered route for the analysis of trade data as well [Bhattacharya et al., 2008]. In the context of this paper, each node in a network represents a country involved in the trade of agricultural products of beans, wheat, or potatoes. The edges, or lines connecting these nodes, illustrate the trade connections between these countries. The thickness of these edges is directly proportional to the trade volume, serving as a visual indicator of the intensity of trade activities between any two connected countries. The employment of a network model also provides the possibility to study clustering effects (such as community detection) and various other statistical measures related to the dynamics and criticality of the constituent nodes and edges. A brief working methodology of the employed network-based analysis is outlined below.

4.3 Louvain Algorithm

The Louvain algorithm is a widely used method for detecting communities in large networks and will be applied in section 5.2 of our analysis. This algorithm is based on the optimization of the modularity score, which quantifies the strength of division of a network into communities [Gupta, 2022]. Mathematically, modularity Q is defined as:

$$Q = \frac{1}{2m} \sum_{ij} \left[A_{ij} - \frac{k_i k_j}{2m} \right] \delta(c_i, c_j)$$

Where:

- m = the sum of all edge weights in the network (if unweighted graph, the sum of edges)
- A_{ij} = weight of the edge between node i and node j; in an unweighted graph, this is 1 if there is an edge between nodes i and j, and 0 otherwise.
- k_i is the degree (total connections) of some node i.
- $\delta(c_i, c_j) = 1$ if both node i & node j are in the same community, and 0 otherwise.

The algorithm begins by considering each node (country, in our case) as its own community. It then progressively merges nodes into larger communities, aiming to maximize the overall modularity of the network. This process continues iteratively until the modularity reaches its maximum value.

4.4 Centrality Measures

Degree centrality is defined as the number of connections a node has. For a node i, the degree centrality is given by:

$$C_D(i) = \frac{\text{deg}(i)}{n-1}$$

where $\deg(i)$ is the degree of the node i, and n is the total number of nodes in the network.
Closeness centrality measures the average length of the shortest path from a node to all other nodes in the network, thus reflecting how close a node is to all other nodes. It is defined as:

$$C_C(i) = \frac{n-1}{\sum_{j \neq i} d(i,j)}$$

wh e $d(i,j)$ is the distance between nodes i and j.
er
Betweenness centrality quantifies the number of times a node acts as a bridge along the shortest path between two other nodes. It is expressed as:

$$C_B(i) = \sum_{s \neq i \neq t} \frac{\sigma_{st}(i)}{\sigma_{st}}$$

where σ_{st} is the total number of shortest paths from node s to node t and $\sigma_{st}(i)$ is the number of those paths that pass through node i.

4.5 Preview on Prediction Forecasting Models

Finally, to improve the study's accuracy in predicting agricultural trade volumes, a detailed subsection on prediction models has been added to the results section of the paper. This addition is critical given the complexity of the database in the past 37 years, shaped by geopolitical, cultural, historical, and other factors. A single forecasting model might not suffice due to different mathematical foundations and design purposes tailored to specific types of data. Therefore, by evaluating multiple models based on their performance across 15 total test cases, we can discern which are capable of capturing essential trends, such as obvious uptrends or downtrends, and which can adjust to the abrupt changes dictated by external variables. Each model was ranked according to how effectively it managed to handle the scenarios presented. In some instances, more than one model proved effective for a specific test case. Detailed insights into the performance of each model, including the rationale behind the selection of the most suitable model, are elaborated in section 5.4.

5 Results

5.1 Current Key Trading Countries and Crop Networks

It is first imperative to study the current trend in the chosen trade commodities. We chose 2022 because it provides the most recent and complete data set available from FAO.
Using various data sources, the major countries involved in the trade network in 2022 were identified for beans, potatoes, and wheat:

- Potatoes and Wheat: Trade data detailing the major countries involved in the trade networks of potatoes and wheat was sourced from [The Observatory of Economic Complexity, 2024] This data helped in mapping out the flow of these commodities between significant trading countries.

- Dry Beans: Information on the major countries within the dry beans trade network was collected from several sources to ensure a robust analysis. These included [Tridge, 2024], which provides information on the global export markets; [Atlas, 2024], which reports the top producing countries; and [IndexBox, 2023], which analyzes the best import markets.

The respective networks are also mapped for the major countries trading beans, potatoes, and wheat in Figures 1-3, respectively, to facilitate a clearer understanding of their trade dynamics. Country names were abbreviated using acronyms, making it easier to trace and comprehend the networks. These acronyms are consistently used throughout this paper, and a complete list of these abbreviations is included in Appendix B for reference.
Table 1-3 presents the reporter and partner countries within the bean, potato, and wheat trade networks as identified from the analysis.

Type	Countries
Reporter	Australia (AU), Brazil (BR), Canada (CA), Germany (DE), Malaysia (MY), Mexico (MX), Myanmar (MM), Netherlands (NL), Poland (PL), South Africa (ZA), United States (US)
Partner	China (CN), India (IN), Japan (JP), Kenya (KE), Mexico (MX), Pakistan (PK), United Republic of Tanzania (TZ), Uganda (UG)

Table 1: Bean Trade Network Countries

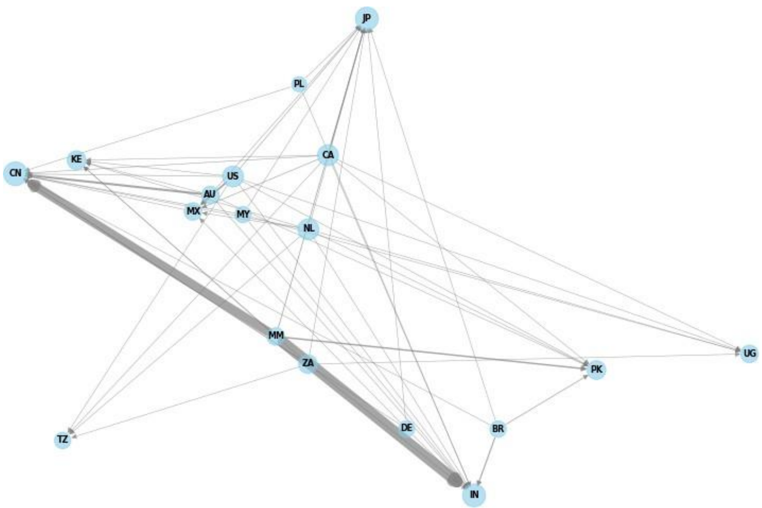


Figure 1: Beans Network Model

Type	Countries
Reporter	Belgium (BE), Canada (CA), China (CN), Egypt (EG), France (FR), Germany (DE), India (IN), Israel (IL), Netherlands (NL), Pakistan (PK), Spain (ES), United Kingdom (UK), United States (US)
Partner	Algeria (DZ), Belgium (BE), Canada (CA), Egypt (EG), France (FR), Germany (DE), Greece (GR), Italy (IT), Mexico (MX), Netherlands (NL), Portugal (PT), Russia (RU), Spain (ES), United States (US), Vietnam (VN)

Table 2: Potato Trade Network Countries

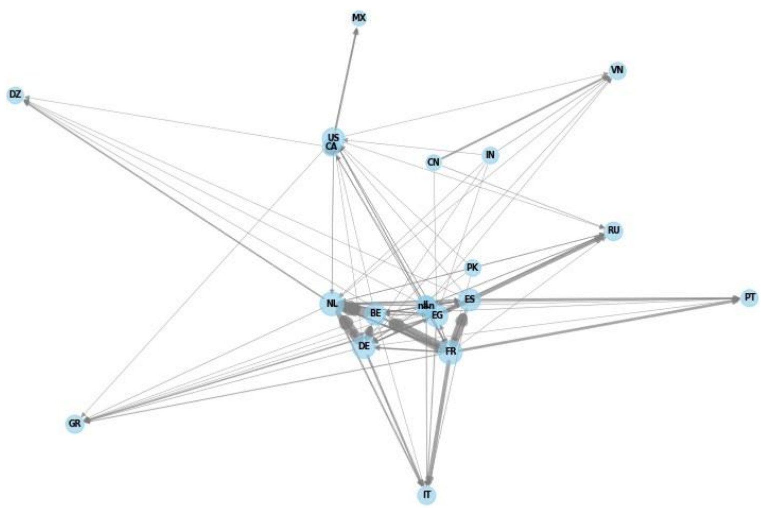


Figure 2: Potato Network Model

Type	Countries
Reporter	Argentina (AR), Australia (AU), Bulgaria (BG), Canada (CA), Czechia (CZ), France (FR), Germany (DE), India (IN), Kazakhstan (KZ), Latvia (LV), Lithuania (LT), Poland (PL), Romania (RO), Russia (RU), Ukraine (UA), United States (US)
Partner	Algeria (DZ), Bangladesh (BD), Belgium (BE), Brazil (BR), China (CN), Colombia (CO), Egypt (EG), Ethiopia (ET), Germany (DE), Indonesia (ID), Italy (IT), Japan (JP), Mexico (MX), Morocco (MA), Netherlands (NL), Nigeria (NG), Pakistan (PK), Philippines (PH), South Korea (KR), Spain (ES), Turkey (TR), Uzbekistan (UZ), Vietnam (VN), Yemen (YE)

Table 3: Wheat Trade Network Countries

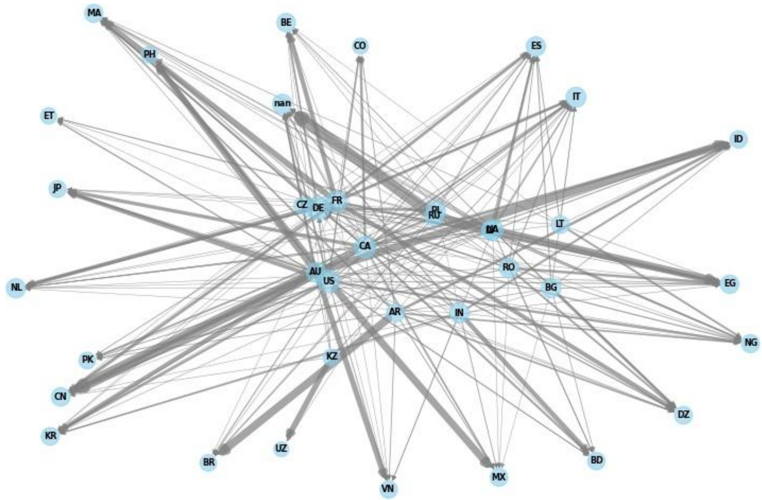


Figure 3: Wheat Network Model

5.2 Identification of Current Community Trends

The next key aspect of this analysis is to discern the presence of communities and clusters within the global trade patterns. While the trade network may appear to be extensively interconnected among numerous countries at a glance, a closer study will reveal distinct community formations, which will be helpful in understanding the dynamics of international trade. The Louvain algorithm is applied to the main countries identified in section 5.1 This allows us to identify the 'strongest communities' within each network, which are characterized by the most densely connected groups of countries.

Crop	Strongest Communities	Modularity
Beans	{'DE', 'CN', 'ZA', 'IN', 'AU', 'MM', 'MY'} {'CA', 'JP', 'MX', 'UG', 'US', 'TZ', 'PL', 'KE', 'NL'} {'BR', 'PK'}	0.14757226023822148
Potatoes	{'RU', 'PK', 'EG', 'NL', 'IT', 'BE', 'GR', 'FR', 'DZ', 'DE'} {'ES', 'IL', 'UK', 'PT'} {'CA', 'US', 'MX'} {'VN', 'IN', 'CN'}	0.34490205302422877
Wheat	{'MA', 'AR', 'MX', 'NG', 'CN', 'US', 'ET', 'DE', 'CO', 'CA', 'CZ', 'JP', 'KR', 'PH', 'LV', 'BG', 'AU', 'VN', 'PL', 'BR', 'LT', 'DZ', 'ID'} {'RO', 'ES', 'RU', 'EG', 'UA', 'NL', 'TR', 'IT', 'BE', 'PK', 'FR'} {'BD', 'IN', 'YE'} {'KZ', 'UZ'}	0.3404614344452484

Table 4: Current Crop Trade Communities and Modularity

The community detection algorithm reveals the characteristics and distribution of communities within the network.
An in-depth examination of these communities, organized by crop type, is presented below.
Beans: The modularity score of 0.147572 for beans suggests that while there are denser links within the commu- nities, the overall network maintains significant connections across different groups. This means a well-connected global trade scenario for beans. The community groupings for beans likely represent regional trade blocs or common trade routes; combinations like Germany, China, India, and Australia hint at a mix of major producers and important consumers in the network.
Potatoes: Potatoes have a modularity score of 0.344902, which shows a clearer community structure compared to beans. This score reflects potato trade networks divided into well-defined groups, likely shaped by regional dependencies or specific trade agreements. The presence of multiple European countries in one cluster highlights strong intra-European connections, whereas North American countries grouped together point to regional preferences or logistical advantages.

Wheat: Wheat shows a similarly high modularity score of 0.340461, highlighting strong community structures within its trade network. This high value likely stems from geopolitical and agricultural influences shaping trade patterns. With major global producers and consumers such as the United States, Canada, and China in large and diverse groups, wheat maintains its role as a crucial global staple. These groups form a network of interconnected countries, which is important for maintaining the stability of global food supplies.

These findings suggest that trade networks do not strictly align with intuitive expectations based on geography or economic status (GDP). For instance, while some trade clusters can be explained by geographical proximity or common agricultural practices, others seem to form based on trade policies, historical ties, and market demands, which may not be immediately apparent from a purely economic or geographical analysis.

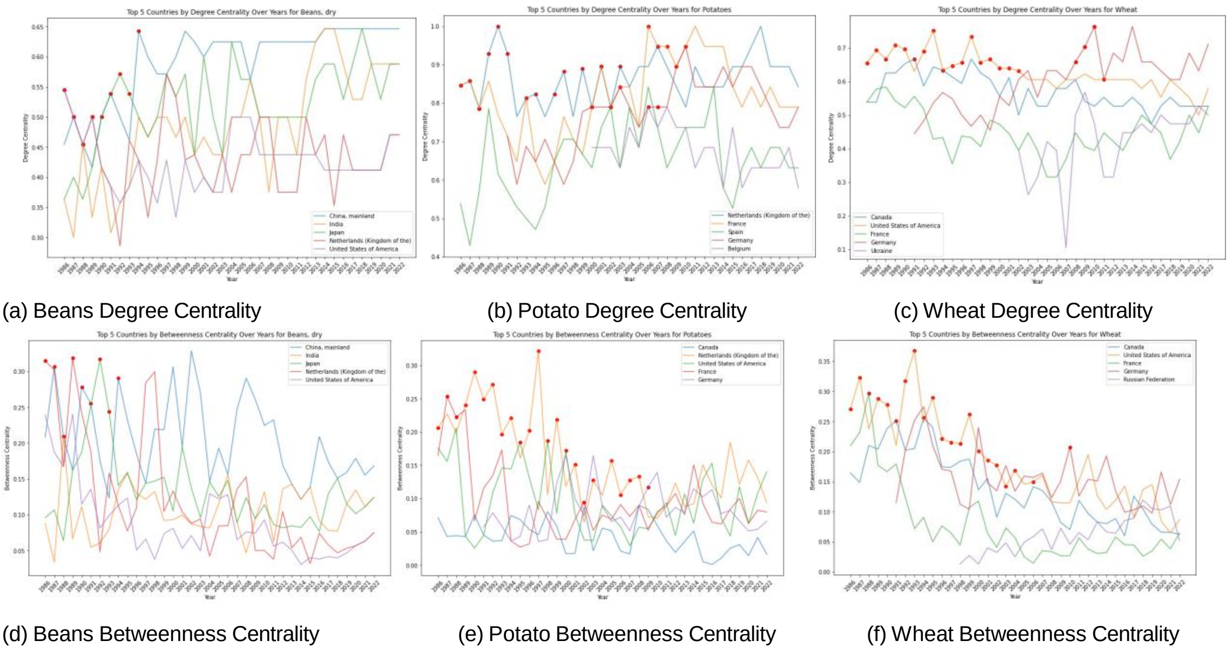
This complexity in trade relationships is the reason why such detailed studies become important. By dissecting the current structure and dynamics of trade networks, we can gain insights that are not readily apparent through simple economic or geographical models. With this approach in mind, an in-depth analysis of both historical data and future projections will be made to further gain knowledge about these elaborate trading patterns.

5.3 Past Centrality Trends: A 37-Year Analysis

Before moving forward to the future trend, the exploration of past centrality trends is necessary, as these metrics reveal how various nodes (countries) have evolved in terms of their influence and connectivity within the global trade network. The last 37 years have witnessed significant changes due to the evolving nature of these trade networks. Analyzing these shifts would be helpful in understanding the transformation in trade patterns and preparing for future trends in wheat, beans, and potato trade networks.

The study has developed a specialized visualization that displays centrality measures for all countries concerning each crop. This plot accentuates the highest centrality values within each period by marking these peaks with dots. This visualization aids in quickly identifying which countries have consistently held the highest centrality for the crop over the last 37 years. For clarity, only the top five countries for a specific centrality are shown in each plot.

The plots are organized by type of crop to illustrate the substantial fluctuations each country experiences over time and how these vary significantly across different crops in the same country.



(a) Beans Degree Centrality (b) Potato Degree Centrality (c) Wheat Degree Centrality

(d) Beans Betweenness Centrality (e) Potato Betweenness Centrality (f) Wheat Betweenness Centrality

Figure 4: Centrality Measure Graphs for Beans, Potatoes, and Wheat

Mainly, the visualization reveals significant fluctuations for nearly every country over the past 37 years, underscoring the volatility inherent in these trade networks.

Beans:

1. Degree Centrality: Shows significant fluctuations among the top countries, indicating changes in their roles as major trading hubs over the years. Notably, countries like India and China display sharp peaks at certain intervals, showing their prominence in bean trade from time to time.

2. Betweenness Centrality: The variability in betweenness centrality across countries like China and the United Kingdom highlights their role as intermittent but important connectors in the trade network, facilitating trade flows between other countries.

Potatoes:

1. Degree Centrality: This centrality measure for potatoes is generally more stable compared to beans; Germany and Canada often appear as consistent central figures in the potato trade and have strong and steady trade relationships.

2. Betweenness Centrality: Shows peaks and troughs, especially notable in countries like Germany, which sometimes acts as a significant bridge in the network, possibly during times of high demand or supply constraints.

Wheat:

1. Degree Centrality: Displays less variability than beans and potatoes, with countries like Canada and the United States showing high centrality and reinforcing their positions as major wheat exporters.

2. Betweenness Centrality: Especially high for countries like Russia and the United States, which could point to their roles in connecting various regions of the global wheat market.

Overall, the patterns observed, such as the stability shown by Germany and Canada in the potato market and the extreme fluctuations seen in India and China's bean trade, show the changing nature of the global agriculture market.

5.4 Prediction of Future Data with Major Forecasting Models

By analyzing past trends, it's clear that many factors including climate change have had an impact on crop trade and networks. Therefore, to aid policymakers and economists in strategic planning for future events, the research will predict agricultural trade volumes from 2022 to 2040 using various forecasting models: Auto ARIMA, Linear Regression, Polynomial Regression, and Gaussian Processes are chosen for this purpose. Each model offers unique strengths and assumptions about data trends, providing a range of perspectives on future trade dynamics. Due to the lack of data points for some crops, it is reasonable to compare different forecasting models to choose the most reliable one. By reviewing all four models side by side and evaluating them manually, the research will determine which model would capture the trend in the most effective way.
For initial analysis, the research focused on three key country pairs to maintain consistency across all models and provide meaningful comparisons:

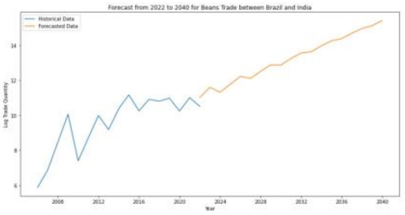
- Beans: Brazil and India - Chosen because Brazil serves as a major exporter and India as a significant importer. This pair helps to understand interactions between a major South American agricultural producer and a large Asian consumer market.

- Potatoes: Netherlands and Belgium - These neighboring countries have deeply integrated trade systems in the potato sector, thus making them a great case for studying intra-European market dynamics.

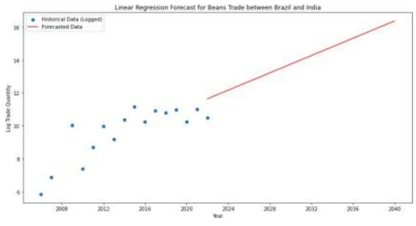
- Wheat: USA and China - As two of the largest players in the global wheat market, this pairing gives insight into how major geopolitical and economic policies such as tariffs and political relations can impact trade volumes. Offers a challenging and informative dataset for analysis.

The representative graphs are shown in the next figures.

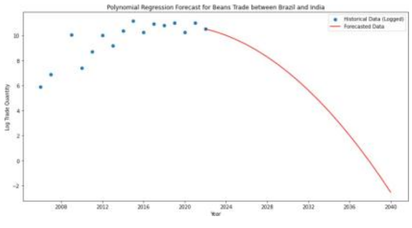
Beans: Brazil and India



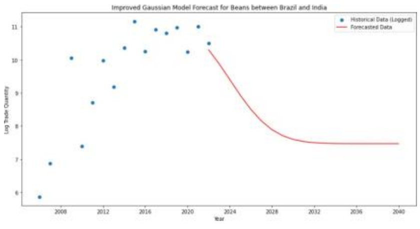
(a) Auto ARIMA



(b) Linear Regression

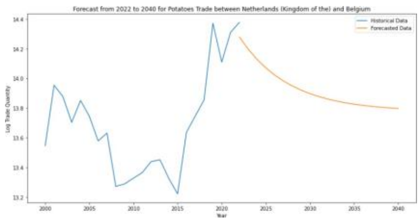


(c) Polynomial Regression

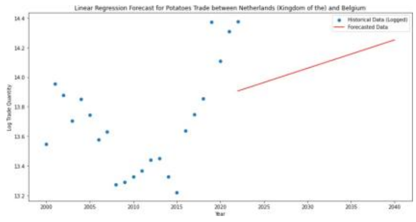


(d) Gaussian Processes

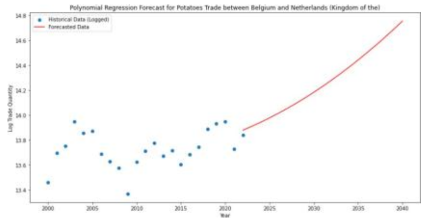
Potatoes: Netherlands and Belgium



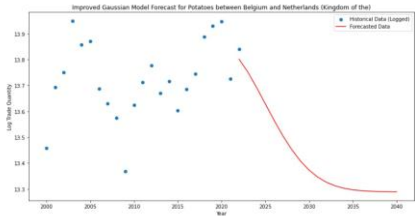
(a) Auto ARIMA



(b) Linear Regression

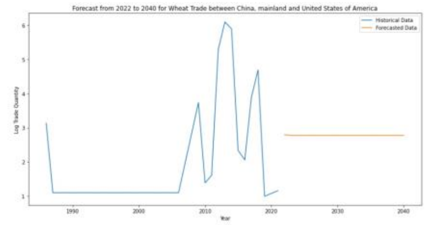


(c) Polynomial Regression

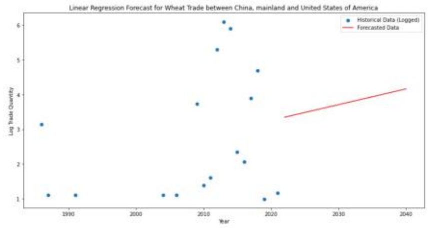


(d) Gaussian Processes

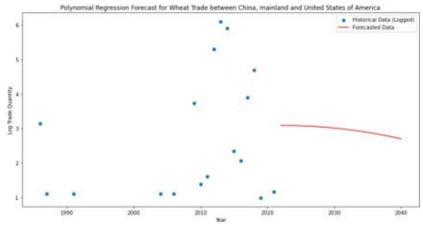
Wheat: USA and China



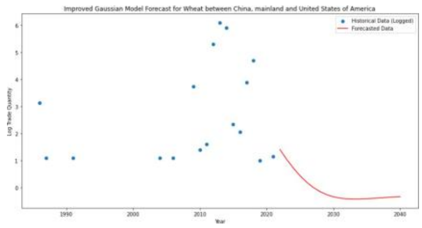
(a) Auto ARIMA



(b) Linear Regression



(c) Polynomial Regression



(d) Gaussian Processes

Figure 5: Forecasting Models Comparison

Building on the analysis of the three major country pairs above for beans, potatoes, and wheat, the research expanded to include twelve additional top country pairs across all three crops. The details of these additional pairs can be found in Appendix A. After evaluating all 15 country pairs, Linear Regression emerged as the well-rounded forecasting model for this particular study. The effectiveness of each model was quantified based on how frequently it was selected as the most dependable for predicting trade volumes across these diverse scenarios. The results were as follows:

- Auto ARIMA: 29.72% accuracy rate. This model was particularly effective in scenarios where the data exhibited strong seasonal patterns.
- Linear Regression: 40.54% accuracy rate. Its strength lies in its ability to model relationships directly and effectively, which makes it the best fit for most of the trade scenarios examined.
- Polynomial Regression: 21.6% accuracy rate. This model performed well in situations where the relationship between variables was non-linear.
- Gaussian Processes: 8% accuracy rate. It was often useful in capturing unpredictable trends due to its flexibility in modeling uncertainties.

In this analysis, for the given dataset characteristics, Linear Regression stood out as the most effective forecasting model overall, marked by a 40.54% accuracy rate. However, the choice of the model also can depend on the specific trade context and the type of crop. For stable and steadily growing markets, simpler models such as Auto ARIMA and Linear Regression can deliver reliable forecasts. However, for markets that are volatile, Polynomial and Gaussian Processes offer better insights that can inform risk management and strategic planning. Decision-makers should consider using a combination of these models to fully capture the outcomes relevant to their focus on specific situations. In the next section, we will utilize Linear Regression as it best captures the trade pattern in most of our test cases.

5.5 Community Comparison of Past and Future Years Based on Global Temperature Changes

In section 5.2, the community structures within global agricultural trade networks have already been analyzed for the year 2022, which is estimated to have a global surface temperature increase of 1.3 degrees Celsius. To advance our understanding of the impact of climate change on these networks, we have selected additional years for comparison. First, the year 2006, with a temperature increase of 0.65 degrees Celsius and half of what was observed in 2022, serves as a historical benchmark. Moving forward, the year 2038 has been chosen for future projections, exactly 16 years after 2022, mirroring the 16-year interval from 2006 to 2022. This symmetrical selection aims to provide a balanced view of how trade communities may evolve as global temperatures continue to rise. These intervals and key years are represented by the green lines marked in Figure 6.

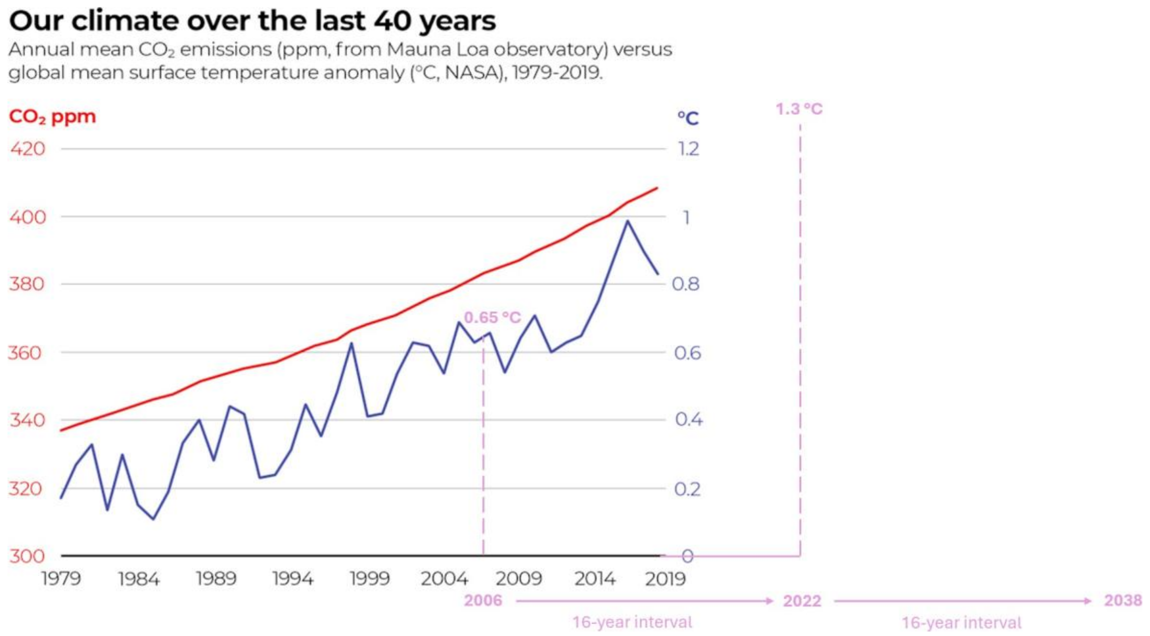


Figure 6: Illustration of the global mean surface temperature anomaly in degrees Celsius (°C) from 1979 to 2019. The blue line represents the steady increase in CO_2 levels, while the red line represents the change in temperature anomalies between years [Nicholls, 2019]

To effectively compare the past (2006) and the projected future (2038), we will employ the same method of community detection used in analyzing the 2022 data. Trade quantities for 2006 will be taken from past FAO data, while projected trade quantity data for 2038 will be taken from Linear Regression, the most context-appropriate model identified in section 5.4. Both sets of data will be applied to identify the strongest communities in both years. This will allow us to examine how trade communities are reorganizing themselves in response to changing climate conditions.

Crop	Strongest Communities	Modularity
Beans	{'NL', 'CN', 'PL', 'ZA', 'TZ', 'MY', 'DE', 'BR'}, {'IN', 'PK', 'AU'}, {'JP', 'CA'}, {'US', 'MX', 'UG', 'KE'}	0.3871
Potatoes	{'FR', 'PT', 'UK', 'IT', 'IN', 'ES'}, {'NL', 'DZ', 'PK', 'BE', 'DE'}, {'US', 'MX', 'CA'}, {'VN', 'EG', 'RU', 'IL', 'GR', 'CN'}	0.3600
Wheat	{'AR', 'CO', 'BR'}, {'NL', 'LT', 'CZ', 'FR', 'MA', 'DZ', 'PL', 'BE', 'IT', 'BG', 'RO', 'DE', 'ES', 'LV'}, {'VN', 'CA', 'AU', 'KR', 'CN', 'ID'}, {'ET', 'JP', 'US', 'MX', 'NG', 'PH'}, {'PK', 'RU', 'IN', 'TR', 'YE', 'EG', 'UZ', 'BD', 'KZ', 'UA'}	0.4857

Table 5: Crop Trade Communities and Modularity for 2006

Crop	Strongest Communities	Modularity
Beans	{'AU', 'BR', 'DE', 'IN', 'PL', 'PK'}, {'TZ', 'JP', 'MX', 'NL', 'US', 'CN', 'ZA', 'MY', 'UG', 'CA', 'KE'}	0.0328
Potatoes	{'PT', 'ES'}, {'BE', 'DZ', 'IL', 'DE', 'FR', 'NL'}, {'IT', 'EG', 'RU', 'UK', 'GR', 'PK'}, {'IN', 'VN', 'CN'}, {'MX', 'CA', 'US'}	0.5792
Wheat	{'UZ', 'KZ', 'CN'}, {'PL', 'CZ', 'DE'}, {'BE', 'AR', 'JP', 'KR', 'PH', 'CO', 'BR', 'MX', 'ES', 'NL', 'DZ', 'US', 'CA', 'FR', 'BG', 'AU', 'LV', 'ET', 'VN', 'MA', 'ID'}, {'IT', 'EG', 'RO'}, {'YE', 'TR', 'RU', 'UA', 'NG', 'PK', 'LT', 'IN', 'BD'}	0.6281

Table 6: Crop Trade Communities and Modularity for 2038

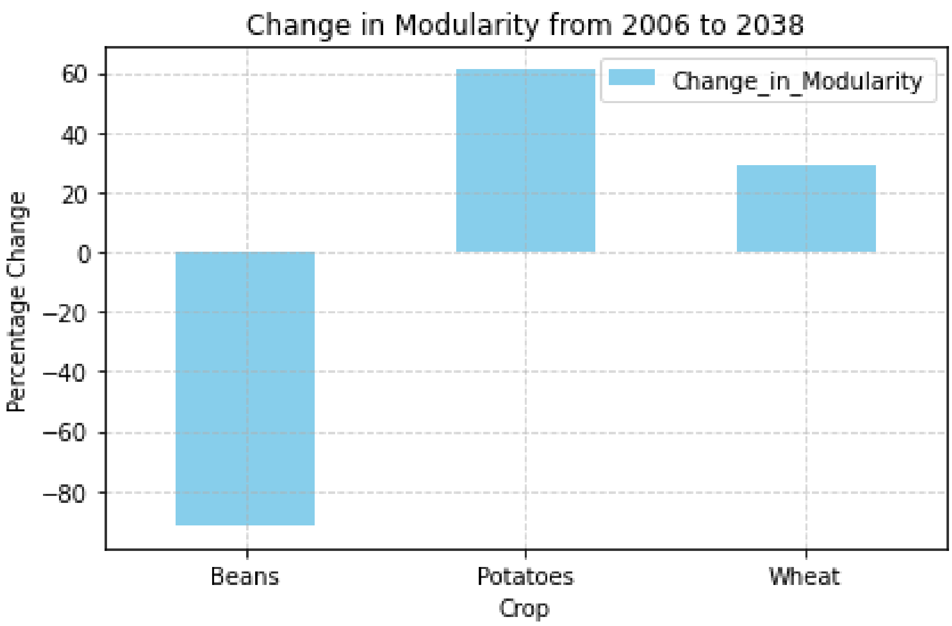


Figure 7: Percentage change in modularity of trade networks for different crops from 2006 to 2038.

In 2006, trade networks for beans, potatoes, and wheat were fragmented with distinct clusters formed by leading trading countries like Brazil, India, and China for beans, and European nations for potatoes and wheat. By 2038, these networks show increased consolidation and interconnectivity. For beans, larger trade communities emerge, likely in response to climate-induced changes in production and the need for diversified trade routes. This results in a less modular, more interconnected bean trade network, with modularity decreasing significantly by approxi- mately 91.52% from 2006 to 2038. Potatoes and wheat are also forming larger, more regionally-focused clusters by 2038. Potatoes show stronger regional ties, possibly due to climate adaptations, with modularity increasing by about 60.89%. Finally, the trade network for wheat is becoming more organized across continents, aiming to enhance food security in the face of climate challenges, with an increase in modularity of around 29.32%.

6 Solutions

To combat the global effects of climate change on crop yield, we have proposed detailed strategies for enhancing agricultural resilience. Our modularity analysis for current crop trends (Table 4) highlights trade communities among major agricultural producers such as Germany, China, India, Canada, and the United States. These communities' diversity in climate resilience and agricultural technology lays a strong foundation for a mutual assistance trade strategy. Such a strategy would entail formal agreements for support during adverse climatic events affecting crop yields. For instance, if a drought impacted bean production in Australia, other community members like India or Malaysia could adjust their export quotas to mitigate the shortfall. [Frohn, 2018] Additionally, countries with advanced agricultural technologies, such as Germany, could share innovations with less developed countries within the community to help increase overall resilience.
The identified trade communities also present an opportunity to form regional hubs focusing on the cultivation of climate-resilient crop varieties. For example, a hub comprising Germany, China, India, and Australia could spe- cialize in developing drought-resistant beans, leveraging Germany's advanced technology and China's production scale [Erbs and Köchy]. Similarly, a hub involving the Russian Federation, Egypt, and the Netherlands could en- hance potato production suited to temperate climates, utilizing Dutch expertise in precision farming and high-yield greenhouse cultivation. [Whiting, 2019] These hubs would improve productivity and stabilize supply chains of agricultural produce through innovative storage and processing technologies.
In Section 5.3, we found that bean trade networks in India and China experience significant shifts, often peaking in demand. Establishing emergency reserves in these regions could help cushion the impact of these sudden changes. Similarly, potatoes and wheat trades, which are crucial in Germany, Canada, the U.S., and Russia, would benefit from strengthened infrastructure to maintain supply during key periods.
Looking ahead to 2038, as discussed in Section 5.5, potato trading is expected to form tighter regional groups. This shift highlights the importance of robust regional alliances that can insulate against the unpredictable global market, especially as it's affected by climate change. By aligning trade policies and enhancing collaborative efforts in logistics and storage, these alliances can safeguard regional food supplies. Moreover, as bean trade networks become more interconnected, there's a pressing need for countries to broaden their crop diversity and forge new trading partnerships. Adapting agricultural practices to the changing climate and diversifying crop genetics are vital steps that can reduce dependence on single markets and improve resilience to environmental shocks.

7 Limitations

Our network model is inherently limited by its data coverage, which primarily considers exports and imports on a global scale. For one, it does not delve into the granular details such as individual behaviors or specific regional policies that might also influence trade dynamics. Therefore, this research should ideally be used in conjunction with more detailed studies that address these aspects, offering a more broad view of the agricultural sector's challenges and opportunities.

8 Conclusion

This study has systematically explored the past, present, and future dynamics of global agricultural trade networks through a network analysis approach, focusing on the trade of key crops such as beans, potatoes, and wheat. By employing various centrality measures, clustering algorithms, and the Louvain Community Detection Algorithm, we have unveiled recent trends and identified significant trade communities that play central roles in the stability of these networks. The research also has predicted agricultural trade volumes for approximately the next two decades using different forecasting models to assess their effectiveness. A comparative analysis of trade quantities from past data (2006) and projected future data (2038) was completed to gain a better understanding of the main trends and shifts in crop trade patterns. Most importantly, this study of global agricultural trade sets the stage for investigations into how climate fluctuations will shape future trade patterns, calling for proactive global cooperation efforts to de- velop adaptive strategies that ensure food security and resilient agricultural systems amid evolving environmental challenges.

Author Contributions

- Olivia Lu: Conceptualization (lead), Data Curation (lead), Formal Analysis (lead), Methodology (lead), Software (lead), Validation (equal), Visualization (lead), Writing – Original Draft (lead), Writing – Review & Editing (lead).
- Arun Kumar Rajasekaran: Conceptualization (support), Formal Analysis (support), Software (support), Validation (equal), Writing – Review & Editing (support).

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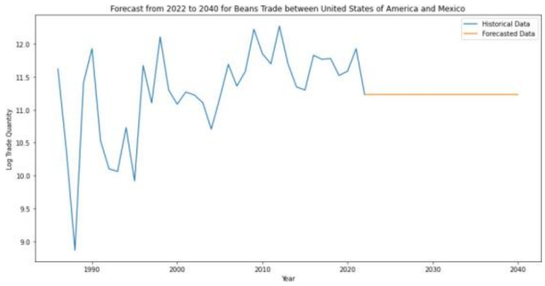
Appendix A: Forecasting Model Comparison and Country Pair Analysis

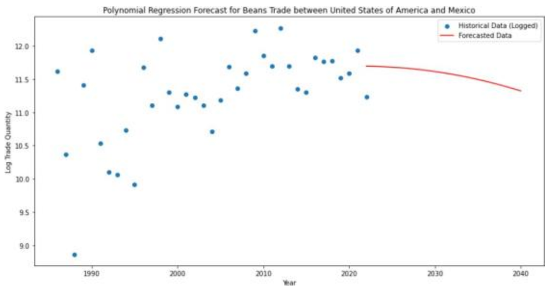
Beans: Additional Country Pairs

United States - Mexico

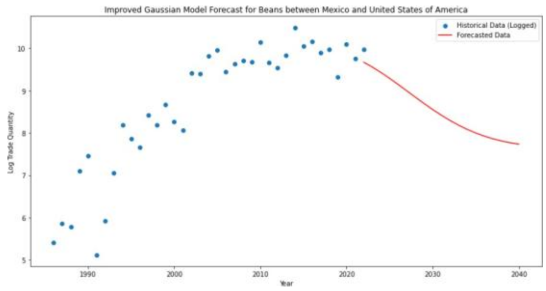


(a) Auto ARIMA

(b) Linear Regression

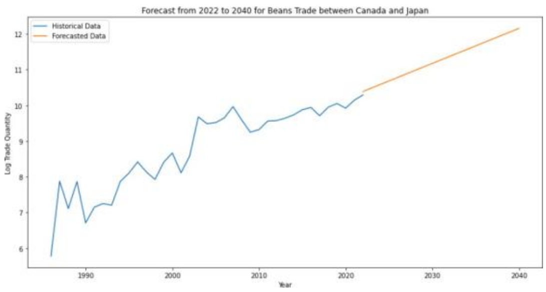


(c) Polynomial Regression



(d) Gaussian Processes

Canada - Japan



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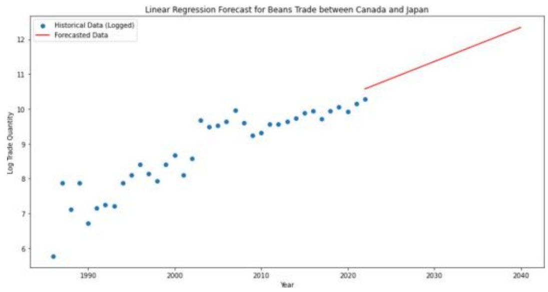
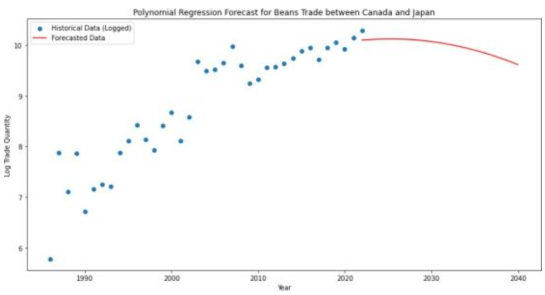
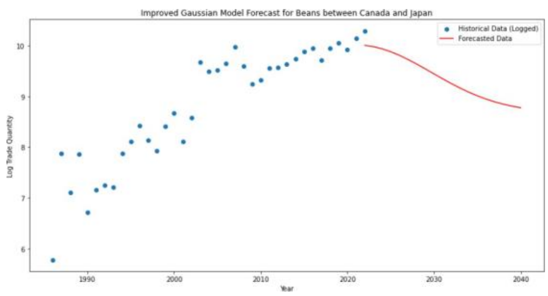


(b) Linear Regression

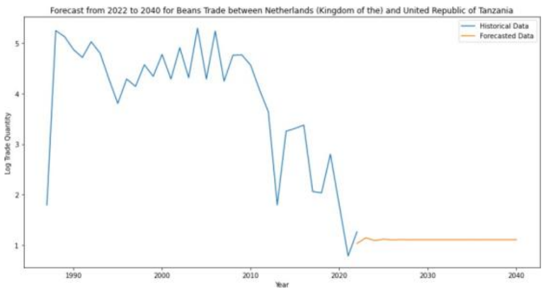


(c) Polynomial Regression

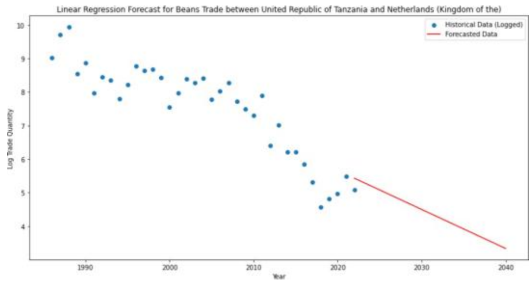


(d) Gaussian Processes

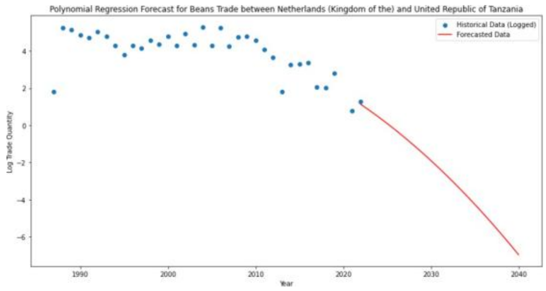
Netherlands - United Republic of Tanzania



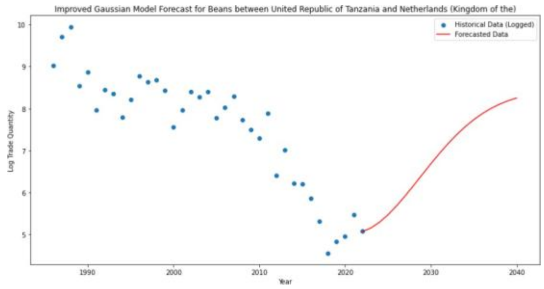
(a) Auto ARIMA



(b) Linear Regression

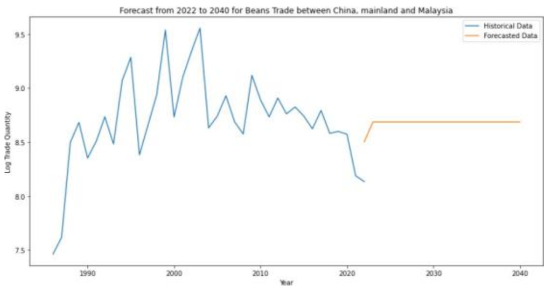


(c) Polynomial Regression



(d) Gaussian Processes

Malaysia - China



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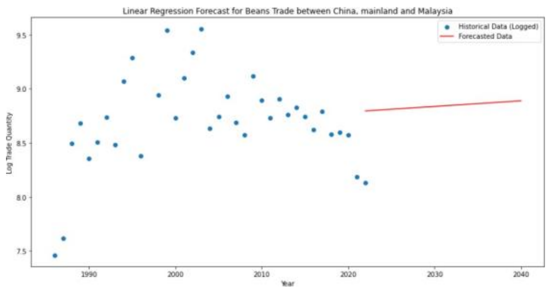

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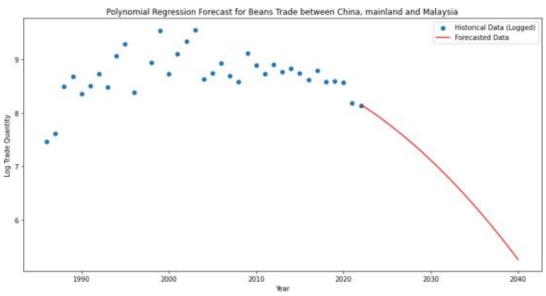

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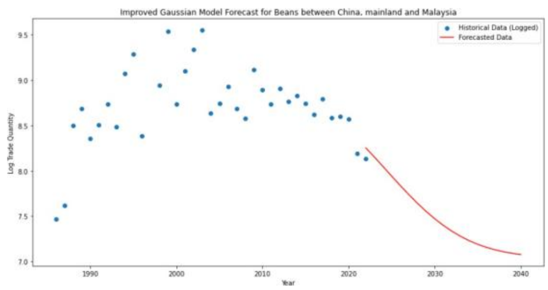

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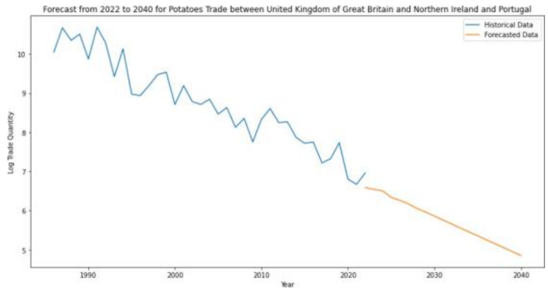
Potatoes: Additional Country Pairs

United Kingdom - Portugal



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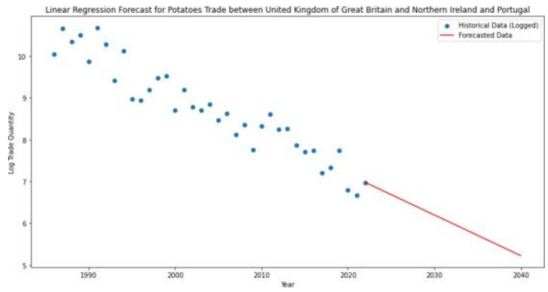

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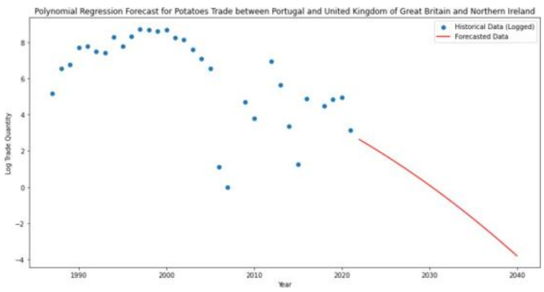

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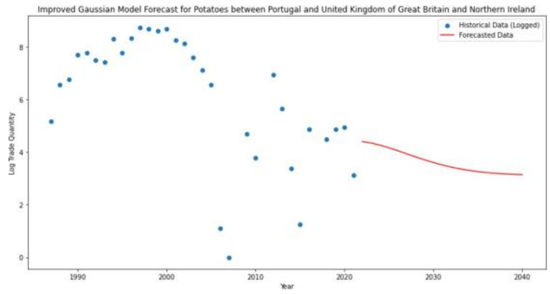

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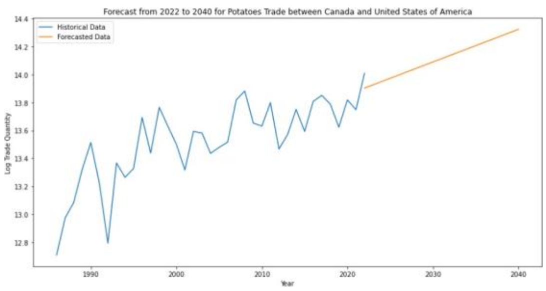
Canada - United States



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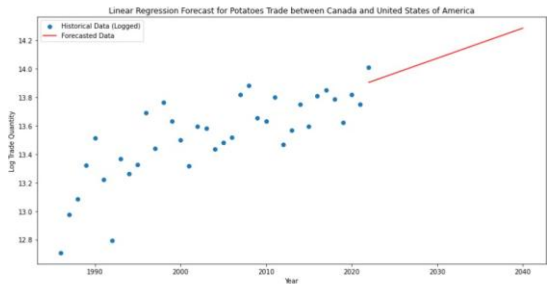

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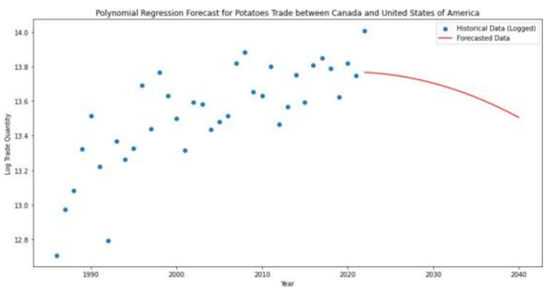

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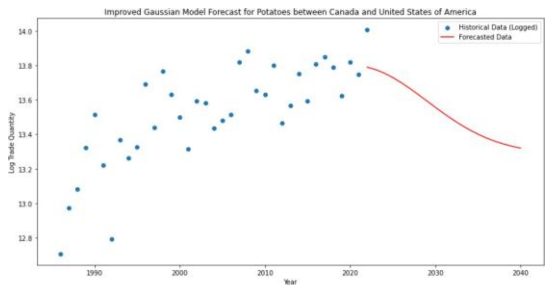

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France - Spain

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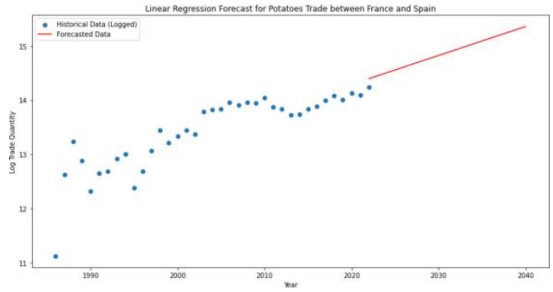

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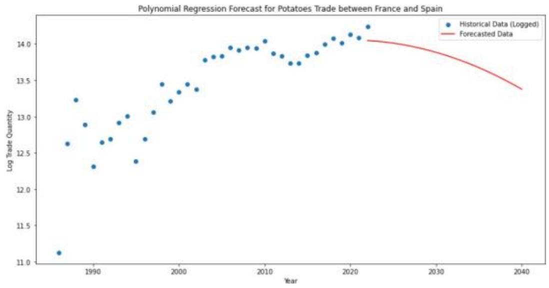

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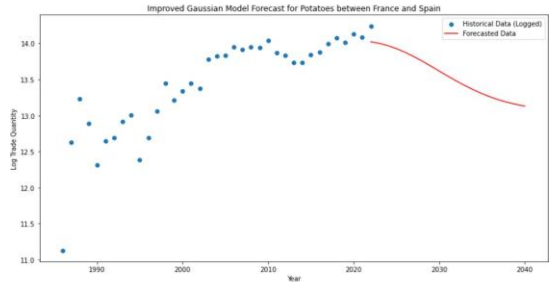
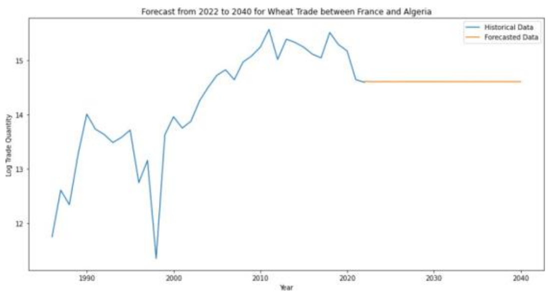


(d) Gaussian Processes

Wheat: Additional Country Pairs

France - Algeria



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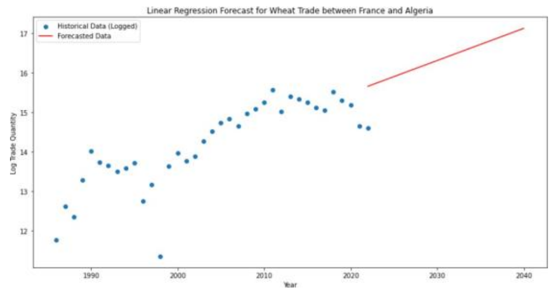

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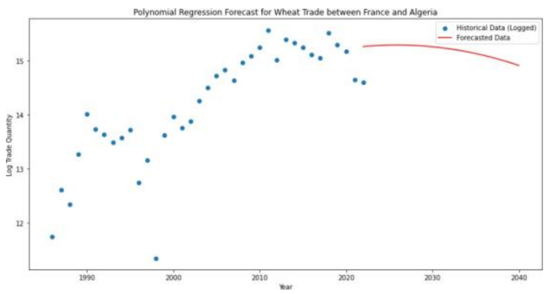

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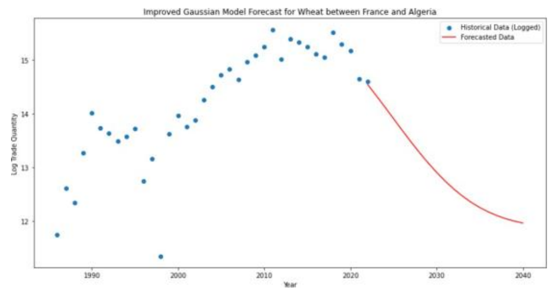

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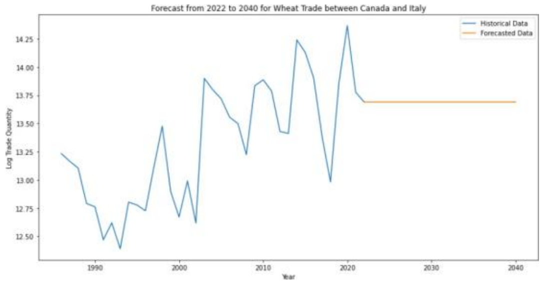
Canada - Italy



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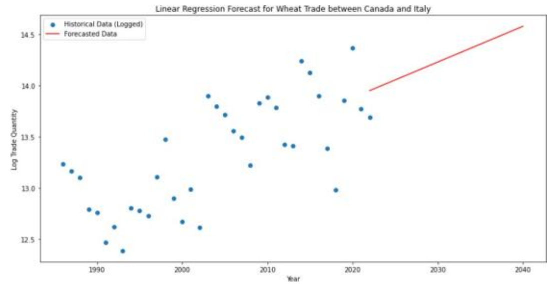

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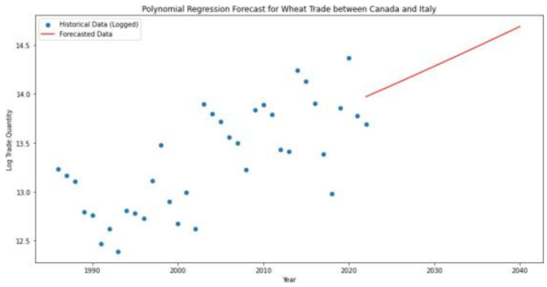

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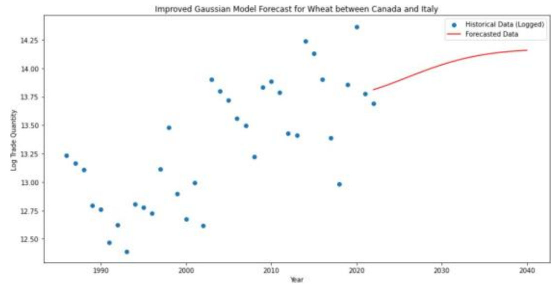

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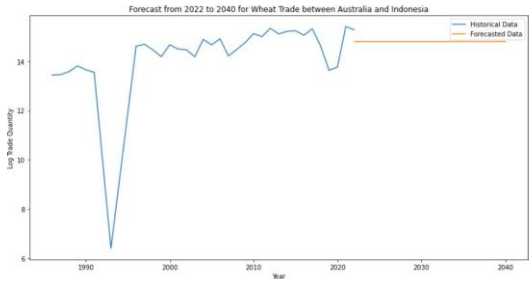
Australia - Indonesia



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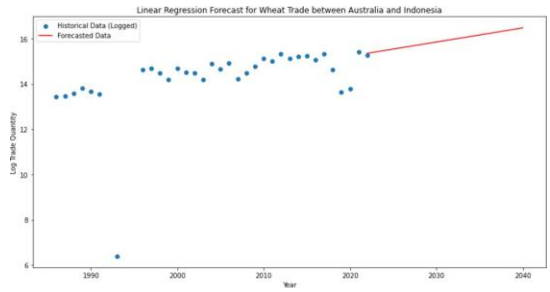

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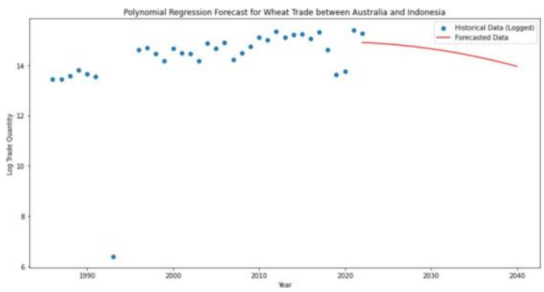

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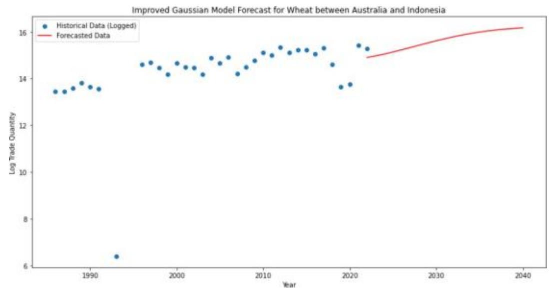

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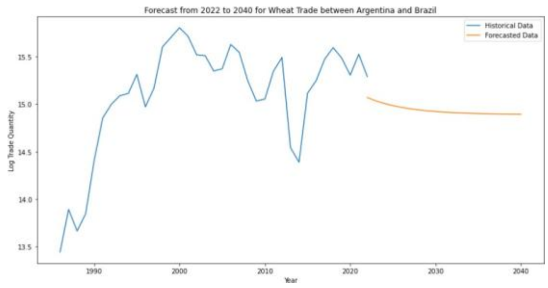
Argentina - Brazil



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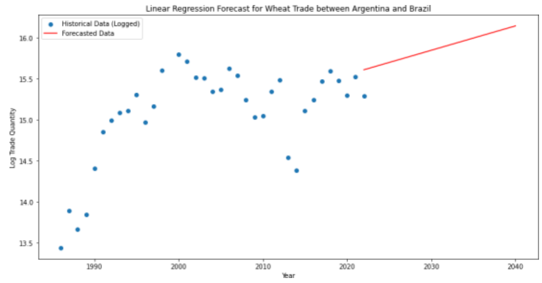

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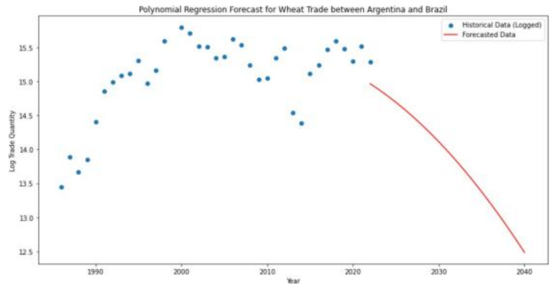

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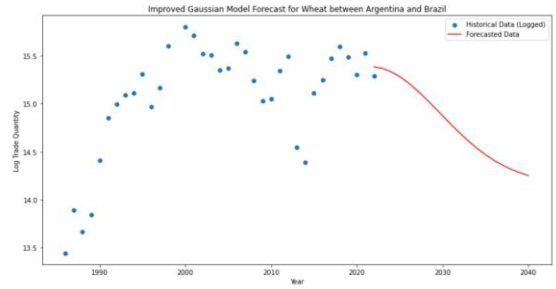

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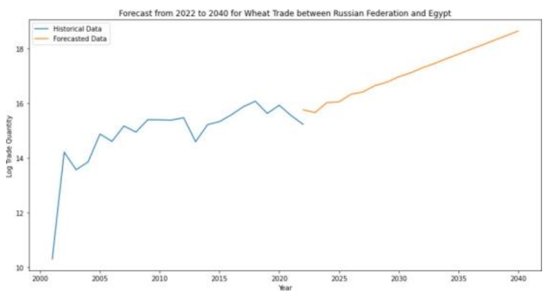
Russia - Egypt



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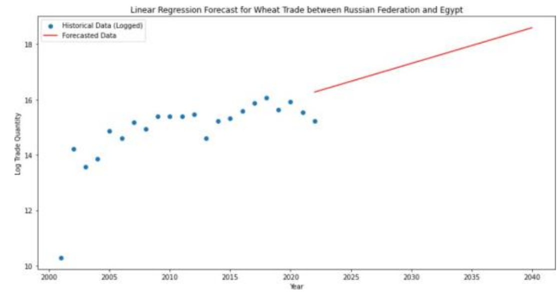

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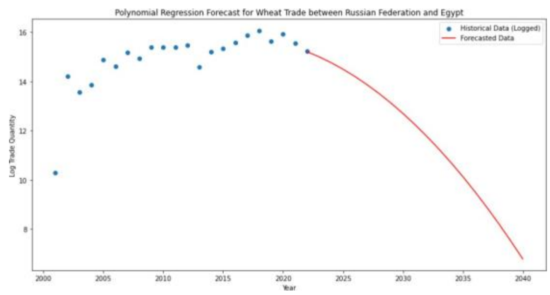

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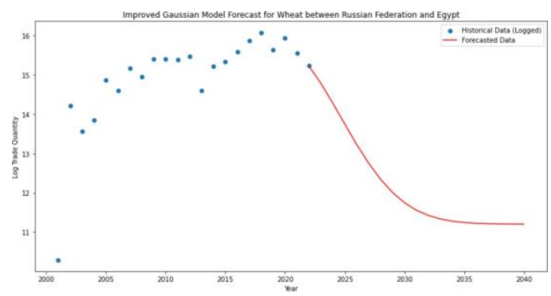

(d) Gaussian Processes

Appendix B: Acronym List for Countries

Country	Acronym	Country	Acronym
Algeria	DZ	Latvia	LV
Argentina	AR	Lithuania	LT
Australia	AU	Malaysia	MY
Bangladesh	BD	Mexico	MX
Belgium	BE	Morocco	MA
Brazil	BR	Myanmar	MM
Bulgaria	BG	Netherlands (Kingdom of the)	NL
Canada	CA	Nigeria	NG
China, mainland	CN	Pakistan	PK
Colombia	CO	Philippines	PH
Czechia	CZ	Poland	PL
Egypt	EG	Portugal	PT
Ethiopia	ET	Republic of Korea	KR
France	FR	Romania	RO
Germany	DE	Russian Federation	RU
Greece	GR	South Africa	ZA
India	IN	Spain	ES
Indonesia	ID	Türkiye	TR
Israel	IL	Uganda	UG
Italy	IT	Ukraine	UA
Japan	JP	United Kingdom of Great Britain and Northern Ireland	UK
Kazakhstan	KZ	United Republic of Tanzania	TZ
Kenya	KE	United States of America	US
Viet Nam	VN	Uzbekistan	UZ

CROP INSURANCE IN EUROPE

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Introduction

This study examines the agriculture insurance in relation to crops in Europe. As climate variability intensifies, European farmers are increasingly exposed to greater risks due to more frequent extreme weather events such as droughts, floods, and hailstorms. These climate-related hazards significantly affect crop yields and quality, leading to higher volatility in agricultural production. By analyzing the risk solution transfer to insurance market we managed to identify how farmers protect themselves from climate risk in different countries around Europe.

A key finding of the study is that in many countries, the development of agricultural insurance is shaped by state subsidies, which not only assist farmers in managing climatic risks but also promote the diversification of risk transfer instruments and enhance market competitiveness. Regarding coverage, hail and frost risks are insured in all countries, while drought risk remains uninsured in some, including Bulgaria, Germany, and Denmark. Parametric insurance, although still in its nascent phase, has been adopted in a few countries, offering additional solutions beyond conventional insurance models.

While risk transfer solutions for climate risks are available in the European agricultural insurance market, their development and diversification vary significantly across countries. This underscores the need for customized support policies and risk transfer instruments to strengthen the agricultural sector's resilience to climate risks.

Key words: crop insurance, climate risk, subsidies, deductible

Literature review

Crop insurance plays a crucial role in safeguarding agricultural productivity and mitigating financial risks for farmers in Europe, especially in the context of increasing climate variability and extreme weather events. The literature on crop insurance in Europe underscores the importance of insurance schemes as a risk management tool for farmers facing growing uncertainties due to climate change.

Several studies highlight that European farmers are increasingly exposed to weather-related risks, such as droughts, floods, hailstorms, and frost, which can severely affect crop yields and quality (Toscani & Finger, 2020; Janssen et al., 2018). The unpredictability of climate conditions has led to heightened volatility in agricultural production, making it essential for farmers to access effective insurance products to mitigate these risks.

The development of crop insurance in Europe has evolved in response to the growing need to protect agricultural income and manage production risks. Traditional crop insurance policies, such as yield-based and indemnity-based insurance, have been widely used across Europe (Enjolras et al., 2012). However, the limitations of these conventional models, particularly in covering systemic risks like drought, have driven the exploration of alternative solutions, such as index-based or parametric insurance. Although still in its early stages, parametric insurance has been gaining traction in countries like Italy and Spain (Castañeda-Vera & Garrido, 2017).

The role of government support is pivotal in the crop insurance landscape in Europe. Many countries provide subsidies to encourage farmers to adopt insurance, as premiums for crop insurance can be prohibitively expensive without state assistance (Bielza et al., 2009). These subsidies have also been instrumental in expanding the coverage and availability of insurance schemes, especially in countries such as France, Spain, and Italy. However, the literature also points to significant variations in state support across countries, leading to discrepancies in the adoption and effectiveness of insurance mechanisms (Meuwissen et al., 2001).

Looking ahead, there is increasing interest in the development of more innovative insurance solutions, such as multi-peril crop insurance and index-based insurance, which offer more comprehensive coverage and simplified payout processes (Goodwin & Vandeveer, 2020). Furthermore, advancements in technology, such as satellite data and remote sensing, are expected to enhance the accuracy and efficiency of risk assessments, paving the way for more tailored and cost-effective insurance products (Hochrainer-Stigler et al., 2014).

The literature on crop insurance in Europe demonstrates its critical role in managing climate-related agricultural risks. While traditional insurance models remain dominant, there is a growing push toward more innovative and accessible solutions, supported by government subsidies. However, significant challenges remain, particularly in terms of uneven adoption, high costs, and the need for region-specific products. Addressing these challenges will be crucial for enhancing the resilience of the European agricultural sector in the face of increasing climate uncertainty.

Methodology

The methodology used in the study focuses on a comparative analysis of crop insurance across European countries, highlighting the availability and adoption of insurance solutions for pure risks. Data were collected through a structured questionnaire, and responses were analyzed to provide insights into insured agricultural areas, the influence of mandatory insurance, and the variety of risks covered. The analysis was based on responses from farmers and industry stakeholders, providing a comprehensive understanding of insurance solutions and protection measures adopted at the national level.

The study used graphical representations to illustrate the insured areas, the mandatory nature of insurance, and the types of risks covered across Europe. These visual analyses compared insured areas by country, showcasing significant differences influenced by factors such as state subsidies and the existence of compulsory insurance schemes. Additionally, the analysis examined risk types covered, such as hail, frost, storm, and excessive rain, as well as the adoption of parametric insurance products.

Key indicators like deductibles, cost comparisons, and state subsidies were also analyzed. The findings revealed the varying levels of market development and competitiveness across countries, as well as the role of government support in expanding insurance coverage. Overall, the methodology provides a structured, data-driven approach to understanding the disparities in agricultural insurance solutions across Europe.

Results

The study results are presented in a comparative format at the European level for each country. Based on these results, a clearer picture of crop insurance across Europe by farmers can be obtained.

It can be observed that there are insurance solutions for climate risks in almost all European countries. Of course, there are significant differences between countries, the main differentiator being subsidies. In countries where state-supported schemes exist, risk transfer solutions are more diversified, allowing farmers access to more protection instruments.

Based on the responses obtained we present below a graphical representation of the insured areas in the EU and how they are influenced by the mandatory nature of agricultural insurance.

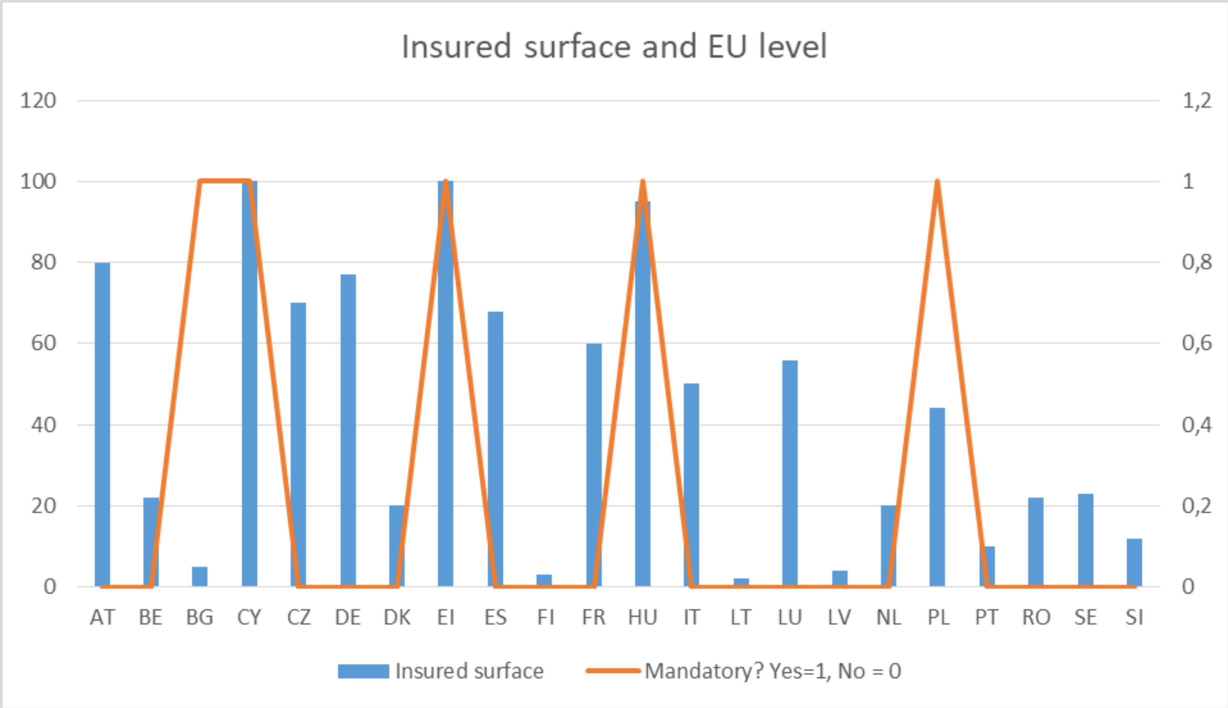

Figure 1: Analysis of insured areas in the EU.
Source: Created by the author

From the analysis of insured areas, we can observe a considerable number of countries insuring over 50% of their area: Austria, Croatia, Cyprus, Czech Republic, France, Germany, Greece, Hungary, Luxembourg, and Spain. Notably, some countries insure nearly 100% of their area: Cyprus, Greece, and Hungary. On the opposite side, we have countries with less than 5% insured area: Bulgaria, Finland, Lithuania, and Latvia.

Regarding the mandatory nature of insurance, there are only a limited number of countries where farmers are required to participate: Bulgaria, Cyprus, Greece, Hungary, and Poland. In Cyprus and Greece, crops are insured through mandatory schemes imposed by the state. In Bulgaria, Hungary, and Poland, insurance is mandatory if farmers wish to receive state subsidies. It can be seen that the obligation in these three countries is indirect, being conditioned by the payment of subsidies.

Considering the insurance solutions for the climate risks we can see in Figure 2 below that traditional single/multi-risk insurance exists in all countries. However, from country to country, parametric index-based insurance has also emerged. The purpose of these is to complement what couldn't be insured through traditional single/multi-risk insurance solutions. Parametric insurances are present in only a few countries and are still in their early stages, not being very common among farmers. These types of insurance can be found in: Austria, Germany, Spain, France, Lithuania, and Romania. In Austria, the most common parametric insurance is precipitation deficit, which monitors two parameters: the precipitation deficit over a specific period compared to an average and the number of heatwave days. This product has been extended to Lithuania and Germany. In Spain and France, the most common product is based on the NDVI vegetation index and its variations compared to a normal crop development phase. In Romania, at a limited level, there is a product that considers precipitation deficit and heatwave days. In all these countries, there are also other parametric products such as production guarantees, soil moisture index, and temperature variation index, though in more limited numbers.

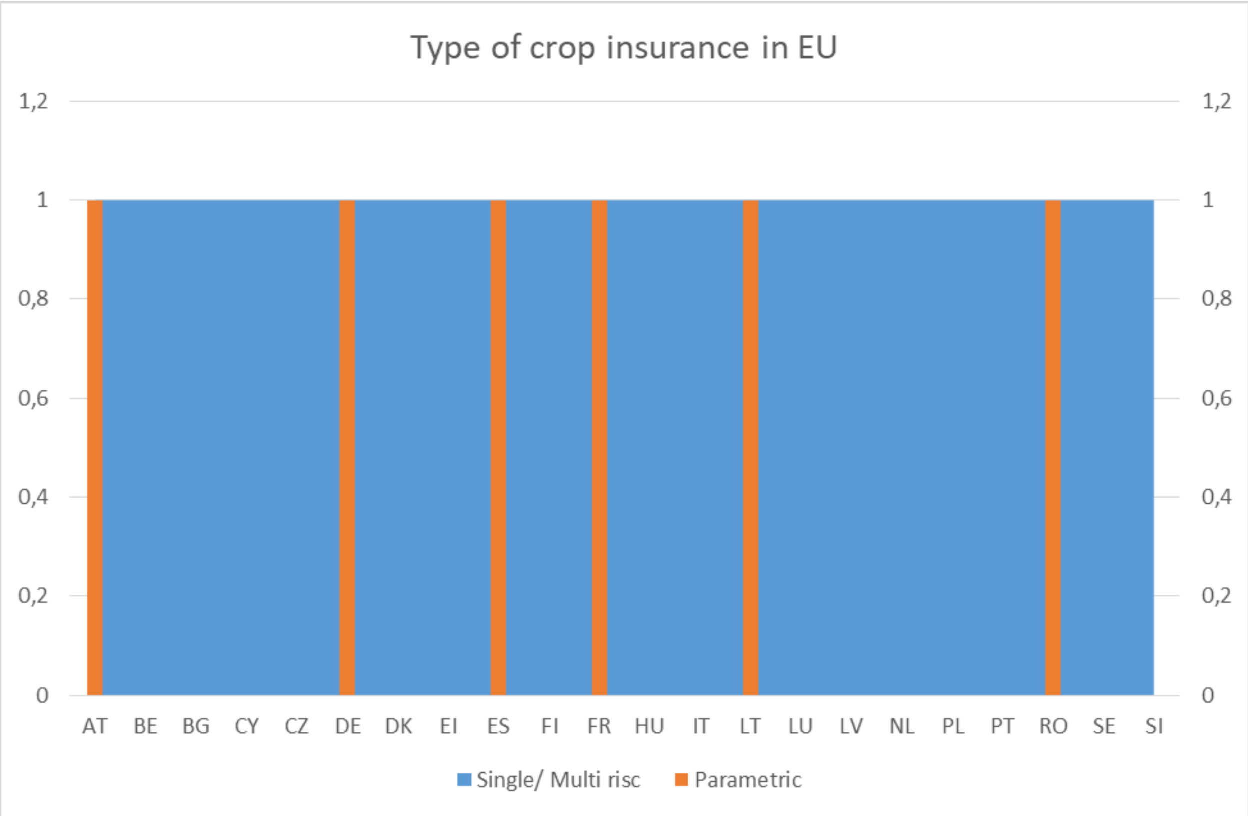

Figure 2: Analysis of insurance types in the EU
Source: Created by the author

In Figure 3 below, we can observe an average deductible of between 10-15%. However, in countries with state-supported insurance schemes, a deductible of 20%-30% is applied for subsidized premiums. The size of the deductible has a direct impact on determining the cost of insurance, but the cost also depends on many other factors such as crop type, region, and types of risks insured. Due to these factors, it is quite difficult to compare prices between countries. However, if we refer to an average cost for multi-risk insurance excluding drought risk, it would be approximately 30 EUR per hectare. Drought-only insurance, depending on the region, can reach costs of around 130 EUR per hectare.

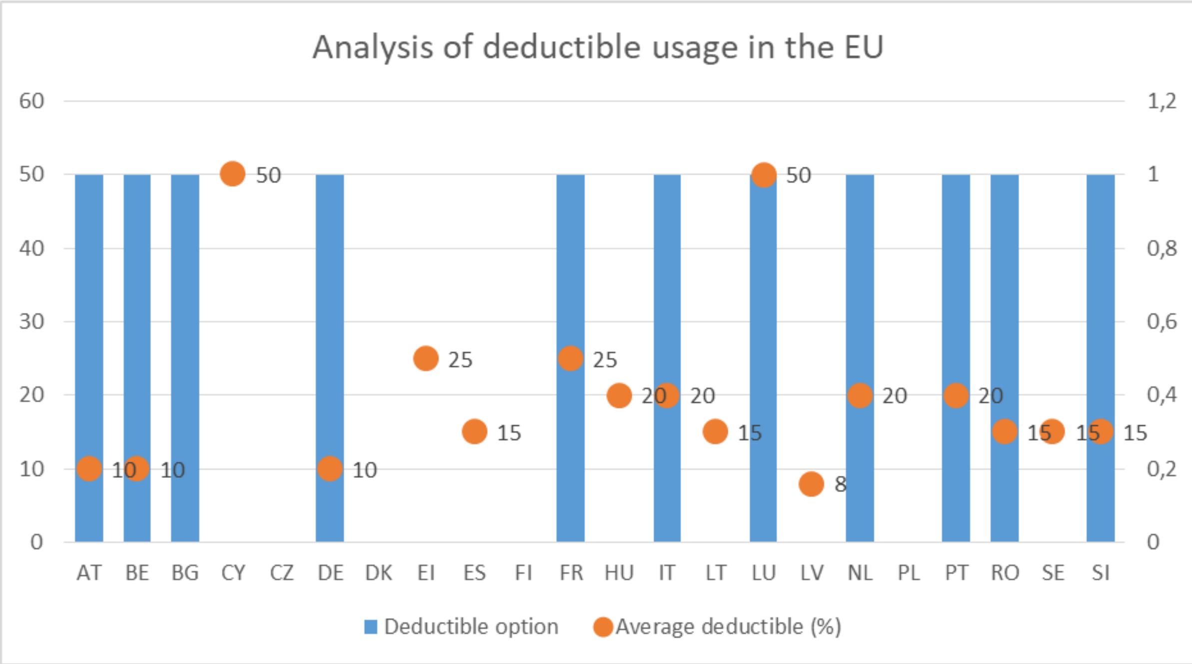

Figure 3: Analysis of deductible usage in the EU
Source: Created by the author

In Figure 4 below, we present the situation of agricultural insurance subsidies at the EU level. Regarding the subsidies offered to help farmers insure crops against pure risks, it can be seen that most countries provide this facility. However, the source of the funds may come from the European Union through the Common Agricultural Policy or local state-level programs. Regardless of the source, the most commonly seen subsidy levels across Europe are 50% or 65%.

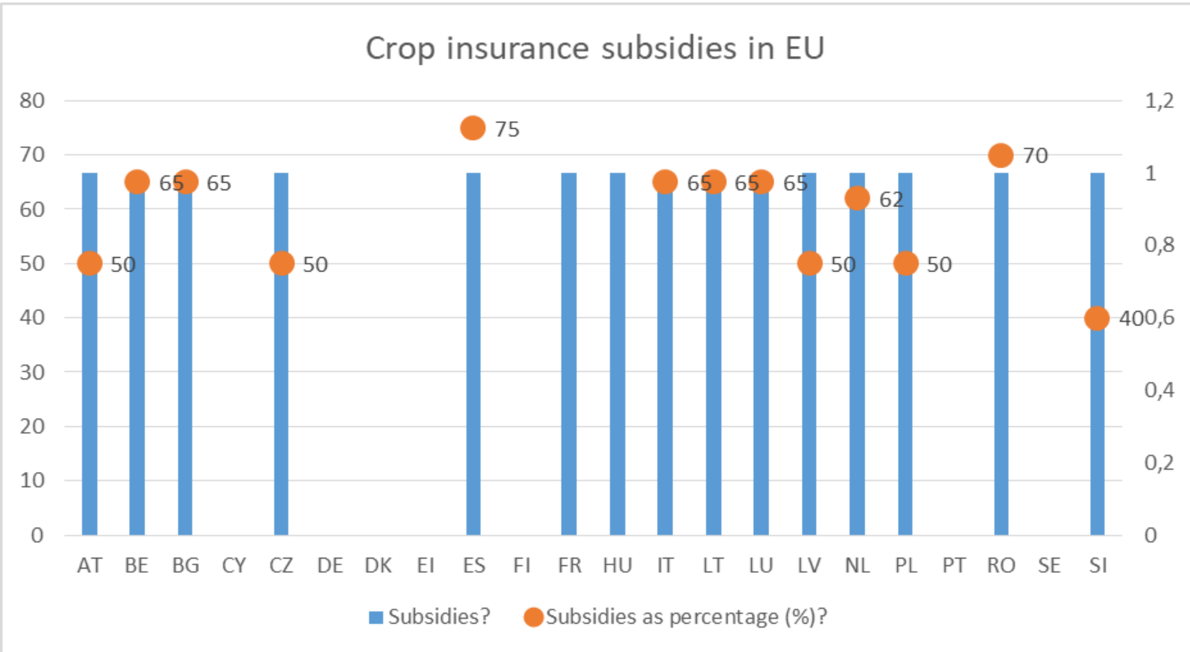

Figure 4: Analysis of agricultural insurance subsidies in the EU
Source: Created by the author

A brief conclusion of the analysis shows that, at the European level, there are solutions for transferring pure risks in the insurance market. However, from country to country, these solutions are more or less developed.

Conclusions

The study reveals that crop insurance solutions for climate risks are available in nearly all European countries, with significant variations driven by the presence of state subsidies. Countries with state-supported schemes tend to offer more diversified and accessible insurance options. A notable number of countries insure over 50% of their agricultural areas, while a few insure almost 100%. Additionally, parametric index-based insurance is emerging in some countries, though it remains in its early stages. Insurance costs and deductibles vary considerably, influenced by factors such as crop type and region. Finally, most EU countries provide subsidies, typically ranging between 50% and 65%.

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όμιλος διοικητικών επιστημόνων

Mini-symposium.

Session in the Greek language: "The Management of Development"

Local Government and Sustainable Development. The implementation of the Sustainable Development Goals in mountain areas

George M. Aspridis[1]
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University of Thessaly, email: aspridis@uth.gr

Abstract

The Sustainable Development Goals (SDGs) have two principal objectives: to enhance the quality of life for residents and to safeguard the natural environment. Ultimately, it can be argued that we have not inherited the land from our ancestors, but rather borrowed it from our children, as the Indian proverb suggests.

The protection of the environment and the improvement of living conditions have been matters of concern to humanity throughout history. In Greek mythology, the figure of Erysichthon is presented as one, who cut down the sacred oak tree of the goddess Demeter. The construction of the Athenian Fleet resulted in the felling of forests in Attica and Boeotia, while substantial quantities of marble were extracted from Penteli for use in the creation of these monumental works. It was Aristotle who first identified the intrinsic relationship between humanity and the natural environment, emphasizing the importance of this relationship for human health, well-being and development.

Subsequently, the classical economists of the 18th and 19th centuries employed the concept of land as a means of describing natural resources. In the view of classical economists, land was a crucial factor in the production of goods and services. Darwin's theory of evolution encompasses the adaptation of species to dynamic environments. Marx emphasised the estrangement of workers from nature and the exhaustion of natural resources. In the 21st century, considerable efforts have been made, and continue to be made, to protect the natural environment. The initial efforts were guided by the principles set forth in the UN Global Compact, which were subsequently operationalised through the implementation of the 17 Sustainable Development Goals. Recent studies have indicated that a balanced development of the various production sectors is necessary to achieve sustainability. Furthermore, examples from international experience will be presented in order to demonstrate the utility of the aforementioned goals in the strategic planning of local government.

The presentation aims to highlight the link between SDS and local government development and the help it can offer to the inhabitants, especially in the most remote municipalities. The 11th objective on sustainable cities and communities directly links local government at both levels with the implementation of SDS in the Greek territory.

In order to achieve the aforementioned objective, a combination of three methodological tools will be employed: the literature review, bibliometrics and the case study. The case study will focus on the former community of Anavra in Magnesia and the municipality of Argithea in the region of Karditsa. It is of particular importance that the conclusions are considered, as their application will significantly contribute to the enhancement of the implementation of the Sustainable Development Goals at the local government level.

Key words: Agenda 2030, environment, local government, sustainability

JEL: Q50, Q56, Q58

Sustainability is no longer about doing less harm.
It's about doing more good.

Jochen Zeitz[9]

1. INTRODUCTION

Sustainable development was defined in the 1987 Gro Harlem Brundtland Report of the International Commission on Environment and Development "Our Common Future" as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". It contributes to economic growth and the protection of social and environmental balances. It aims to improve the living conditions of individuals while preserving the environment in the short, medium and, above all, long term (Aspridis, 2015; Moussiopoulos, Ntziakhristos & Slini, 2015). It is one of the long-term objectives of the EU, according to Art. 3 of the Treaty on European Union.[10]

In this context, Agenda 2023 delineates the 17 Sustainable Development Goals (SDGs), which are designed to enhance living conditions and safeguard the environment. The objective is to emphasise the interconnection between the SDGs and the initial level of local government. In order to achieve the objective, a literature analysis and bibliometric analysis will be conducted.

A combination of research tools was employed to facilitate a more comprehensive analysis of the issue. The review of the literature, bibliometric analysis and case study. The literature review is based on a critical, analytical and synthetic study of the texts under consideration. The objective of the method is to identify the most effective theories and practices for managing diversity in contemporary organisations. This will enable the optimisation of organisational effectiveness and efficiency (Saunders et al., 2019). The case study is a method of presenting previous studies and understanding complex issues. This study refers to descriptive studies, which describe the strategies and phenomena analysed (Lazaridou, 2019). The results of the bibliometric analysis will be presented in the following chapter.

The findings of this study, pertaining to the implementation of the SDS by local governments, can be extrapolated to mountainous municipalities across mainland Greece. Further research could concentrate on the perspectives of elected officials at the local government level or on the residents of these municipalities.

2. LITERATURE REVIEW

> The Sustainable Development Goals represent a pathway to a more equitable, peaceful, and prosperous world, as well as a healthier planet. Furthermore, it constitutes a call for intergenerational solidarity. **António Manuel de Oliveira Guterres**[11]

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[9] Entrepreneur, CEO and chairman of the board of a multinational company.

[10] On line available on the website https://gym-pastr-new.kef.sch.gr/wp-content/uploads/2021/11/%CE%931-%CE%932-%CE%91%CE%95%CE%99%CE%A6%CE%9F%CE%A1%CE%9F%CE%A3-%CE%91%CE%9D%CE%91%CE%A0%CE%A4%CE%A5%CE%9E%CE%97.pdf.

[11] UN Secretary General.

Local government and decentralisation are regulated in the Constitution and in Articles 101 and 102. More specifically, Article 101 (Administrative Decentralisation) stipulates that "1. The administration of the State shall be organized according to the principle of decentralization. 2. The administrative division of the Country shall be based on geoeconomic, social and transportation conditions”. The article 102 (Local Government) defines that «1. The administration of local affairs shall be exercised by local government agencies of first and second level. For the administration of local affairs, there is a presumption of competence in favour of local government agencies. The range and categories of local affairs, as well as their allocation to each level, shall be specified by law. Law may assign to local government agencies the exercise of competences constituting mission of the State. 2. Local government agencies shall enjoy administrative and financial independence. Their authorities shall be elected by universal and secret ballot, as specified by law. 3. Law may provide for compulsory or voluntary associations of local government agencies to execute works or render services or exercise competences belonging to local government agencies; these shall be governed by elected administrations».

The Treaty on the Functioning of the EU in Article 11 states that "environmental protection requirements must be integrated into the definition and implementation of the Union's policies and activities, in particular with a view to promoting sustainable development" (EC, 2020).

Efforts to protect the environment were initiated by the Global Compact on Corporate Social Responsibility (CSR) which states that organisations (a) should take a proactive approach towards problems related to the environment, (b) it is necessary to take initiatives to promote the greatest possible environmental responsibility and finally (c) they should enhance the development and dissemination of environmentally friendly technologies (Aspridis, 2015).

The Sustainable Development Goals were then defined in order to formulate the appropriate institutional and policy framework for the implementation of best practices. The SDGs cover a broader spectrum which includes actions ranging from climate change to poverty and hunger eradication, promoting innovation, sustainable consumption and more (Figure 1) (Aspridis et al., 2022).

Figure 1: SDGs

Source: On line available on the website https://sustainabilitytools.eu/basics/sustainable-development-goals/

Sustainability is defined as "the ability of the earth's diverse ecosystems, including human cultural and economic systems, to maintain and adapt to changing environmental conditions in perpetuity" (Tyler Miller & Spoolman, 2022: 607).

The work of Tsiara & Andreopoulou (2015) assessed the prospects for sustainable development in mountainous areas. A municipality in PE Pieria was studied. The research focused on factors that contribute to the development of the region. Demographic data as well as data related to productive sectors that affect the development of the region, such as agriculture, livestock and mountain tourism, were recorded and analysed. The results of the survey showed a clear bias of the local population towards mountain tourism, a significant decline in agriculture, which in the research area is closely linked to tobacco cultivation, and a steady growth in livestock farming. The findings of the survey suggest that a more balanced development of the different production sectors is needed in order to achieve sustainability, especially with regard to the uneven development of tourism and the decline of agriculture.

Vardopoulos et al (2021) focuses on the evaluation of the practices, processes and results obtained in order to determine whether the municipal solid waste (MSW) management implemented in three municipalities of the Greater Attica urban area could be considered sustainable. The results are very useful for policy makers and local authorities to take actions related to the objectives set by the circular economy strategies, as well as the objectives set by the United Nations Development Programme and the European Green Deal Strategy.

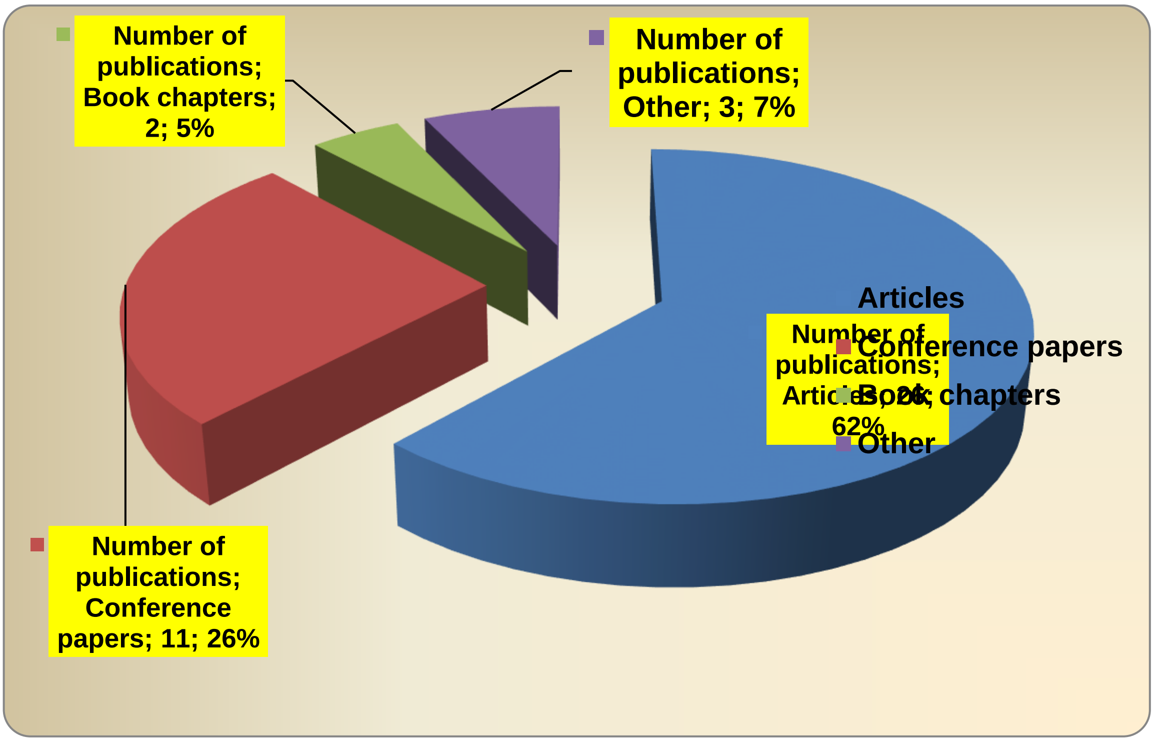
According to Ansell, Sørensen & Torfing (2022) there are many factors that motivate local government to adopt the SDGs. For example, promoting local projects and initiatives requires structural support and leadership. Local government can attribute to the structural and leadership dimension, influence on local conditions to pursue social and economic well-being, social equity and finally environmental protection.

Bazeed's (2023) study concluded that there is a need to define a general framework for local governance that defines clear roles for local government to achieve sustainable local development and develop methods for selecting local leaders. Strategic planning is about implementation and monitoring to achieve sustainable local development through the adoption of the SDGs.

3. BIBLIOMETRICS

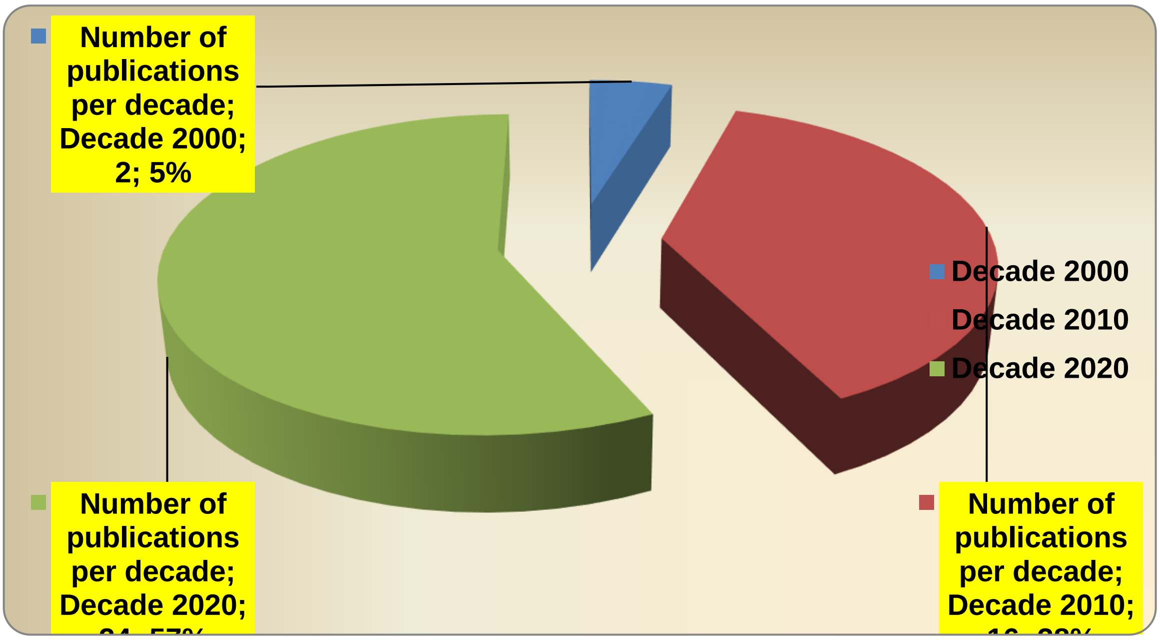
The bibliometric analysis recorded the existing literature and articles related to sustainable development and its implementation in local government in Greece. The aim was to highlight its increasing importance in the modern era. Through the bibliometric analysis, the number of publications related to the subject matter, the number and type of publications per time period and finally the most popular terms used in research (Sarantinoudis et al., 2023; Haleplioglou & Papavlasopoulos, 2022; Papavlasopoulos, 2015) are presented - among others.
The present bibliometric analysis was based on the academic database Scopus and the words "sustainability" and "municipalities" and "Greece" were used in the search and 42 results appeared. The bibliometric study was conducted in February 2024 and the VOS Viewer software was used for the graphical representation.
All articles published on the relevant platform are in English, and at least thirty (30) texts have at least one Greek author or all members of the writing team are Greek. The first relevant article on sustainable development and local government is that of Basbasm, Papaioannou & Kokkalis, 2006, entitled «The role of environment studies: Need for a new approach», in Fresenius Environmental Bulletin, Vol 15, 8B.

Chart 1: Publications



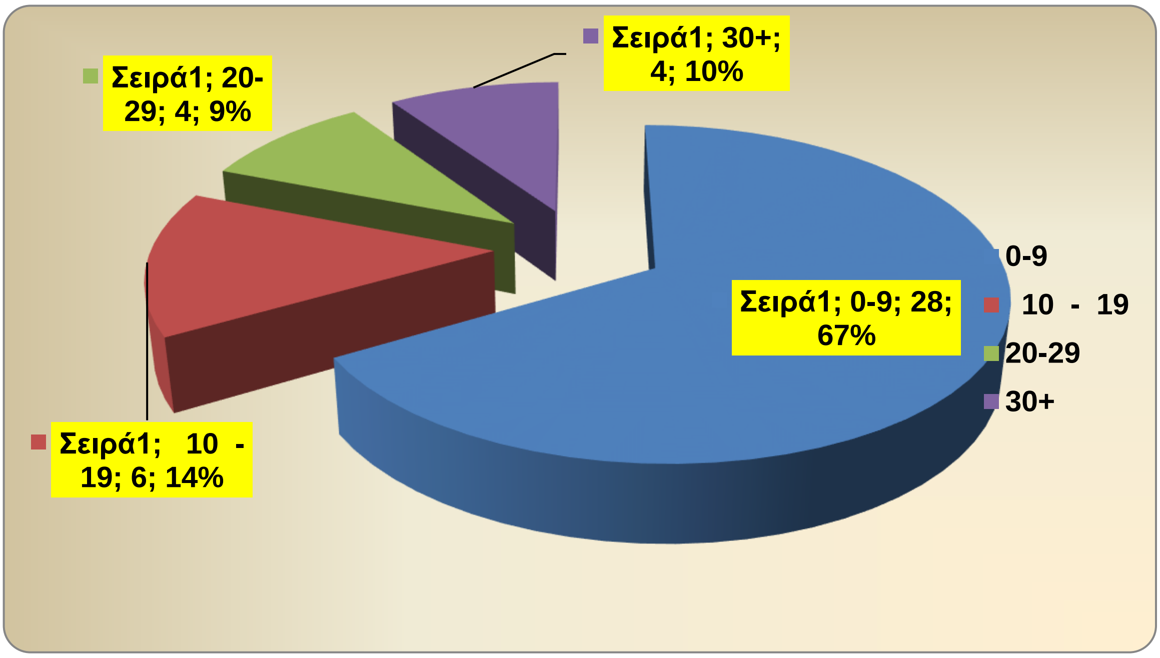
In total, 26 articles have been published in international journals, 11 papers in conferences and conference proceedings, two chapters in edited volumes and 3 in various other forms of publications (chart 1).

Chart 2: Publications over the years



Research and academic interest in this topic has become particularly intense in the current decade. It is noteworthy that before 2000 no publications appeared on the Scopus platform. Only two articles were published in the 2000s. In the following decade, 16 articles were published. In the current decade, 24 texts have already been published and the number is expected to increase geometrically compared to previous decades (chart 2).

Chart 3: Citations



In terms of the number of citations, the vast majority (28 texts) have received between 0 and 9 citations. Four texts have received between 20 and 29 and more than 30 or more citations. Finally, 6 texts received between 10 and 19 citations (chart 3).
Two articles have received the most citations, more than 35. These texts are the article of Fantozzi F., Bartocci P., D' Alessandro B., Arampatzis S. & Manos B. (2014). «Public-private partnerships value in bioenergy projects: Economic feasibility analysis based on two case studies», Biomass and Bioenergy, Vol 66 and Pedrero F., Grattan S.R., Ben-Gal A. & Vivaldi G.A. (2020).

«Opportunities for expanding the use of wastewaters for irrigation», Agricultural Water Management, Vol. 241.

Table 1: Articles with most citations

Authors	Title	Journal	Year of publication	Number of citations
Fantozzi F.; Bartocci P.; D'Alessandro B.; Arampatzis S.; Manos B.	Public-private partnerships value in bioenergy projects: Economic feasibility analysis based on two case studies	Biomass and Bioenergy	2014	35
Pedrero F.; Grattan S.R.; Ben-Gal A.; Vivaldi G.A.	Opportunities for expanding the use of wastewaters for irrigation of olives	Agricultural Water Management	2020	35
Vardopoulos I.; Konstantopoulos I.; Zorpas A.A.; Limousy L.; Bennici	Sustainable metropolitan areas perspectives through assessment of the existing waste management strategies	Environmental Science and Pollution Research	2021	32
Feleki E.; Vlachokostas C.; Moussiopoulos N.	Holistic methodological framework for the characterization of urban sustainability and strategic planning	Journal of Cleaner Production	2020	30
Papaioannou T.G.; Dimitriou N.; Vasilakis K.; Schoofs A.; Nikiforakis	An IoT-based gamified approach for reducing occupants' energy wastage in public buildings	Sensors (Switzerland)	2018	29

Table 2: Clusters

Cluster 1 (3 items)	Cluster 2 (1 item)
Greece	Sustainable development
Metropolitan area	
Sustainability	

According to table 2 and chart 4 the keywords used are Greece, Metropolitan area, Sustainability and Sustainable development. Metropolitan area is linked to Greece and sustainability, similarly sustainable development is linked to Greece and sustainability. There is no direct link between metropolitan area and sustainable development.

Chart 4: The graphic representation

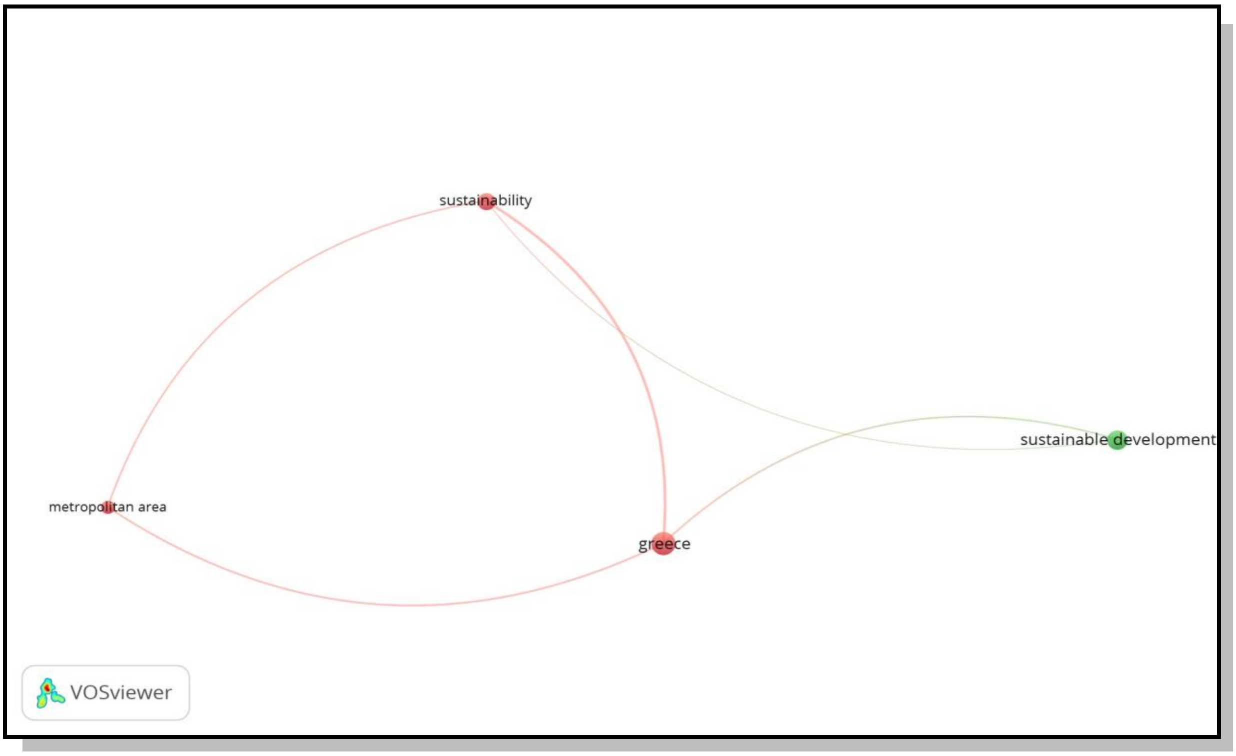


Table 3: Indicative publications by Greek authors

Authors	Title	Journal	Year of publication
Moustairas I.; Vardopoulos I.; Kavouras S.; Salvati L.; Zorpas A.A.	Exploring factors that affect public acceptance of establishing an urban environmental education and recycling center	Sustainable Chemistry & Pharmacy	2022
Feleki E.; Vlachokostas C.; Moussiopoulos N.	Holistic methodological framework for the characterization of urban sustainability and strategic planning	Journal of Cleaner Production	2020
Vardopoulos I.; Konstantopoulos I.; Zorpas A.A.; Limousy L.; Bennici	Effects of European Union agricultural policies on the sustainability of grazingland use in a typical Greek rural area	Land Use Policy	2017
Tsiaras S.; Andreopoulou Z.	Sustainable development perspectives in a less favoured area of Greece	Journal of Environmental Protection and Ecology	2015

4. LOCAL GOVERNMENT AND SDGs

To-do list for people and planet
Paolo Gentiloni[12]

In the National Strategy for Sustainable and Equitable Development Plan, the "Road to Fair and Sustainable Development (2019) goes through the exploitation of local assets and opportunities that local communities are best aware of. Unfortunately, the local government has been one of the biggest victims of the crisis resulting in operating underfunded and understaffed. Today, in cooperation with local authorities, a significant effort is being made to overcome these difficulties in order to upgrade its development role across the board. These central interventions focus on four levels: institutional, financial, staffing and digital upgrading."

[12]Commissioner, European Commission, Responsible for Economy and for Eurostat. European Union 2020.

According to the KEDE report on the implementation of the 2030 Agenda, "the SDGs are directly linked to the responsibilities of local and regional authorities, particularly in terms of their role in the provision of basic services; their involvement is absolutely essential for the success of sustainable development. However, the local and regional authorities that develop and implement these policies are often unaware of their own potential relationship with specific SDGs. Thus, what is needed are actions that raise awareness and support the active role of local actors, as well as support for local authorities to make decisions that contribute to the achievement of the SDGs...Although Greek regions may need more resources and capacities, they intend to play a leading role in the implementation of policies and plans to achieve the SDGs".[13]

In the city of Santana de Parnaiba, Brazil, SDG 16: Peace, justice and strong institutions was adopted with the professional development of the police, the establishment of the first women's police station to combat domestic violence. These activities allowed the city to tackle crime and today it is one of the safest cities in Brazil. Similarly, in India and Darjeeling, the development of Agenda 2030 was supported through the implementation of a series of SDGs such as 6 (Clean Water and Sanitation), SDG 11 (Sustainable Cities and Communities) and SDG 12 (Responsible Consumption and Production). The strategic plan involves the implementation of a comprehensive plan based on the contribution of all members of the local community.[14]

According to the Local Action website, a number of objectives can also be implemented by local government. For example, SDG 6: Clean water and sanitation, SDG 7: Cheap and clean energy, SDG 17: Working together for the goals and finally SDG 11. SDG 11 (Sustainable Cities and Communities) is one of the SDGs related to local government. This objective highlights the role of SDGs in driving change, from the bottom up. That is, from local communities to central government. In general, the acceptance of SDGs at the local government level provides opportunities for development and partnerships to achieve economic and social sustainability of cities regardless of their size and contributes to improving the quality of life of city residents. It is characteristic that the implementation of the SDGs will contribute to the establishment of the principle of subsidiarity and to addressing and solving local problems at the lowest possible level (Stylianou, 2023).

The Municipality of Aghios Dimitrios has adopted and implemented most of the SDS. For example, under SDG1 it has contributed to the social care of families in need of assistance through the provision of rations, medicines and general support. Under SDG11 it has helped to improve the digital processes provided to citizens. Under SDG4 it has helped to increase the number of students attending the social tutoring courses. Finally, in the context of the SDG12, it helped to improve the quality of life and environmental protection (recycling, circular economy, etc.).[15]

5. COMMUNITY OF ANAVRA

The Sustainable Development Goals were adopted by the 70th UN General Assembly in 2015 to formulate policies and commitments for developed and developing countries to integrate the dimensions of sustainable development, namely social, environmental and economic policies. Our country accepted that the implementation of the Goals will contribute to the development of the country.

But is this the case? Were the Goals implemented in the 2010s in Greece? History shows the opposite. In the 1990s a mountain community in what is now Magnesia, Anavra[16] and under the

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[13]On line available on the website https://kede.gr/i-atzenta-2030-kai-i-topiki-aftodioikisi/.

[14]On line available on the website https://sdgs.un.org/partnerships/achieving-sdgs-one-city-time-towards-local-authority-voluntary-review.

[15]On line available on the website https://dad.gr/oi-deiktes-viosimis-anaptyxis-toy-dimoy-agioy-dimitrioy/.

[16]A similar situation was in Spain in the village of Marinaleda in Western Andalusia, with zero unemployment rate among its inhabitants. The mayor at the time, Juan Manuel Sanchez Gordillo (Juan Manuel Sanchez Gordillo) had incorporated a number of the Objectives that were established in the following years. In particular, he incorporated Goals 1-Nil poverty,

administration of Dimitris Tsoukalas, was an example of sustainable development. Geographically Anavra is 72 km from the capital of the Magnesia region, Volos, and is part of the Municipality of Almyros. According to the last census of ELSTAT (2021) the Municipal Unit Anavra has 405 inhabitants.

How do the Goals relate to the actions taken in the Anavra community in the early 20th century? Some examples are presented below.

- At the beginning of the 20th century the water supply network was almost destroyed and inadequate. For example, people and animals drank water from the same places. One of the first actions of the community leader was to restore the water supply network and make the water potable (SDG 6: Clean water and sanitation).

- Living standards improved to be among the highest in Europe, with an average annual income of between €30,000 and €100,000 (SDG 1: Zero Poverty, SDG 2: Zero Hunger, SDG 8: Decent Work and Economic Development, SDG 10: Less Inequality). All actions were carried out with the equal participation of both genders (SDG 5).

- The infrastructure of the schools in the community was improved, sports facilities, an indoor gym and a folklore museum were created (SDG 4: Quality education, SDG 11: Sustainable cities and communities).

- A wind farm was established which met the community's energy needs and also contributed to the community's revenue (SDG 7: Cheap and clean energy, SDG 9: Industrial, innovation and infrastructure).

- To achieve all of the above, it was necessary for all stakeholders, the community, residents, the region and even the EU, to work together through the absorption of funds for the investments that needed to be made (SDG 17: Collaboration on objectives).[17]

8-Decent work and economic development and 10-Less inequality. On line available on the website https://tvxs.gr/apopseis/arthra-gnomis/xoyan-manoyel-santses-gkorntigio-oi-agores-ebalan-ta-krati-na-plirosoyn-ta-spasm/.

[17]According to the websites https://www.aftodioikisi.gr/ota/dimoi/anavra-thavma-pou-esvise/ and https://www.topontiki.gr/2024/03/09/anavra-to-chorio-thavma-pou-iche-mideniki-anergia/.

Photograph 1: Photo of Anavra[18]

Source: On line available on the website https://www.aftodioikisi.gr/ota/dimoi/anavra-thavma-pou-esvise/

6. MUNICIPALITY OF ARGITHEA- REGION OF KARDITSA

The Municipality of Argithea is a mountainous municipality of the Karditsa Region with its seat in Anthiro. It has an area of 372.837 km^2 and the population is 5.414 inhabitants and was created by the implementation of the provisions of the Kallikrates Programme.

In the strategic environmental impact assessment of the Municipality of Argithea (2016:6) an initial link between the SBA and the local government emerges. Specifically, it is stated that "According to the principle of sustainable development, human intervention in the environment should be carried out in a way that ensures a balanced relationship between the exploitation of natural resources and the evolution of ecosystems and for the benefit of future generations. Therefore, the proposed spatial development model for the municipality should ensure a balance in space between the productive, residential, environmental and social aspects and guarantee the sufficiency in time of natural and man-made resources".

In recent years, interventions in the municipality (concerning the environment, social policy and others) have been carried out based on the adoption of the principles of the SDGs. The principles on climate change (SDG 13) have been implemented, especially after the natural disasters of September 2023.[19] Defibrillators were placed on the mountain paths of the Municipality for the protection of hikers. In addition, a private medical centre supported the health centre and clinics of the Municipality with medical equipment as well as pharmaceutical and sanitary equipment, while the Municipality also participated in the "Travel for Health" programme of this group (SDG 3: Good Health and Wellbeing). Within the framework of the same Objective, the Municipality also participated in actions of the Hellenic Cancer Society to prevent smoking in playgrounds. With the aim of protecting children. In the framework of the SDG11, actions were adopted to protect the environment and the ecosystem of the lake, with the aim of improving the quality of life.

At the same time, actions for the tourist promotion of the Municipality, such as long and short distance races and dancing over the waters of Lake Stefaniada..[20]

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[18]The photograph is presented with permission of the contact persons of the website www.aftodioikisi.gr.

[19]On line available on the website https://www.in.gr/2024/05/21/politics/aftodioikisi/sto-epikentro-diasyndesi-tis-argitheas/.

[20]On line available on the website https://mouzakinews.gr/2024/06/aerial-dance-gia-proti-fora-sti-limni-stefaniadas-

The main disadvantage in the implementation of the SDGs in the Municipality is the absence of women's participation in the Municipal Council and thus the lack of implementation of the Gender Equality Goal. It is noteworthy that only one woman has been elected to the City Council.[21]

Photograph 2: Community of Anthiros[22]

Source: On line available on the website https://argithea.gov.gr/choria-tis-argitheas/dytiki-argithea/anthiro/

Figure 2: SDGs in Local Government

dimou-argitheas/.

[21]On line available on the website https://argithea.gov.gr/

[22]The photograph is presented with permission of the Mayor Andreas Stergiou.

7. CONCLUSIONS

According to the General Directorate of Development in Cyprus are encouraged to conduct regular and comprehensive reviews of progress at national and sub-national level". The SDGs refer to the adoption of strategic policies that address society, the environment and the economy and promote the linkage of the SDGs to the policy and institutional framework. This is why it is necessary to mobilise the powers of local government, in line with the principle of subsidiarity, to solve problems at the level closest to the people.

From the preceding reports, the implementation of the objectives has been underway - albeit without the knowledge of local authorities in Europe - since the early 2010s. Particularly from the regions of southern Europe that were hit hardest by the economic crisis. The initial accumulated knowledge formed the basis for the formulation of a global strategy, through the dissemination of this and the good practices that had been implemented.

The study highlighted this perspective and how sustainable development policies can be applied in the Greek reality. Besides, the 11th objective concerning sustainable cities and communities directly links first and second level local government with the implementation of SDGs in the Greek territory.

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The impact of economic adjustment programme reforms on aspects of social protection and pensions in Cyprus, Greece, Ireland and Portugal: from generosity to austerity

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Abstract

This article offers a comparative analysis of the structural reforms in the social protection and the pension systems of Cyprus, Greece, Ireland and Portugal, all euro area periphery countries, subjected to unprecedented Economic Adjustment Programmes (EAPs). We explore the cumulative impact of these reforms on asymmetries and divergences between core and periphery euro area countries. We conceptualize a core of highly developed countries and a periphery of less advanced countries. The qualitative analysis of the EAPs official documents and reviews shows how these reforms differ from past social protection and pension reforms in Germany and France, two core euro area countries not subjected to EAPs. Our findings from exploiting comparative data on old age expenditure and social protection benefits in euro per inhabitant indicate an exacerbation of divergence between the two axes', the core and the periphery, to the detriment of the latter. Similar trends are observed when comparisons are drawn between the periphery and the euro area average across the same indicators. We argue that the identified extension of asymmetries is associated to the imposed EAP structural reforms. We suggest that social divergences will continue to increase if the context remains unchanged.

Keywords: structural change, welfare state, dependency, social policy, economic reform.

JEL classification codes: I38 Welfare, H55 Social Security and Public Pensions, H53: Government Expenditures and Welfare Programs

1. Introduction

The new Economic Governance in the Economic and Monetary Union (EMU) or euro area was gradually enforced (see Scharpf, 2021; De Grauwe, 2020; Lapavitsas, et al., 2018; Tamborini, 2018; Costantini, 2017; Gouliamos, 2014; Zeitlin and Vanecko, 2014; Hallerberg et al., 2011) in the aftermath of the 2008 international financial crisis. Interrelated to this development is the unique in the history of the EU, imposition of Economic Adjustment Programmes (EAPs) of structural financial, fiscal, labour and product markets reforms to Cyprus, Greece, Ireland, and Portugal. These programmes involved structural reforms in the form of conditionalities (Scharpf, 2021; De Grauwe and Ji, 2020; Zeitlin and Vanhercke, 2014; Schwartz, 2014; Costamagna, 2012). The alternative to the imposition of EAPs would have been debt restructuring after lender countries expressed unwillingness to provide more financing (Pisani-Ferry et al. 2010). Following a request for bilateral financial assistance to allow the Greek government to meet its fiscal financing needs due to excessive interest rate on government bonds (Gibson et al., 2012), the first Greek EAP was agreed in May 2010. After a similar unsustainable rise of the interest rate on government bonds and the revelation of major vulnerabilities across the national banking sector, the Irish EAP was agreed in December 2010. In Portugal the EAP was formally adopted in May 2011 while in April 2013 an EAP was approved for Cyprus.

All four countries share a similar context, inasmuch as they are euro area periphery countries subjected to EAPs for financial support (Alcidi et al., 2016).[23] With the implementation of the EAPs, austerity measures were enforced to reduce government debt primarily through severe cuts to public spending, in particular to social expenditure (Costamagna, 2012), including pension funds, social insurance schemes and healthcare (Schwartz, 2014). In spite of recent EU initiatives, seen by some scholars as extending social regulation (Miro et al., 2023) and as fertilizing an increased emphasis on social objectives in the priorities of the European Semester (Zeitlin & Vanhercke, 2018), income inequality (Creel and Herradi, 2019) and economic inequality conditions in the euro area are worsening (Baiardi & Morana, 2018). Avlijaš (et al, 2021) exposed a strategy of competitive impoverishment in indebt countries of Southern Europe after 2010, through the imposition of intrusive MoU (Memoranda of Understanding) by EU institutions and the IMF or troika (the European Commission, European Central Bank and the International Monetary Fund (IMF)). This took place in a wider framework of a “new European interventionism” focusing on public sector wages and the decentralisation of collective bargaining systems in the -under troika surveillance- periphery (Schulten and Müller, 2013. p. 340), an arena where as Rathgeb and Tassinari (2022)

[23] Under the terms of the Financial Assistance for the Recapitalisation of Financial Institutions by the European Financial Stability Facility (EFSF), Spain signed in July 2012 an MoU for a financing package of up to EUR 100 billion for recapitalisation and restructuring of the Spanish financial sector. As such, policy conditionality was financial-sector specific. Although Spain did take structural measures, these were in the framework of country-specific recommendations under the European semester and not in the form of specific MoU conditionalities as in the case of Cyprus, Greece, Ireland and Portugal. For this reason, Spain was not included in the focus of this article. (See MEMORANDUM OF UNDERSTANDING ON FINANCIAL-SECTOR POLICY CONDITIONALITY. SPAIN MEMORANDUM OF UNDERSTANDING ON FINANCIAL-SECTOR POLICY CONDITIONALITY 20 JULY 2012 pp. 54-63 in European Union (2012). The Financial Sector Adjustment Programme for Spain. EUROPEAN ECONOMY. Occasional Papers 118 https://ec.europa.eu/economy_finance/publications/occasional_paper/2012/pdf/ocp118_en.pdf).

insist, EMU countries compete for wage and labour market flexibility, a form of internal devaluation to prevent increases in unit labour costs. It is relevant to remind that Johnston (2021) suggested that one of the reasons behind the aforementioned EU institutions strategy (of low growth and high unemployment equilibrium, as he maintains) vis a vis peripheral Eurozone countries [24] was the influence of Germany in the European Council constellation. Germany, in the post reunification environment, followed a prolonged wage restraint direction together with significant competitiveness reforms, a pathway of sacrifices, perceived now as appropriate for the Southern in-debt countries (Johnston, 2021).

In this article, we comparatively study structural reforms in the social protection and pension systems of Cyprus, Greece, Ireland and Portugal. By exploiting data on old-age expenditure (OAE) and social protection benefits (SPB) per inhabitant from the Eurostat, we explore the cumulative impact of the identified Economic Adjustment Programme reforms on asymmetries and divergences between the axis of the above stated periphery countries and the core, Germany and France. We thus relate core-periphery different trajectories to the extent of divergences in social protection and pension. The coincidence of changing pension systems (to less generous) and changing labour markets (where non-standard employment patterns are now more frequently present) poses a significant challenge (Hinrichs, 2021) motivating further research.

The study of core-periphery patterns (see also Gräbner et al., 2020) in the framework of the Monetary Union is substantial including based on the Varieties of Capitalism literature (see Johnston & Regan, 2016) and on the theory of endogenous Optimal Currency Areas (see Campos and Macchiarelli, 2021). Our theoretical approach draws on the distinction between core and periphery countries from an adaptation of a world systems perspective, where the notions of centre (or core), periphery and semi-periphery which concern various features of mainly economic development and dependency of states and regions of the world are considered. The centre-periphery concept is an established method of analysis to describe asymmetric relations (Rama & Hall, 2021) and has attracted scholarly attention after the 2008 crisis (see Weissenbacher, 2019; Magone et al., 2016; Grinin et al., 2016; Johnston et al., 2014). Different variations of this school of thought identify unequal exchange (Amin, 1988), the structure and terms of trade (Prebisch, 1949), foreign debt payments (George, 1990) and foreign direct investment as the major mechanisms of exploitation and surplus transfer. Through these mechanisms "a substantial part of the social product is sucked out of the periphery and transferred to the centre, there converted into capital, leaving workers and producers on the periphery to bear the heavy social costs of this 'development' and survive in the wreckage left in its wake" (Petras & Weltmeyer, 2007, p. 22). The core-periphery pattern may potentially underplay internal (national) social tensions and divergences. Therefore, we relate core-periphery analysis to the idea that does not underestimate the ability of capitalism "to depend less directly in colonial rule and conquest of the old days…"and more "through the enforcement of strict reforms, to use aid or loans, or investments, or debt relief for the benefit of "imposing and manipulating the operations of the capitalist market" (Wood, 2005, p.21). As Anderson argues (2012), contemporary imperialism is characterized mainly by economic involvement to politically "independent" countries dominated, to different degrees, both by more powerful countries and by capital based in them. We argue that the imposition of strict structural reforms as a conditionality to financial assistance in the periphery can, at least to some extent, be understood under the previous analysis to the extent that social protection and pension policies in the periphery were subordinated to the superior objectives of increasing competitiveness, improving fiscal sustainability, reducing debt to GDP ratio and recovering the financial stability.

[24] A strategy which included policies of comprehensive wage moderation and decentralisation of wage-setting together with market friendly structural labor market reforms and welfare provision cuts, altogether, as presumed, would cut the deficit and inflation and increase competitiveness.

Such perspective may offer an alternative angle to discussions of recent developments in the euro area. We schematically view the euro area as a union where core highly developed countries, for the purposes of this paper, Germany and France, and a group of less advanced countries in the periphery, Cyprus, Greece, Ireland and Portugal can be identified (see Parker and Tsarouhas, 2018; Amin, 2019) in times of uneven development and heterogeneity in the EMU (see also Gräbner et al., 2020; Lapavitsas, 2019; Laffan 2016). Although imbalances between 'creditor' or 'surplus' states and 'debtor' or 'deficit' states in the euro area are not a new phenomenon, the crisis renders the 'core–periphery' concept increasingly relevant (Parker &Tsarouhas 2018). Germany and France, despite not subjected to MoUs, have also implemented social protection reforms which have led to a worsening of the "social circumstances of their citizens" (Palier, 2004, p. 3). We briefly take these reforms into consideration in section 2. We argue, however, that structural adjustment in the four countries of the euro area periphery where of such nature as to lead to an extension of divergences across the core-periphery axis to the detriment of the periphery and vulnerable social categories. To return to the relevance of the "core and periphery" contrast, this insinuates that highly developed core countries exploit a less developed periphery in conditions, as we argue, where an EU structural reconstitution of capitalism is endeavoured- with hegemonic capitals as motors-, a state of play which is enforced to the interior of unevenly developed states or even regions (Gouliamos 2014) where "national welfare states compete – and adapt their policies – to attract or retain mobile capital" (Van Apeldoorn, April 2012), inviting the rise of social inequalities (Denk and Cournède, 2015) which are exacerbated by the crisis and newly institutionalised policies (Magone et al., 2016). The level of welfare provisions, the assessment of which remains a complex, context-dependent procedure (Sowula, et al., 2023) is one of the features of the core, periphery and semi-periphery concepts formulated by Wallerstein (1974, 1979) whereas advanced countries have high(er) levels of welfare, semi-periphery low(er) levels while in the periphery there are no welfare services or they are under subsistence.

The comparative study of this new environment in order to understand the present and future of social protection in the euro area periphery allows more informed approaches to discussions on social inequality. Some of the effects of the structural reforms in the EAPs are not immediate but will be felt by the societies in the periphery in years to come. One such case is the pension system reforms and the gradual increase in the retirement age. This is a complex and demanding study which has scrutinised MoUs documents, revisions and post programme surveillance reports. By doing so, we aspire to contribute to the existing literature on core-periphery disparities and the competitive impoverishment argument, addressing the exacerbation of socioeconomic divergence as opposed to convergence within the EMU in the fields of social protection, the welfare and pension system in the EMU which, as we will discuss in sections two and three, were subjected to the principal goals of the EAPs. Such an approach is urgent in so far, the initiation of the EMU facilitated a double promise of unity and prosperity, as underlined by ex-Commissioner for Finance P. Moscovici. "Unity, because it has always aspired to be infinitely more than a fixed currency. Prosperity, because the single currency had to pull its members up and progressively bring the lowest performing countries to the level of the countries/locomotives of economic development" (Georgakopoulos, 2018, pp. 32-33). While previous studies address core- periphery disparities, there is a limited focus on comparing all four country cases of the euro area periphery with Germany and France while especially Cyprus is only occasionally integrated in such comprehensive studies. Our study attempts to limit these gaps.

1.1 Methodology

We follow a comparative qualitative approach insofar we study and analyse the content of social protection and pension reforms in the euro area periphery under EAP (Cyprus, Greece, Ireland and Portugal) to relate them to the trajectory of specific indicators. To identify social protection and pension reforms, we used the official classification of the European Stability Mechanism (ESM, Conditionality Dashboard) where these are classified under the categories either of fiscal structural changes or structural labour-market reforms.[25] Social protection and pension reforms that did not fall under the category of structural reforms were not considered. In sections 3 and 4 we present and analyse the content of the aforementioned reforms as identified in the original Economic Adjustment Programme documents and official reviews and as per the ESM Programme Database. Secondary sources retrieved for analysis include European Economy Occasional Papers on Economic Adjustment Programmes. To assess the impact of the above stated reforms, we use comparative quantitative information on social protection categories and/or functions estimated by following ESSPROS (2019 edition) which cover: Expenditure on old age (OAE) function by type of benefit and means-testing (at constant 2010 prices); Social protection benefits (SPB) in Euro per inhabitant (at constant 2010 prices). Such indicators presented in euro per inhabitant are not uncommon in comparing social protection among countries (Adam & Papatheodorou, 2016; Androniceanu & Georgescu, 2022) although more categories of social protection are necessary to gain a holistic representation (see Sowula et al., 2023). The data presented in this article are in the form of consecutive three-year time span, from the commencement of the EAPs, moving towards the period of implementation of structural reforms in social protection and pension policy (2010-2019). To harvest a more comprehensive picture, we compare the course of the periphery with those of Germany and France, two core euro area countries not subjected in EAPs (despite both countries have previously undertaken reforms in social protection and welfare, see p.p. 10-11) and the euro area average. Our pursuit is to identify if the structural reforms have by 2019 led to a change of the 2010 balance between the periphery, the core and the euro area (average), in other words, if divergence in OAE and SPB between the poles is the same, or has increased/decreased. Comparisons to euro area average and to core euro area countries are thought to offer a more unbiassed glance in discussing the “dichotomy” of core and periphery countries and may enhance the internal validity of the comparisons among core and periphery countries. Comparisons exclude data during the 2020-2022 COVID-19 pandemic period due to the extraordinary measures in national budgets. Post COVID-19 data (2023) are not available for all countries under study)

The remainder of this article is organised as follows: we firstly situate social protection in the context of the EAPs and briefly discuss past social protection and pension reforms in Germany and France. We then identify and analyse major welfare and social protection reforms introduced through the Economic Adjustment Programmes for Cyprus, Greece, Ireland and Portugal. We show that these reforms, unlike the reforms in Germany and France, are subordinated to the philosophy and overarching aims of the EAPs. Building upon the above approach, we proceed with investigating pension reform in the four countries of the euro area periphery. Lastly, we present comparative evidence on the evolution of old age expenditure and social protection benefits in euro per inhabitant in the periphery, the core and the rest of the euro area.

2. Background

2.1 Social protection in the context of the Economic Adjustment Programmes and reforms in Germany and France

“Austerity measures endanger social protection schemes, including pensions, thereby dramatically affecting the enjoyment of the rights to social security and to an adequate standard of living” (OHCHR, 2013, p.17). De Schutter and Dermine (2016) explain that the conditionalities attached

[25] European Stability Mechanism-Conditionality Dashboard https://www.esm.europa.eu/financial-assistance/programme-database/conditionality

to the financial assistance loans to the bailed-out countries had dramatic repercussions on the general level of social and economic rights. Fundamental rights appear not to have been prioritised for the allocation of spending cuts and budgetary efforts in any of the countries under EAP.

In the framework of the EMU, high current account deficits in the periphery are considered excessive and as such were thought to demand treatment via "supply-side, structural policies" (Tamborini, 2018, p. 5). Such reforms address the modification of policies related to nominal unit labor costs, inducing further flexibility of labour markets in order to enhance competitiveness. The aim is to increase the "allocation of productive resources of capital and labour under the doctrine of profit maximization and thus enhance efficiency translated into return" (Rodrick, 2016). The neoliberal approach[26] to EAP structural reforms in the countries of the EMU periphery, primarily focuses on increasing price flexibility and competition (De Grauwe and Ji, 2020). Ensuing labour market reforms involving new measures such as "relaxing job protection, cuts in unemployment benefits" (De Grauwe and Ji, 2020, p.1) may challenge social protection (Dymski and Kaltenbrunner, 2021). Important conditionalities influence basic services in the field of social protection, education and healthcare" (Costamagna, 2012, p. 9) for the sake of the financial stability target. In Greece alone, conditionalities and revisions agreed, consisted of 3,958 structural policy reforms (Christodoulides and Gouliamos, 2022).

The definition of social protection encompasses all interventions from public or private bodies intended to relieve households and individuals of the burden of a defined set of risks or needs, provided that there is neither a simultaneous reciprocal nor an individual arrangement involved.[27] The list of risks or needs that may give rise to social protection are: Sickness/Health care, Disability, Old age, Survivors, Family/children, Unemployment, Housing and Social exclusion not elsewhere classified.[28] Social protection at the heart of policies can generate a buffer shield to income loss, through income redistribution "both over the life-course and between individuals" (Fritzell & Ritakallio, 2010). The income condition for workers may depend on social protection spending which subsequently "supports their disposable income and protects them against unexpected risks" (Koratzanis, 2021, p. 2). As a result, the quantity and quality of social protection acquires increasing importance in conditions where monetary policy, particularly in times of, endemic to capitalism, crisis (De Grauwe, 2013) exacerbated by the EMU (Parker & Tsarouhas, 2018), increase income and wealth inequality, the levels of which are conventionally managed through the means of fiscal transfers and taxation (Creel and Herradi, 2019). In fact, the legacy of the crisis and of subsequent policies, may have led to sharp disparities between the economies of the core and periphery (see Laffan, 2016).

Despite never subjected to EAPs, Germany and France have also enforced social protection reforms. These have led to a deterioration of the "social circumstances of their citizens" (Palier, 2004, p. 3). Although the purpose of this article is not to analyse social protection reforms in these two core countries, before proceeding to the subsections which analyse structural reforms in the periphery, a non-exhaustive reference is here presented in order to gain a broader perspective when the outcomes of such policies are weighted in section four. As Arcanjo (2012) suggests, due

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[26] The term neoliberalism in this article refers to "a class project that coalesced in the crisis of the 1970s. Masked by a lot of rhetoric about individual freedom, liberty, personal responsibility and the virtues of privatisation, the free market and free trade, it legitimised draconian policies designed to restore and consolidate capitalist class power. This project has been successful, judging by the incredible centralisation of wealth and power observable in all those countries that took the neoliberal road" (Harvey, 2010, p.10).

[27] Social protection (spr) Reference Metadata in Euro SDMX Metadata Structure (ESMS) Compiling agency: Eurostat, the statistical office of the European Union https://ec.europa.eu/eurostat/cache/metadata/en/spr_esms.htm

[28] Old age expenditure and social protection benefits, parameters analysed in the next sections are therefore included among the social protection needs.

to social protection reforms, the rise of unemployment in the two core countries between 2002-04 was not met with higher social protection expenditure.[29] Germany was in fact, the first country to pass strict reforms against a background of rising public pension expenditure in view of future financial sustainability (Hinrichs, 2005; Ebbinghaus, 2015). [30] Since 1989 the country experienced more than ten pension reform acts which, like in the rest of Europe, were formulated towards containing public pension spending, shaping people's perceptions of fairness (Hinrichs, 2021). Measures such as increasing the pensionable age, the introduction of the sustainability factor in the benefit formula, private involvement in retirement income package to supplement lower replacement ratios by public schemes (2001-2004 reforms) have been implemented in Germany before the 2007/08 crisis (Hinrichs, 2021) so as to transform the generous old age insurance system of Germany into "a more meagre pension" (Ebbinghaus, 2015, p. 12). Lastly, with "The Agenda 2010" and the so called Hartz laws which have reorientated the welfare state towards activation policies and to a considerable reduction of the generosity of the unemployment benefit, the country turned away from being a "traditional 'social insurance' welfare state model" (Schwander & Manow, 2017). France, like Germany, adopted measures to reduce benefits including the extension of the contribution time in order to be entitled of unemployment benefits, the tightening of the preconditions to receive benefits, a reduction of early retirements and measures that disincentivise not accepting a job irrespective of (missing) skills (Palier, 2004). Morel argues that social tax expenditures, a form of what he calls "hidden" government intervention, were applied as "a means to circumvent existing welfare and labor market institutions, or to discreetly reform them contributing to the "incremental institutional transformation of the French welfare state, with possibly important distributional effects also" (Morel et al., 2018, p.2). The previous summary shows that both Germany and France underwent significant reforms in their respective social protection and pension systems which though, as we shall later see did not prove as deep as to negatively affect the levels of social protection in comparison to the euro area periphery. In the next subsections, we identify the related to the aims of this article structural reforms in the fields of social protection, enforced in the four countries of the periphery as were agreed and included in the original MoUs of the Economic Adjustment Programme documents and or EU Commission documents and ESM conditionalities database. We show the subordination of social protection reforms to the superior aims underpinning the EAPs, a relation which may explain an exacerbation of divergences between core and periphery states.

2.2 The EAP of Cyprus and structural Reforms

The EAP for Cyprus was activated through the MoU on Specific Economic Policy Conditionality agreed on 2 April 2013. It is not to be ignored that at the time, Cyprus was already enforcing significant consolidation measures, already implementing the vast majority of fiscal measures for 2012-14 as outlined in the draft MoU agreement of 22 November 2012 (IMF Press Release No. 13/175 May 15, 2013). A clear differentiation in comparison to other periphery countries was the imposition of the so-called "haircut" or bail-in (Zenios, 2013; Artemou, 2016), a contribution upon uninsured bank depositors for the recapitalisation of the two largest banks in Cyprus. Core programme objectives included the implementation of "structural reforms to support competitiveness and sustainable and balanced growth, allowing for the unwinding of macroeconomic imbalances, in particular by reforming the wage indexation system and removing

[29] As Arcanjo puts it (2012) there exists a consensus "on classifying France and Germany within the same welfare regime, despite the different names attributed: conservative (Esping Andersen 1990), Bismarckian (Ferrera 1996), or continental (Bonoli 1997)".

[30] It is well substantiated that pension reforms directed towards achieving long-term financial sustainability are known to increase the risk of old-age poverty (Hinrichs, 2021).

obstacles to the smooth functioning of services markets".[31] The course of unit labour costs, wages and compensation in Cyprus after the accession of the island to the EU and the EMU were identified by the lenders as the main contributors to a "persistent competitive disadvantage" (European Union, 2013 Occasional Papers 149 p. 17). For this reason, structural reforms in the labour market and the public sector, including reforms of the wage indexation and pension systems, to "improve fiscal sustainability, competitiveness and raise potential growth, especially in the medium- to long-term", were imposed.[32] An avalanche of permanent or quasi permanent fiscal measures (of 9 percent of GDP for years up to 2016) to achieve primary surplus were enforced, covering the revision of compensation (for the public sector) and social benefits, the pension system and tax increases. In the welfare system, reforms concentrated in consolidating, lowering, targeting or abolishing a number of benefits and tightening means-testing criteria with a view to balancing welfare to take up job (European Commission, European Economy, OP 149 p.51), therefore it seems that the lenders interpreted the then welfare system as an incentive to continuous unemployment. A new guaranteed minimum income scheme (GMI) in replacement of the Public Assistance system was established, mirroring the above criteria (p.87).[33] Ultimately, the new Cypriot welfare system with the formal objectives of strengthening the protection of vulnerable households while ensuring an appropriate balance between welfare benefits and work incentives (European Commission, 2014, p.90) was finalized in 2014.[34]

2.3 The EAPs of Greece and structural reforms.

Following a request by the government, Greece, the Commission, the ECB and the IMF, finalized an agreement on a three-year programme of economic and financial policies (eventually extended to two more EAPs) on May 2nd, 2010. The analysis of the EU institutions, from the onset to the "end" of the EAPs, implicated Greek "imbalances" for the loss of market access and the subsequent crisis.[35] Our analysis shows that one of the most prominent indicators criticised as unsustainable, was a *lower*-by 15 percent - income inequality and particularly the ten-year reduction of the income gap between Greece and the Euro-area. As declared, "high real wage increases, rapid credit growth – supported by financial sector liberalization and low real interest rates associated with euro adoption – and loose fiscal policy contributed to buoyant growth".[36] Therefore, increases to real wage and low interest rates were categorised as contributing factors, explaining the crisis in Greece.

The main objectives of the EAP for Greece consist of three pillars.[37] Under the short-term programme, the target was to restore confidence and maintain financial stability. The medium-term

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[31] Memorandum of Understanding on Specific Economic Policy Conditionality in DG ECFIN, the EAP for Cyprus European Economy Occasional Papers 149, p.66.

[32] DG ECFIN the EAP for Cyprus European Economy Occasional Papers 149 May 2013, p. 41.

[33] ANNEX 4 Programme Documents 67 Memorandum of Understanding on Specific Economic Policy Conditionality in European Commission Directorate-General for Economic and Financial Affairs The Economic Adjustment Programme for Cyprus First Review - Summer 2013 EUROPEAN ECONOMY Occasional Papers 161

[34] ANNEX 4 Programme Documents, p.69 Memorandum of Understanding on Specific Economic Policy Conditionality p.90 in European Commission Directorate-General for Economic and Financial Affairs The Economic Adjustment Programme for Cyprus Fifth Review - Summer 2014 EUROPEAN ECONOMY Occasional Papers 209

[35] "In the face of massive external and internal imbalances, which resulted in the loss of market access…". DG ECFIN (2017). The ESM Stability Support Programme Greece, First & Second Reviews – July 2017 Background Report European Economy Institutional Paper 064.

[36] DG ECFIN (2010), the EAP for Greece. European Economy. Occasional Papers No. 61.

[37] Greece Memorandum of Economic and Financial Policies May 3, 2010, in DG ECFIN (2010) the EAP for Greece

objective was to improve competitiveness and change the structure of the economy towards a more investment and export-led growth model. An overarching objective was to durably restore Greece's credibility for private investors. Most measures concerning the fiscal programme were not set as one-off but rather on a more or less permanent horizon. The restructuring of the state administration, of the labour market and of income policies together with the product market and the business environment, were subjected to the doctrine of advancing competitiveness. To realize lower prices, unit labour cost was readjusted and on top of it, consumption as such[38] had to be reversed so as to justify social devaluation (15 percent of consumption was categorized as unjustified)[39]. In conformity to the new context, a fiscal strategy was anchored to cut the debt to GDP ratio and the general government deficit to well below 3 percent of GDP by 2014 from 13.6 percent of GDP (2009)[40] and public debt which stood at 115 percent. The three immediate structural measures focused on curbing incomes and social protection through reductions in the public sector wage bill, in pension outlays, and further increases in the VAT and selected excises (together with other measures yielding 2½ percent of GDP in further savings already in 2010) to generate a dramatic decrease of the government deficit by 5 percent for 2010 alone, while revenues from income taxes would equal 4 percent of GDP. These were only the initial measures. A further 7 percent decrease in expenditure for the coming years (until 2013) entailed the reduction of public wages, consumption, and social transfers[41] in search for increased productivity and decreased labour costs which in turn would improve competitiveness for external business and provide an attractive destination for investments, particularly foreign capital.

The restructuring of the Greek labour market encompassed the so-called rationalisation of social benefits (other than pensions) to generate savings of EUR 300 million or 0.2 percent of GDP in years 2013-2014 (European Union, 2012 p.27).[42] Unemployment benefits were reduced for specific geographical areas through the elimination of benefits for workers in industries with seasonal employment patterns (Memorandum of Understanding on Specific Economic Policy conditionality p. 251). Structural labour market reforms, designed to promote business and job creation, decentralisation of wage negotiations and flexible forms of employment were envisioned to cut unemployment. The EAPs provided for an impressive reduction of the cost of unemployment by 2015 of 36 percent including cuts in unemployment benefits.[43] Instead of a viable and responsive to the social needs of the long-term unemployed persons monthly benefit, a rather discouraging

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[38] For example, reduction in intermediate consumption by €300mln was imposed (see GREECE Memorandum of Economic and Financial Policies May 3, 2010, p. 57).

[39]European Commission Directorate-General for Economic and Financial Affairs The Economic Adjustment Programme for Greece EUROPEAN ECONOMY Occasional Papers No. 61, p.9

[40] Only for years 2013-2014 fiscal consolidation measures amounted to over 6.5 percent of GDP see European Commission Directorate-General for Economic and Financial Affairs The Second Economic Adjustment Programme for Greece Second review – May 2013 EUROPEAN ECONOMY Occasional Papers 148, p. 21

[41] Memorandum of Economic and Financial Policies, May 3, 2010, p.48 in European Commission Directorate-General for Economic and Financial Affairs (2010) The Economic Adjustment Programme for Greece EUROPEAN ECONOMY Occasional Papers No. 61

[42] European Commission Directorate-General for Economic and Financial Affairs The Second Economic Adjustment Programme for Greece First Review December 2012 EUROPEAN ECONOMY Occasional Papers 123

[43] European Commission Directorate-General for Economic and Financial Affairs The Economic Adjustment Programme for Greece Fifth review - October 2011 EUROPEAN ECONOMY Occasional Papers 87 p. 98

€200 per month benefit for one year was introduced "to help cushion the impact of our fiscal adjustment on the most vulnerable."[44] Moreover, with a view to changing the labour market conditions, minimum dismissal notification time was reduced, and an upper limit to statutory severance pay was set, both measures taking more burden off the shoulders of employers and increasing social risks and needs for households and individuals.[45]

2.4 The EAP of Ireland and structural reforms

The formal end of the Irish EAP in December 2013, was seen by the lenders as evidence of great success of the financial assistance they had provided as Ireland appeared to have become the fastest growing economy.[46] As the CEO of the EFSF, Managing Director of the ESM K. Regling emphasised, the country was back on the correct track of "sustainable growth, declining unemployment and improved business confidence".[47]

Four key elements were established around the overarching aim of the EAP for Ireland, namely to restore financial market confidence in the Irish economy's banking sector and the sovereign (debt). These were firstly a strategy for downsizing and reorganizing the banking sector; secondly, a consolidation strategy of expenditure restraint for achieving fiscal sustainability; thirdly, a set of thorough structural reforms in the labour, and fourthly, the product markets. Labour market reform targeted the elimination of barriers to achieve increased competitiveness through the adjustment of minimum wage and of a strategy towards of activation measures. As far as the product market is concerned, liberalisation via the opening up of identified sheltered professions, was put forth.

In this context, the comprehensive Irish National Recovery Plan for the years 2011-14, provided for a €15 billion consolidation measures or 9 percent of GDP budgetary correction[48], downsizing social protection, pensions, public expenditure and public service on the one hand and increasing revenues through taxation on the other. Complex modelling[49] revealed the tools to attain the EAP

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[44] Memorandum of Economic and Financial Policies, 7 December 2012 p.p. 160 and 182 in European Commission Directorate-General for Economic and Financial Affairs (2012) The Second Economic Adjustment
Programme for Greece First Review December 2012
https://ec.europa.eu/economy_finance/publications/occasional_paper/2012/pdf/ocp123_en.pdf

[45] European Commission Directorate-General for Economic and Financial Affairs The Second Economic Adjustment Programme for Greece First Review December 2012 EUROPEAN ECONOMY Occasional Papers 123, p. 223

[46] "Your country has since made a remarkable recovery. Last year, the economy grew by 7.3 percent, by far the fastest in Europe." Speech by Klaus Regling, ESM Managing Director in Central Bank of Ireland, Policy Network Event Dublin, 9 May 2018. https://www.esm.europa.eu/speeches-and-presentations/%E2%80%9Ceurope-will-not-be-made-all-once-or-according-single-plan-european

[47] EFSF financial assistance for Ireland ends with successful Irish exit 08/12/2013. EFSF Press releases https://www.esm.europa.eu/press-releases/efsf-financial-assistance-ireland-ends-successful-irish-exit .

[48] Memorandum of Economic and Financial Policies, p.53 in Annex – Programme documents, European Commission Directorate-General for Economic and Financial Affairs The Economic Adjustment Programme for Ireland EUROPEAN ECONOMY Occasional Papers 76

[49] Ibid, pp. 35-36 "Stylised simulations carried out for the Irish economy by D'Auria et al. (2009) using the QUEST 24 Of all EU countries only Luxemburg (EUR 1683) had higher monthly minimum wages than Ireland (EUR 1461) in January 2010. As a percentage of the average and median wage the minimum wage is not particularly high, because Ireland is a high-income country. However, for firms' costs it is the absolute value of the minimum wage that matters. III25 model show that, after 10 years, a decline in nominal wages of 0.6% leads to a 0.3% increase in employment and a 0.2% increase in GDP compared to a baseline scenario of no policy change. A decrease in the unemployment benefit replacement rate is also

purpose of transforming the labour market: to use newly restructured nominal wages[50] and social (including unemployment) benefits as disincentives to refusing a precarious job, thus decreasing costs, enhancing productivity and improving profits. The initial forced decrease of the national minimum wage by 12 percent [51] despite being supplemented by a concomitant compensation for employers, was indicative of impending worsening of the social situation. Since 2011, rates of working age, child benefit and job seeker payments were reduced and single-parent family payment was confined to those with youngest child below 14 years of age, while rent supplement schemes demanded larger contributions by certain social welfare recipients.[52] Lastly, penalty sanctions for beneficiaries not in compliance with job-search conditionality were enforced. [53]

2.5 *The EAP of Portugal and structural reforms*

On 17 May 2011, Portugal entered into an international agreement, a Memorandum of Understanding on Specific Economic Policy Conditionality, with the EC, the ECB and the IMF. The formal aims of the Portuguese EAP, were to restore financial market confidence and reinforce economic growth and macro-financial stability.

The EAP for Portugal involved the conditions to substantially reduce the government deficit (fiscal devaluation[54]) from 8.5 percent of the GDP[55] to 3 percent between years 2011-2013, through the implementation “of high-quality permanent measures”[56] and apply structural changes to reduce the debt-to-GDP ratio while conserving consolidation to the end goal of a balanced budgetary position. These would be achieved via containing expenditure and supporting competitiveness.[57] The key point to this strategy was the “need to reduce the public sector’s large claim on resources”, confirming therefore that fiscal structural changes would serve the purpose of redirecting ownership of resources from the public sphere to private ownership, a re-allocation of productive resources of capital and labour. The second front under EAP was the stabilisation of the financial-banking sector with measures such as deleveraging and resolution. Lastly, the third element was the execution of profound structural reforms centred on labour, competition and business[58] underpinned by the

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likely to have sizeable effects on employment and output. In a scenario where the unemployment benefit replacement rate is reduced by 5 percentage points, total employment increases by 1% and GDP by 0.7% after 10 years relative to the baseline. The measure is particularly beneficial for low-skilled workers, whose employment rate increases by 1.8%.”

[50] “Reduce by €1.00 per hour the nominal level of the current national minimum wage” Ireland Memorandum of Understanding on Specific Economic Policy Conditionality 8 December, 2010, p.63 in European Commission Directorate-General for Economic and Financial Affairs The Economic Adjustment Programme for Ireland EUROPEAN ECONOMY Occasional Papers 76

[51]Ibid p.20 «The authorities have already introduced in the job’s initiative an equivalent reduction in the pay-related social insurance contribution (PSRI) to offset the impact from the minimum wage reversal on employment by reducing firms' cost of hiring”.

[52] European Commission Directorate-General for Economic and Financial Affairs The Economic Adjustment Programme for Ireland Spring 2011 Review EUROPEAN ECONOMY Occasional Papers 78 p.15

[53] IRELAND MEMORANDUM OF UNDERSTANDING ON SPECIFIC ECONOMIC POLICY CONDITIONALITY (FOURTH UPDATE) 1 MARCH 2012, p.42 in European Commission Directorate-General for Economic and Financial Affairs Economic Adjustment Programme for Ireland Winter 2011 Review

[54] Portugal—Memorandum of Economic and Financial Policies, p.52 in DG ECFIN the EAP for Portugal European Economy Occasional Papers 79

[55] DG ECFIN the EAP for Portugal European Economy Occasional Papers 79 p.6

[56] Portugal—Memorandum of Economic and Financial Policies, p.59 in DG ECFIN the EAP for Portugal European Economy Occasional Papers 79.

[57] Portugal MoU on Specific Economic Policy Conditionality 17 May 2011, p.59.

[58] DG ECFIN the EAP for Portugal European Economy Occasional Papers 79, p.23.

strategy of "enhancing competitiveness, increasing flexibility and improving the business environment"[59] constituting Portugal "a more flexible economy and a more attractive investment location".[60] Assessments prepared by the lenders describing the labour market and social provisions in Portugal as "outdated", paved the way for an avalanche of social restructuring in light of achieving competitiveness and cost reduction. These assessments included describing employment protection as "excessively strict", the unemployment system as "generous", increasing "the risk that unemployment becomes entrenched" and the wage setting framework as unresponsive to the needs of the market.[61] Under the Portuguese EAP, two thirds of non-retirement social benefits savings came from sickness/healthcare (European Union, 2016, p.61)[62] while tax allowances were reduced from 30 to 10 percent of taxes or even eliminated for those considered as the highest earners.[63] A sanction system aimed at "facilitating the transition from unemployment to employment" was imposed. Unemployment benefits were capped at 2.5 times the Social Support Index and a reduction of 10 percent in the benefit amount after 6 months of unemployment was introduced[64] while the necessary contributory period to have access to unemployment insurance was effectively reduced to 12 months, therefore excluding more of the unemployed from a supportive system.

3. Pension structural reforms in the aftermath of the implementation of the various EAPs

Pensions are among the main tenets of social protection and may account for a large part of social protection benefits (Adam & Papatheodorou, 2016). Principle 15 of the European Pillar of Social Rights (EPSR) highlights the right to adequate pensions and dignified old age. In the same line, the European Commission's Green (2009) and White Paper (2012) on Pensions and Green Paper on Ageing (2021) declare that pensions need to be adequate and sustainable. To address the issue of financial sustainability of the pension systems in light of progressing life-expectancy, many countries amended the parameters and rules of their pension systems in terms of "retirement ages, contribution rates, benefit formula, indexation rules, pension accruals, qualifying conditions, pension decrements/increments (Bravo and Ayuso, 2021, p.2). Consequently, the relative levels of pension in many EU countries were cut and benefits reduced under what Busch et al. (2013) identify as neoliberal reforms of social security systems. Extending retirement age appeared as a "common policy choice" (Lamnisos et al., 2021, p. 6). What is though important for policy makers to consider is that in the face of a decrease in the ability of elderly persons to re-enter the labour market and improve their income, "poverty in the old-age is usually persistent" (Koutsampelas, 2012, p.69). An

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[59] DG ECFIN (2014). The EAP for Portugal 2011 – 2014 European Economy Occasional Papers 202, p.61.

[60] Ibid.

[61] "Labour market reforms are key to improve growth prospects and recover competitiveness. The most critical are excessive employment protection of permanent contracts, generous unemployment benefits, rigid working-time arrangements and a wage bargaining system that has not been capable to keep wage growth aligned to developments in productivity and external competitiveness. The rules for individual dismissal of permanent workers are strict and the compensation upon dismissal high by international standards. The strong protection of workers on permanent contracts has led to a two-tier labour market. The strict employment protection legislation (EPL) is also responsible for the very low labour turnover and very long duration of unemployment. Restrictive dismissal rules combined with generous severance payments may also have contributed to higher wage outcomes. Furthermore, the rigid working time regulations represent a burden on firms and hamper labour mobility and job creation." DG ECFIN the EAP for Portugal European Economy Occasional Papers 79, p.12.

[62] European Commission Directorate-General for Economic and Financial Affairs (2016) Ex Post Evaluation of the Economic Adjustment Programme Portugal, 2011-2014 EUROPEAN ECONOMY Institutional Paper 040, p.61

[63] Compliance was Observed 12/1/2011

[64] Second Update, 12/9/2011

increase to the statutory retirement age to maintain elderly people in the labour market is an option which can though "induce unwanted effects on youth employment" (Koutsampelas, 2012, p.86). In sum, all European Union member states have reformed their pension systems (Hinrichs, 2021) so as to place them on what has been perceived as a more sustainable footing, in tune with demographic changes (European Commission, 2012; Schoukens and Pieters 2007; Whitehouse et al., 2009; World Bank 2009; Bonoli and Shinkawa, 2005). The post-2008 crisis environment though, posed to in-debt EMU countries, significant new challenges. As Hinrichs underlines, in order to obtain financial assistance from the EU and the IMF, some countries implemented large pension reforms with substantial and immediate impact which can be rightly called "rapid policy changes", a means to supposedly, as he stresses, secure the viability of public pension schemes (see Hinrichs, 2015, pp. 4-5). This background is precisely what distinguishes the euro area periphery from the rest of the countries. Stergiou (2015) posits that during periods of fiscal adjustment, it gets harder and more complex to strike a balance between sustainability and adequate pensions. On the one hand, the financial crisis exerts financial pressure on welfare institutions, which absorb a significant proportion of spending (Angelaki and Carrera, 2015). On the other hand, greater emphasis is put on the social protection of the most vulnerable groups but at the expense of the parameters of proportionality and equivalence: what they have actually contributed to the social security system. The impact of changing pension systems (to less generous) and changing labour markets (where non-standard employment patterns as opposed to continuous full-time employment are now more frequently present) poses a significant challenge (Hinrichs, 2021) motivating further research. We now turn to the pension related structural reforms undertaken by the four countries of the periphery as evidenced in the MoUs and the ESM data base.

3.1 *Pension structural reforms in Cyprus*

The leading objective of envisioned fiscal structural changes in the MoU for Cyprus was the reduction to the pace of increase of expenditure in pensions. In order to extend the viability of the system to 2060 and to limit the fiscal subsidy to the General Social Insurance Scheme, a series of structural changes were implemented.[65] In terms of content, the reforms embraced the increase of retirement age, the increase of the minimum age unreduced pension by 6 months per year, the introduction of an early retirement penalty of 0.5 percent per month and the inception of automatic mechanisms for calculating retirement age every five years on the basis of changes in life expectancy.[66]

Not only was the earliest eligibility age for unreduced retirement increased, but also pensions were actually reduced while contributions raised. Overall, contemporary and future generations were, through rapid and comprehensive structural reforms, forced, at least to some extent, to sacrifice their contributions for a promise that their sacrifices would allow future generations to enjoy someform of pension rights. This view still causes heated debate and trade unions struggle for change.[67]

3.2 *Pension structural reforms in Greece*

Within a context of severe recession, exacerbated by the enforcement of EAPs [68], the general government deficit of Greece as a percentage of GDP was reduced from 15.6 percent in 2009 to

[65] MoU on Specific Economic Policy Conditionality, p.82 in DG ECFIN the EAP for Cyprus European Economy Occasional Papers 149.

[66] European Commission, 'The European EAP for Cyprus', May 2013, §55, available at: http://ec.europa.eu/economy_finance/publications/occasional_paper/2013/pdf/ocp149_en.pdf

[67] See https://cyprus-mail.com/2024/07/17/our-view-no-point-discussing-early-retirement-when-decisions-have-been-taken/

[68] Matsaganis and Leventi (2014, p.1) assess that by 2013, three years after the first EAP, "so deep and

3.2 percent in 2013. This allowed the Commission services and the Eurogroup to declare a first victory under the title "Success stories of the EAP" in Greece.[69] In this framework, profound pension reforms took flesh and bones (in 2015 and 2016), including some unprecedented pension measures[70], all of which envisioned to generate savings up to 2.5 per cent of GDP by 2025.[71] Reforms of the pension (and health) system adopted by then, projected a very small increase of approximately 1 percent in pensions until 2060, therefore decreasing –below inflation rates – pensions would be in a standstill for generations to come.[72] To be sure of the scale of the reforms, eight years after the first MoU for Greece (as was admitted in a formal ESM document), pensioners were unable to cope with daily expenses and "find it more difficult to compensate for income loss".[73]

Within this context, our analysis shows that austerity measures endorsed in line with the target of setting the debt-GDP ratio on a declining path, appear draconian. [74] Pension benefits were annually reduced by 6 percent for people entering retirement between the ages of 60 and 65 with a contributory period of less than 40 years. Additionally, the age of retirement was increased by 2 years (1 January 2013)[75] while cuts in the main, auxiliary and lump sum pensions were enforced. The list of heavy and arduous professions was reduced to 10 percent of employment.[76]

In addition, under the title "Sustainable social welfare" (Supplemental MoU, 2016 p.14) and in view of establishing expenditure savings of more than 1 percent of GDP, a renewed pension reform aimed at strengthening the link between contributions and benefits. It involved the elimination of the solidarity grant, the freezing of pension benefits and a series of other components, austere in orientation.[77] A new structure, single fund ETEA, was created while the automatic withholding of income tax for pensioners was legislated.[78] Additionally, "tightening" pension eligibility criteria for uninsured individuals and of pension entitlements was established while the aim to reduce disability

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drawn out a recession simply has no precedent in the economic history of any advanced economy in peacetime".

[69] DG ECFIN the second EAP for Greece Fourth Review – April 2014 European Economy Occasional Papers 192 p.10.

[70] "…a significant reduction in pension entitlements of new retirees without pro-rata application – which is unprecedented among EU pension reforms". DG ECFIN (2017). The ESM Stability Support Programme Greece, First & Second Reviews – July 2017 Background Report European Economy Institutional Paper 064, p.4

[71] Ibid, p. 4.

[72] DG ECFIN the Second EAP for Greece Fourth Review – April 2014 European Economy Occasional Papers 192 p.10.

[73] Supplemental MoU Fourth Review of the ESM Programme Draft – 20 June 2018, p.1 https://ec.europa.eu/info/sites/default/files/economy-finance/draft_smou_4th_review_to_eg_2018.06.20.pdf#page=13

[74] The adjective draconian (for laws, government actions, measures etc.) as per the Cambridge Advanced Learner's Dictionary & Thesaurus © Cambridge University Press) "are extremely severe, or go further than what is right or necessary". Costamagna (2012, p. 4) considers adjustment programmes imposed to euro area countries of the periphery as incorporating draconian measures: "In all these cases, recipient States have been invariably required to adopt draconian austerity measures in order to have access to the financial help".

[75] Greece MoU on Specific Economic Policy Conditionality, p.219 in DG ECFIN the Second EAP for Greece First Review December 2012 European Economy Occasional Papers 123 https://ec.europa.eu/economy_finance/publications/occasional_paper/2012/pdf/ocp123_en.pdf#page=219 .

[76] Assessment of compliance with the MoU on Specific Policy Conditionality (fourth update, 2 July 2011) https://ec.europa.eu/economy_finance/publications/occasional_paper/2011/pdf/ocp87_en.pdf#page=148 .

[77] Supplemental MoU 16. 06. 2016 p.p. 14 – 16 https://economy-finance.ec.europa.eu/document/download/418978c5-9a48-4906-a16b-4ea4c8dac253_en?filename=ecfin_smou_en_2016_06_16.pdf .

[78] DG ECFIN the Second EAP for Greece Fourth Review – April 2014 European Economy Occasional Papers 192.

pensions to no more than 10 percent of the overall number of pensions by 2015 was applied.[79] It does not come as a surprise that well respected conservative news outlets like “ekathimerini” underlines that the outcome of the aforementioned changes can be summarised in six words: more years of work, lower pensions.[80]

3.3. *Pension structural reforms in Ireland*

The EAP for Ireland, published in December 2010, provided for far reaching reforms including reductions in public service pensions, tax relief and welfare spending.[81] By 2012, the Services Pension Act (2012) was put in place.[82] The dominant approach insisted that the welfare system including pensions, family and unemployment benefits was more generous than contributions.[83] Consequently, reform of the Irish pension system occurred in areas where it overlapped with other reform areas such as regulating the pension entitlements of new civil servants in September 2011 where severe cuts to pension levels were envisaged. Importantly, the reduction of pensions in the public sector reduced existing pensions, by at least 4 percent while those retiring after 2012 received lower pensions and lump sums (on average by some 7 percent).[84] A milestone decision was the gradual increase of the retirement age from 65 to 68 years by 2028. As a consequence of pension reforms, the field still remains an open “battleground”.[85]

3.4 *Pension structural reforms in Portugal*

In 2007, due to the excessive deficit procedure against Portugal, the country enforced new pension measures so deep as to reduce pension expenditure from 20.8 percent to 13.6 percent of GDP by year 2050, as projected by the European Commission services (2009, p. 104). A few years later, significant pension cuts, despite being sponsored by the consortium of the Portuguese government, the EC, the ECB and IMF, were rejected by the Constitutional Court of the country on the premises of disproportionality.[86] In 2014 though, the so called "convergence law" aligned the rules for public sector pensions with those in the general social security system. This alignment involved an increase of the retirement age from 65 to 66 years[87], the adjustment of the reference salary for pensions' calculation and its inflation index, and the suspension of the pensions for pensioners who work for the State and could choose between the pension and the salary.[88] Further to the

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[79] DG ECFIN the Second EAP for Greece Second review – May 2013 European Economy Occasional Papers 148.

[80] https://www.ekathimerini.com/economy/1236879/more-years-of-work-lower-pensions/

[81] DG ECFIN EAP for Ireland European Economy Occasional Papers 76, p. 26.

[82] Ireland MoU on specific economic policy conditionality (second update) 3 September 2011, p.39 DG ECFIN, EAP for Ireland Summer 2011 Review European Economy Occasional Papers 84

[83] DG ECFIN, EAP for Ireland European Economy Occasional Papers 76, p.17

[84] European Union (2012) Economic Adjustment Programme for Ireland— Winter Review 2011 Occasional Papers93|March2012 p.15
https://ec.europa.eu/economy_finance/publications/occasional_paper/2012/pdf/ocp93_en.pdf

[85] See https://www.ictu.ie/blog/what-should-be-done-about-pension-age

[86] Such as the new calculation formula for surviving dependents’ pensions, the suspension of both the holiday and the Christmas allowances, the reduction in pension benefits granted within the pension scheme for the public sector as well as by the new rules for the recalculation of pension benefits already in payment. Conversely, the extraordinary solidarity contribution on higher pensions (applied from 2011-2014) and a cut in the pension supplements of employees in SOEs (state owned enterprises) were both ruled as proportional due to their structural nature. See DG ECFIN (2014). The EAP for Portugal 2011 – 2014 European Economy Occasional Papers 202, p.21.

[87] Based on the automatic indexation of pension ages to life expectancy, as of year 2025, the retirement age will further increase to 66 years and seven months.

[88] EAP for Portugal 2011 – 2014 European Economy Occasional Papers 202, p.41.

aforementioned, pension reforms in line with the approach enforced in the rest of the periphery, although not as comprehensive as the lenders[89] and Portuguese governments had envisaged, adapted the adjustment of pension benefits to the increase in life expectancy and hence, labour market participation was associated to the enhancement of the long-term sustainability of pensions. Thise changes may have paved the way to the increase of pensioners' financial needs, some of whom (13 percent) according to the Labour Force Survey (2023) continue to work after receiving old-age pension. [90]

4. Old Age Expenditure and Social Protection Benefits after Structural Reforms

Figure 1 illustrates the trajectory of total old age expenditure (OAE) by type of benefit and means-testing in euro per inhabitant at constant 2010 prices) from 2010 to 2019.

- Greece is the only country in the euro area periphery with a 5 percent decrease in euro per inhabitant on OAE. Expenditure per inhabitant in Greece was already in 2010 at a significant distance from the euro area average (less by 22 percent). The gap doubled in 2019 to reach 42 percent from the euro area average. A significant deterioration is identified when Greece's OAE trajectory is compared to Germany's (from -24 percent in 2010 to -47 percent in 2019) and to France (from -35 percent in 2010 to -54 percent in 2019). In contrast, in the rest of the countries, an increase of more than 20 percent is identified.
- An increased divergence between Ireland and the euro area (by -3 percent) and to Germany (by -8 percent) is also identified, while from France the distance was sustained (-35 percent).
- OAE in Portugal was by 41 percent less compared to the eurozone average throughout the reference period. The gap of Portugal vis-à-vis Germany is maintained at high levels and has somewhat increased (from -43 percent to -46 percent) while from France it has marginally decreased (from -51 percent to -48 percent).
- As far as Cyprus is concerned, findings show some deterioration when compared with the euro area (from -43 percent to -45 percent) and Germany (-42 percent increased to -46 percent) while divergence from France (-54 percent) persists.

[89] The assessment by the lenders of court rulings reversing specific pension reforms was that the pension ratio should not stand beyond the EU average: "the generosity of the pension system measured by the benefit ratio – the average benefit of public pension earnings as a share of the average wage – remains above the EU average." DG ECFIN Post-Programme Surveillance Report Portugal, Summer 2016 European Economy Institutional Paper 036, p.21.

[90] The Labour Force Survey by the Statistics Office of Portugal on "Pensions and labour market participation" in 2023 was co-funded by the European Union https://www.ine.pt/ngt_server/attachfileu.jsp?look_parentBoui=665727988&att_display=n&att_download=y

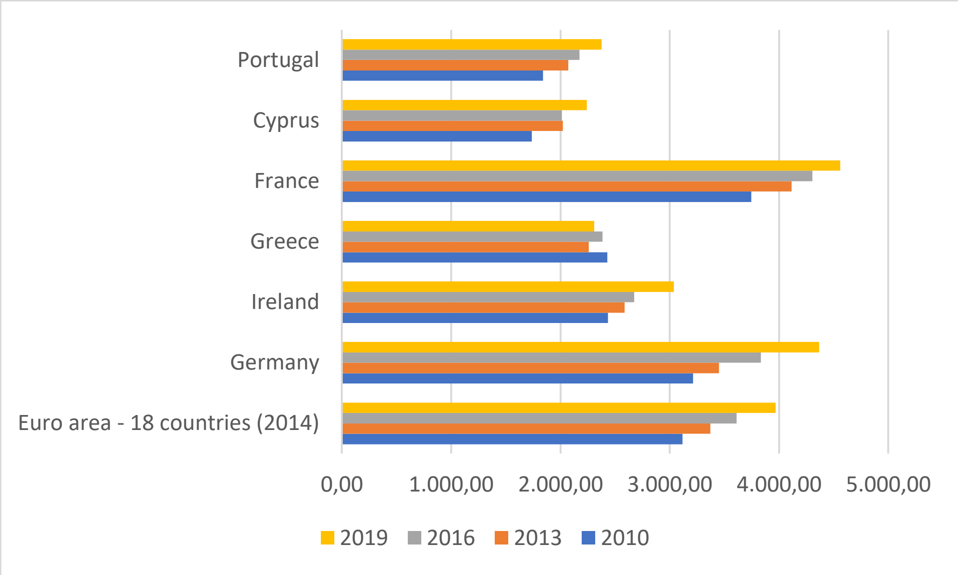

Figure 1. Expenditure on old age function by type of benefit and means-testing in euro per inhabitant (at constant 2010 prices)

Source: Eurostat. [spr_exp_fol__custom_14062770]

At this point, we present and analyse social protection benefits (SPB) in euro per inhabitant to consider the trajectory of social protection. Figure 2 presents changes in SPB across all units (core, periphery countries and euro area average) and Figure 3 shows the impact of the implementation of structural changes on the distance or divergence among the different units in the period of reference (2010-2019). We therefore compare SPB levels in individual countries, euro area core and periphery groups and also provide comparisons to the euro area average.

- In 2010, prior to the commencement of the EAPs, SPB per inhabitant in the countries of the periphery, with the exception of Ireland, was close to half of the average level of benefits in the euro area. Admittedly thus, a significant divergence pre-existed the structural reform period. By the end of 2019 though, not only was this trajectory sustained and widened to some extent but what is more, the Eurozone average, gradually surpassed the SPB in Ireland, the only periphery country under EAP which was previously leading the table.
- In the course of the 2010-2019 period, Germany substantially improved its SPB performance in relation to the euro area average and to all countries of the periphery. France extended the gap of social protection in comparison to the periphery. In sharp contrast to the above, the distance in social protection benefits between all four countries of the periphery and Germany and France has substantially increased. The increase of divergence in social protection benefits in euro per inhabitant is captured and illustrated in Figure 3.

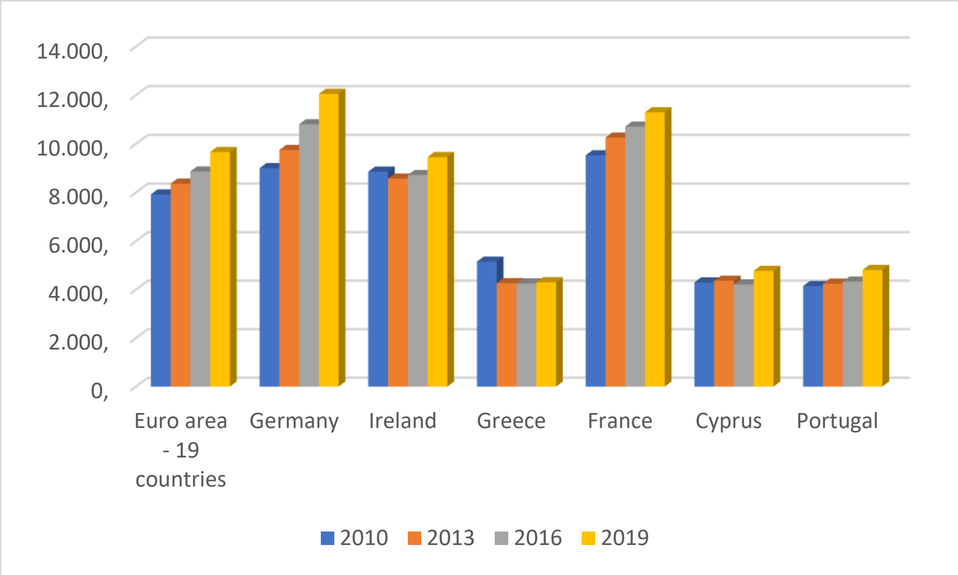

Figure 2. Social protection Benefits (Total)) in euro per inhabitant (2020-2019)

Source: Eurostat- Expenditure on social benefits by function [spr_exp_func__custom_14057923]

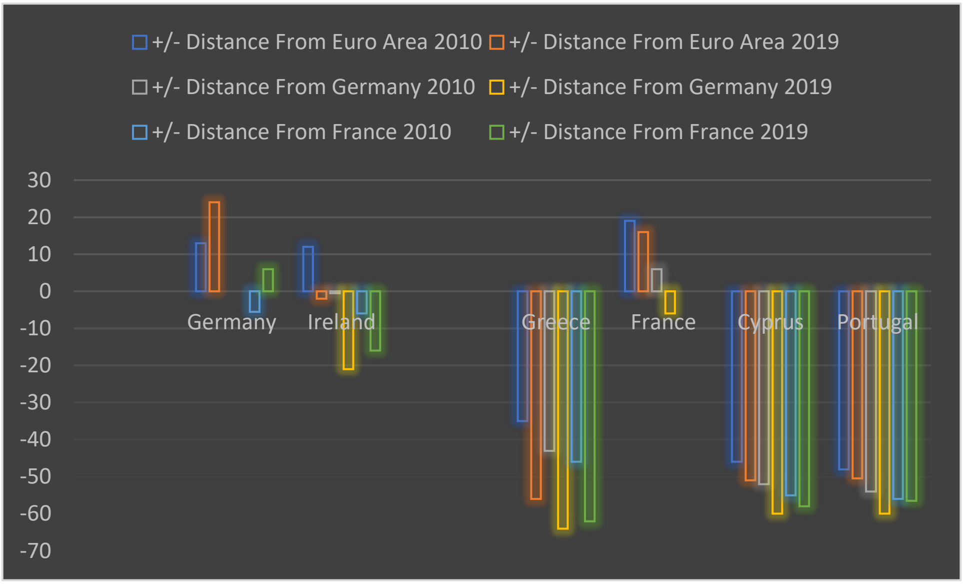

Figure 3. Core-Periphery Distance (Divergence) on Social Protection Benefits Expenditure (Total functions) in euro per inhabitant (2010-2019).

Source: Eurostat- Expenditure on social benefits by function [spr_exp_func__custom_14057923]. Authors' own calculations

Discussion

This article has sought to critically analyse the canvas of structural social protection and pension reforms introduced in the Economic Adjustment Programmes of Cyprus, Greece, Ireland and Portugal. We have shown that unlike past reforms in Germany, France and the rest of the euro area, these structural changes have served the philosophy and the key aims of the EAPs, a wider framework prepared and imposed by the EU institutions and the IMF, a premise which may explain the unique in-depth, if not unprecedented, impact of those reforms. Comparative data on the evolution of old age expenditure and social protection benefits in euro per inhabitant across the periphery, the core and the rest of the euro area, demonstrate that the cumulative force of the structural reforms has fueled the extension of divergences to the detriment of the periphery instead of the promise of convergence. Although other indicators of SPB and OAE can be useful, this cannot undermine the gravity of the findings presented. Despite differences within the periphery cluster, the strategy to enhance competitiveness, decrease the debt to GDP ratio and bring about fiscal sustainability and macro-financial stability (the common pillars of the EAPs), in all four cases, has led to the increase of social divergences in the Core-Periphery axis. Figures 1 and 2 substantiate our argument and Figure 3 provides a clear illustration of extended divergences in social protection benefits in the period under study.

The identified impact of welfare and pension (systems) reforms in Germany and France was more limited in comparison to the reforms in the periphery under the dynamics of the EAPs. There are of course, some differentiations within the periphery cluster. Divergence is significantly extended to the detriment of Greece when compared to the core countries and the euro area. Disparities in OAE between the rest of the group of the periphery, namely Cyprus, Ireland and Portugal and the euro area average and core countries in the period from 2010-2019, have also increased, but to a lower extent. The EAPs have conditioned SPB thus the countries of the periphery, increasingly diverge both from the euro area average and the core euro area countries, in spite of increased social risks (Petmesidou & Guillén, 2014). As highlighted by Cieślukowski (2024), the largest increases among all EU countries in the average tax burden on pension expenditure (PETR)[91] for years 2010-2020 were recorded in Portugal, Cyprus, Greece and Ireland, verifying thus a common course of the periphery.

The philosophy of the EAPs appears to rest on a common denominator: the radical reform of the framework for social protection, including pensions, towards a new austerity culture which replaced the “old” socially more generous one. Competitive impoverishment (Avlijas et al., 2021) in a context of subordination of wages and public benefits to the superior targets of servicing public debt, competitiveness, increased flexibility and business confidence, seems tied to the future of the periphery. This takes place in conditions of forced structural convergence in the EMU (Scharpf, 2021)[92] where the periphery is undergoing a process to “become cheap enough to become competitive” (Avlijas et al., 2021, p.38). Is it possible to reverse the tendency of polarisation (Iancu, 2008) or divergence between the core and the periphery which clearly undermines the social condition of those in need? A continuous rise in disparities both within the periphery (between social categories) and across the core-periphery spectrum would not come as a surprise unless structural reforms are possibly, radically reoriented. The core-periphery divide is currently of such force that some scholars predict the disintegration of the Eurozone, unless policy interventions materialize (Gräbner et al., 2020).

Further research can address and compare different indicators of social protection between core-periphery countries, including in purchasing power standards towards a more holistic approach. “Reforming the reforms” in the social protection and pension systems in the euro area periphery calls for an approach that focuses on decreasing social risks.

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[91] PETR shows the average tax burden imposed on pension expenditure and is calculated using the formula PETR = GPE-NPE/GPE. This indicator is the ratio of the difference between gross pension expenditure (GPE) and net pension expenditure (NPE) to gross pension expenditure (GPE).

[92] As per Scharpf (2021), forced structural convergence in the EMU implies a process where among other “The main emphasis is on reducing unit labor costs in order to improve international competitiveness – and thus to achieve export-led economic growth.”

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The Information Economy in the Age of Digitalization: Key Characteristics, Distinctions and Development Trends

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Abstract
The information economy, which uses knowledge and digital technologies as primary resources, has transformed traditional economic models and practices. Despite its growing significance, there are varying and often conflicting interpretations of the essence and unique features of the information economy. This article aims to explore the theoretical foundations on which the information economy is studied to define its main characteristics. Through an in-depth analysis, a classification of the core characteristics of the modern information economy was established, highlighting its reliance on digital information, knowledge-intensive activities, and network effects. Additionally, based on market data, the study identifies key development trends within the information economy, emphasizing the impacts of increasing digitalization and globalization. These findings provide a comprehensive understanding of the evolving nature of the information economy and its influence on broader economic practices.

KEYWORDS: digital economy, information, information society, digitization

JEL CODE: B52: L86; D80

1. Introduction

We live in the so-called "information age," where technology has advanced to a level that allows us to access and obtain knowledge at any time and place of our choosing. The information economy represents a relatively new stage in the development of the global economy and society, where information, knowledge, and digital technologies play a leading role, transforming traditional economic models and practices.

Unlike the classical economy and its accompanying industrial revolution, which was based on producing tangible goods and industrial processes, the information economy focuses on intangible assets and services. Despite its growing significance, various and often contradictory interpretations of the essence and unique characteristics of the information economy exist.

This article aims to explore the theoretical foundations underlying the study of the information economy to define its primary characteristics and highlight how it differs from the industrial economy. Furthermore, the study seeks to examine key trends in the information economy development based on market data, particularly emphasising the impact of increasing digitalisation and globalisation.

2. The Information Economy – core characteristics

The information economy began to emerge as early as the late 18th century. Still, it gained greater attention in the late 20th and early 21st centuries with the advent of the Internet and related production technologies. New information and communication technologies, which allow for the creation, processing, and distribution of vast amounts of data and the informatization of socio-economic systems, form the technological structure of the information economy. The technological framework facilitates broader communication and connectivity between economic entities, enhancing the exchange of resources and information (both electronic and real) within society. “The level of development of the contemporary ‘information economy’ is determined by the degree of organization in the exchange of information within society" (Vasilev, 2015 [1]). This leads to the intensive and efficient use of existing information to derive new insights, converting it into knowledge and innovation.

Since the inception of the information economy, numerous economists and sociologists have studied its essence and characteristics, thereby developing its theoretical and practical foundations. Various approaches exist for exploring the concept of the information economy and defining its core attributes, leading to different identified characteristics. These distinctions arise from the authors' interpretations of the subject of the information economy.

The subject of the "information economy" can be considered in a broad and narrow sense. In the narrow sense, the information economy focuses on its primary production resource—information itself and includes the emerging economic relations related to the production, processing, distribution, exchange, storage and consumption of any type of data and information. In a broad sense, the subject of the information economy is associated with the characteristics and dynamics of the newly formed kind of economy, as well as the socio-economic impacts resulting from its imposition. The information economy faces challenges such as providing universal and generally accessible services, promoting the consumption of information as a good while at the same time overcoming digital inequality, increasing the population's digital literacy, establishing appropriate legal regulations for property rights within the information sphere and enhancing qualifications of workforce in the information sectors (Iliev, 2014 [2]).

Some authors, such as Machlup (2014) [3], Bermeo Giraldo, Patino Toro, Valencia Arias, Benjumea Arias & Bran Piedrahita (2022) [4], and Kuleshov, Untura & Markova (2017) [5], portray the information economy as a knowledge economy. In this view, various types of knowledge and information are produced and disseminated to achieve higher economic growth and productivity through investments in human capital development and innovation. Other scholars, including Muminjonovich (2024) [6], Izmaylov, Yegorova, Maksymova & Znotina (2018) [7], Śledziewska & Włoch (2021) [8], Litvinenko, Smirnova, Solovykh, Aliyev & Li (2019) [9], and Xia, Gongming, Wang & Ding (2023) [10], equate the information economy with the digital economy. They associate it with economic activities driven by digital information and communication technologies, emphasizing its virtual, networked nature tied to e-business, e-commerce, and the production and provision of personalized digital goods and services, with transactions often conducted using electronic money. Similarly, Zysman & Weber (2001) [11] and Dzwigol (2019) [12] present the information economy as primarily an electronic and virtual economy, while Amosha, Pidorycheva & Zemliankin (2021) [13] identify it as a network economy.

The new concept of the information economy, as explored in the works of Porat (1977) [14], Castells (1996) [15], Anie, Budak & Kajh (2016) [16], Fırat, Karaçor & Özkan (2017) [17], Sukhodolov, Popkova & Litvinova (2018) [18], Trushkina (2019) [19], Badalzade (2023) [20], and many others, is described as an integral part of the development of the new information society and it is inextricably linked to the emerging socio-economic interactions formed through the exchange and creation of information. The information economy, as defined by these scholars, is an economic system in which intellectual and innovative activities constitute the majority of the gross domestic product and where digital technologies are utilized for the production, processing, storage, exchange, and distribution of information and information products. As a result, the extraction of new knowledge and innovations allows for the effective resolution of a country's socio-economic issues, offers higher value to consumers, and expands connectivity. Information thus becomes a critical competitive advantage and a "driver of globalization in the information society" (Izmaylov, Yegorova, Maksymova & Znotina, 2018 [7]).

Based on the literature on the concept of the information economy discussed above, the following main characteristics can be summarized:

First, information and knowledge are dominant resources and, at the same time, targeted outcomes. Existing information is utilized to create new information that is accessible to a broad audience but protected under intellectual property law. I.e., the emphasis is on intellectual capital, skills and technological know-how, and high-value information products.

Secondly, existing and new information are considered equal. The main criteria for the value of information are not its novelty but rather its accuracy, applicability, and frequency of use. While new information is more accessible, the prevalence of information does not necessarily make it more accurate or of higher value.

Thirdly, it is virtual. Electronic and virtual are the dominant forms of creating, distributing, storing, exchanging, and consuming information. More and more services are moving into the online space. In this way, many people can be included and excluded simultaneously and individually in these processes. Digitalization transforms traditional economic models by implementing digital technologies, such as artificial intelligence, cloud technologies, big data, the Internet of Things, and technological advancements that automate routine tasks and optimize business processes (e-commerce, digital platforms, shared economy).

Fourthly, it is global and network. The information economy utilizes the World Wide Web and technologies that connect markets into a single global market, forming network effects. In this market, geographical barriers are minimized, and information can be shared and used in real-time anywhere in the world due to the openness of the economic system for exchange. In this way, the value of the service increases with the number of users. At the same time, global connectivity facilitates international trade, investment, and cooperation, allowing businesses to reach consumers from any point in the world at minimal costs. Network effects can create significant economies of scale, leading to the emergence of natural monopolies.

Fifthly, innovations and creativity are enhanced through adequate protection of intellectual property. The significance of intangible assets, such as software, patents, copyrights, trademarks, trade secrets, and data, is increasing in the information economy. Intellectual property rights protect these assets, stimulate innovation, and create competitive advantages. Companies often derive significant value from their intellectual property, which can be more valuable than physical assets.

Sixthly, it has a high degree of dynamism, allowing for rapid adaptation to technological changes. The information economy is much more dynamic than the industrial economy, with a high level of innovation and adaptation to new technologies. Businesses must quickly adapt to new technologies, market trends, and consumer demands. This dynamic environment fosters a culture of innovation, entrepreneurship, and continuous learning.

Seventh, it is characterized by low marginal production costs. Information goods differ from traditional ones in that their quantity does not decrease as more consumers use them, and the expenses associated with copying and distributing information are minimal, approaching zero. As a result, the marginal costs are drastically reduced compared to physical goods, where producing each additional unit requires significant resources and expenses.

Eighth, it facilitates the decentralization of economic activities, allowing direct interaction between producers and consumers. Traditional intermediaries, such as physical retailers and wholesalers, are increasingly bypassed by digital platforms, enabling a more efficient and transparent marketplace.

Ninth, it facilitates the personalization of offered products and services, which sharply contrasts with the standardized, mass-production approach of the industrial economy. Advanced data analytics and artificial intelligence enable businesses to provide highly personalized products and services, tailoring their offerings to individual consumer preferences.

Tenth, information and communication technologies form the technological infrastructure of the information economy, upon which all processes of creating, processing, exchanging, storing, and consuming information in society are based. This necessitates their continuous development and maintenance, as well as the development of specific skills for their use and the qualification of the labour force, in contrast to the industrial economy. For these reasons, new industries that intensively use information and knowledge are emerging, such as software development, biotechnology, finance, education, and media. These sectors are dominant players in the information economy.

Eleventh, the role of services has increased. Services, especially those related to information technology, data management, and digital platforms, play a crucial role in the information economy. Services are often information-intensive and can be delivered remotely, facilitated by digital technologies. The shift from goods to services is evident as economies focus more on providing solutions, experiences, and value-added services rather than solely physical products, as in the industrial economy.

Twelfth, it requires continuous learning and innovation. The speed of change in the information economy also leads to changes in the labour market, necessitating a culture of constant learning and innovation. Organizations must continuously adapt to new technologies and changing market demands, making skills and knowledge crucial for competitiveness. There is an increasing demand for personnel with skills in creative and intellectual activities, such as programming, data analysis, digital marketing, and other specialized digital competencies. At the same time, new and flexible forms of employment are emerging—remote and hybrid work and freelancing.

Thirteenth, the new industries with intensive use of information are factors for high efficiency and economic growth.

3. Distinction of Information economy from Industrial Economy

While studying and analysing the literature on the formation and development of the concept of the information economy, the main characteristics of the new "information economy," which significantly differs from the industrial economy, were highlighted. Based on this, the following key differences between the information and industrial economies have been systematized (Table 1).

Table 1. Differences Between the Information Economy and the Industrial Economy

Characteristics	Information Economy	Industrial Economy
Key Resources	Intangible - information, data, knowledge, and intellectual property	Tangible - land, physical labour, and capital
Production Process	Non-physical production, i.e., provision of digital and intangible services	Physical production of goods based on industrial processes and machinery
Nature of Goods	Goods are mainly non-rival and non-excludable	Primarily rival and excludable goods
Product Personalization	High levels of personalization are possible, based on insights derived from data	Standardized products, with limited personalization due to mass production techniques
Role of Technology	They are the main driver of economic activity and innovations	Used for automation and improvement of production processes
Production Costs	Low marginal costs for production and distribution, with high initial fixed costs	High production costs and increasing marginal costs
Value Creation	Value is created through generating, analysing, and applying information and it is often subjective	Related to tangible goods and effective distribution of physical resources
Economic Scale and Network Effects	Economies of scale are driven by network effects, where the product's value increases with the number of users. Growth is not necessarily tied to equivalent physical investment	Economies of scale are achieved through increased production volumes and effective resource use. Growth often requires significant capital investments in physical infrastructure
Distribution Channels	Uses digital channels, including e-commerce, social media, and	Distribution often involves multiple intermediaries and

Characteristics	Information Economy	Industrial Economy
	cloud-based services, for immediate access to global markets, digital platforms	relies on physical channels
Customer Interaction	Interactive and participatory, with continuous feedback through digital platforms allowing direct engagement with consumers	Limited feedback loops with customers, often one-way communication from producer to consumer
Market Structure and Competition	Markets are dominated by digital platforms/tech giants and network effects, often leading to monopoly or oligopoly structures. Characterized by lower barriers for startups but high scaling barriers	Characterized by traditional competition among firms producing similar goods, often with high entry barriers in capital-intensive industries
Role of Labour, Employment, and Skills	Decreasing the role of labour in favour of automation and intellectual capital. Focus on cognitive, creative, and technical skills	Labour is a primary factor of production and is often simple and manual. Emphasis on physical tasks in production
Speed of Innovations and Changes	Rapid, disruptive, and lead to swift and often unpredictable market changes	Typically linked to physical processes and machinery and are relatively slow and predictable
Geographical Impact	Location is less critical, work can be done remotely, and digital products can be delivered globally without physical constraints	Economic activities are often tied to specific locations due to the need for natural resources, factories, and physical distribution networks

Source: Own development

From the table, it can be concluded that the information economy differs from the industrial economy in the following ways: it produces intangible products, primarily information-based products, using information as the primary resource. Interaction with customers is interactive, and the products are personalized and primarily distributed through digital channels. Production is mainly creative, with the newly created value being subjective, and the additional costs for producing each new product unit are low, approaching zero. The economic incentives of the new economy are related to economies of scale driven by network effects, and the activity growth is not necessarily tied to equivalent physical investment. The role of technology has reached a level where it becomes a key factor for growth, while the role of labour decreases in favour of automation. Innovations are rapid and disruptive, often causing unpredictable market changes. The market, in turn, is dominated by large technology giants whose geographical location is not critically important, as remote work is possible, unlike in the industrial economy, where economic activities are carried out in specific geographical locations.

4. Key development trends in the Information Economy – the impact of increasing digitalization and globalization

The information economy is rapidly evolving under the influence of digitalization and globalization. These two forces are changing industries, transforming business models, and rethinking how value is created and distributed worldwide. According to data from www.statista.com [21], several key trends in the development of the information economy can be outlined:

1) **Ongoing Digital Transformation of Business Models** - companies across all sectors utilise digital technologies such as cloud computing, artificial intelligence, and big data analytics to enhance their operations, customer service, and innovation, and this trend

is expected to continue growing. In 2023, spending on digital transformation reached $2.15 trillion. By 2027, global spending on digital transformation is anticipated to reach $3.9 trillion.

- **Rise of Cloud Computing and Software as a Service (SaaS)** - cloud technologies have revolutionized business by offering organizations scalable and cost-effective solutions, ranging from data storage to access to computing power, software, and other cloud-related functions, without the need for on-premises hardware or significant initial investments. This enables firms of all sizes to compete on more level playing fields. SaaS products are available to both B2B and B2C customers, unlike IaaS (Infrastructure as a Service) and PaaS (Platform as a Service) products. The SaaS market accounted for approximately two-thirds of the cloud services market in 2023, reaching nearly $197 billion. It is expected to grow to $247 billion by the end of 2024.

- **Increasing Interest in AI Technologies and Automation** - Artificial intelligence (AI) and machine learning are automating routine tasks and enhancing decision-making processes, creating new opportunities for personalized customer service. AI technologies are transforming industries, reducing costs, and opening new avenues for revenue generation. By early 2024, the AI market is expected to reach $184 billion, marking an impressive growth of 27% compared to 2023. This remarkable growth is anticipated to continue over the next decade, with projections indicating that the market could reach $826 billion by 2030. Steady growth is expected globally across all subsectors of AI technologies **by 2030:**

  - *The Machine Learning Market* exceeded $150 billion in 2023. By 2030, it is expected to maintain stable and consistent growth, adding approximately $50 billion annually, potentially reaching nearly $500 billion.

  - *Natural Language Processing (NLP) Market* is projected to grow to over $60 billion by 2030. In comparison, the natural language processing market reached over $23 billion in 2023.

  - *Autonomous and Sensor Technology Market* is expected to grow to nearly $60 billion, having reached $20 billion in 2023.

  - *Computer Vision Market* is anticipated to grow to almost $50 billion, with a valuation of $20 billion in 2023.

  - *AI Robotics Market* is expected to exceed $35 billion. By 2024, the market is projected to have grown by 30% compared to 2023, reaching over $19 billion.

- **Unleashing Data Potential and Data-Driven Decision Making** - the vast data generated from digital interactions enables companies to make more informed decisions. IoT technologies are leading to a more significant proliferation of smart objects with enhanced connectivity and the capability for real-time data collection. The adoption and commercialization of 5G technology (with a 59% penetration rate in 2023) has further increased connectivity and facilitated the deployment of cellular IoT modules. By 2027, the penetration of 5G smartphones is projected to exceed 82%. As a result, the number of IoT devices worldwide is expected to reach nearly 30 billion by 2030. The widespread integration of IoT devices into various aspects of life allows for improved data-driven decision-making and innovation in addressing complex challenges. This data-centric approach is crucial for maintaining competitiveness in the information economy.

2) **The Rise of the Platform Economy (PaaS) -** the platform economy, characterized by digital platforms directly connecting producers and consumers, is another transformative trend. PaaS accounts for 20% of the total cloud services market, with revenues exceeding $145 billion in 2023. The leading players in the global PaaS market that have "disrupted"

traditional industries include Microsoft Azure, Amazon Web Services, IBM Cloud and Google Cloud Platform. Businesses are increasingly adopting cloud solutions, and more consumers are using and planning to use the digital platforms offered by these companies. This trend indicates continuous growth and innovation within the PaaS market.

- **Expansion of Network Effects and Market Dominance** - platforms leverage network effects, where the value of the service increases as the number of users grows. As of June 2024, the global number of internet users has reached 5.44 billion. Easier access to computers, modernization and improvements in digital infrastructure worldwide, and the continually decreasing prices of smartphones have enabled people to use the internet more frequently and conveniently. By 2023, there were nearly 1.5 billion fixed broadband subscriptions worldwide, with Europe leading in broadband penetration at approximately 36 subscriptions per 100 residents. As of early 2024, mobile internet was accessible to nearly 70% of the world's population (2.17 billion of which are 5G mobile subscriptions), with leaders in Northern Europe and North America having over 97% coverage. All of this has led to increasing connectivity among the global online audience, which is growing steadily. The total number of internet users is projected to continue rising, expected to reach 7.3 billion users by 2029. The growing number of users creates conditions for expanding network effects and the emergence of dominant players who can capitalize on them. Examples of such giants include Amazon, Alibaba, Uber, and Airbnb.

- **Rise of the Gig Economy and Flexible Employment** - platformization is transforming the labour market, enabling freelance work and on-demand hiring. Many creative industries, as well as those related to various consulting services (insurance, finance, etc.) and transportation, have transitioned or are considering transitioning to digital labour platforms. The COVID-19 pandemic accelerated this trend. The share of remote employees increased to approximately 28% by the end of 2023, compared to just 13% in 2020. The technology sector has the highest proportion of remote workers globally, with over 67% of tech employees worldwide working either entirely or predominantly remotely in 2023. According to the European Commission, the number of platform workers in the EU is expected to reach 43 million by 2025. Remote and hybrid work allows employees to have flexible schedules and lifestyles from anywhere. Despite challenges regarding job stability and workers' rights, this form of employment is becoming the preferred work structure for more employees worldwide (91% of remote workers report that they choose either fully remote or hybrid working arrangements, favouring remote work).

- **Innovation Ecosystems** - platforms also serve as ecosystems that foster innovation by providing developers and entrepreneurs access to a broad user base and data. These platforms further facilitate access to financial instruments, consulting services, real-time environments for testing products and services, and more. This openness stimulates the creation of new products and services, as well as new business models, supporting economic growth and competitiveness.

3) Increasing Globalization of Digital Markets - the growing digitalization and connectivity have significantly accelerated the globalization of markets. Businesses now have the opportunity to quickly reach international customers and participate in the global market through cross-border e-commerce, digital payment systems, and virtual services.

- **Expansion of the E-commerce/M-commerce and Global Commerce Market** - the emergence and development of e-commerce platforms enable businesses of various sizes to access global markets and expand consumer choice. The most popular social platform used by merchants in 2024 is Facebook, followed by Instagram and LinkedIn. B2C professionals prioritize

Facebook and Instagram, while B2B marketers focus their efforts on LinkedIn, as it connects people and companies in a corporate context. Some benefits these platforms provide include increased exposure, higher traffic, and the opportunity to attract new customers. Consequently, online shopping has gained popularity recently, with e-commerce accounting for over 19% of global retail sales in 2023. It is expected to exceed USD 7 trillion by 2025 and to constitute nearly a quarter of total global retail sales by 2027. Leading e-commerce markets worldwide are in Asia, primarily China, projected to grow by over 14% annually through 2027. The Asian market is followed by Latin America, which is also expected to experience rapid growth in the coming years, given the continuously improving online access, particularly in mobile internet communities. In 2023, revenues from mobile e-commerce reached approximately USD 1.7 trillion (about 50% of e-commerce). The share of mobile devices is expected to increase steadily, reaching 63% by 2028.

- **Expansion of Digital Services and Remote Work** - the development of artificial intelligence, digital transformation, and platformization is broadening the global scope of digital services and driving growth in the IT services market. Businesses strive to implement AI technologies, enhance analytics, and automate processes while taking advantage of IoT capabilities while continuing to prioritize digital transformation. The segment of the IT services market related to IT consulting and implementation is expected to grow steadily, reaching USD 92.95 billion by 2029. This growth is also associated with changes in the labour market. As previously mentioned, digital and hybrid forms of work are becoming increasingly preferred, particularly in the IT industries. Consequently, remote work and online collaboration tools will enable companies to tap into global talent, transforming labour markets and contributing to the rise of digital nomadism.

- **Growth of Cross-Border Data Flows** - data has become an essential resource for the development of the global economy. Businesses increasingly rely on data-driven services that transcend national borders. The volume of cross-border data stored on the internet is expected to reach 175 zettabytes by 2025, with half of it stored in cloud environments. The growth of cross-border data flows enables improvements in national economies and living standards and raises concerns regarding data trust and privacy, digital sovereignty, and regulatory compliance across different jurisdictions. At the national level, investments in building national data spaces are expected to increase, along with establishing standards for data exchange, best practices, governance tools, and mechanisms to achieve operational compatibility among available public data and information systems. At the micro level, businesses are increasingly seeking modern solutions for networking, storage, and databases. In the future, corporate spending on cloud infrastructure services and data centres is expected to rise, which amounted to USD 270 billion in 2023, representing a 20% increase compared to 2022.

4) **Cybersecurity and Data Protection** - the increasing digitization has led to a rise in cross-border data flows and the growing vulnerability of businesses to cyber threats. Breaches related to trust and data privacy, as well as digital espionage, pose significant risks for businesses and consumers. Consequently, cybersecurity has become a critical issue for the information economy. Key trends related to cybersecurity include:

- **Increase in Cybersecurity Investments** - companies are forced to implement more robust cybersecurity measures to protect their data and systems, which are increasingly moving to the cloud. There is a growing need for investment in enhancing the infrastructure of their information technology systems. To ensure data security, next-generation security technologies that provide integrated security solutions are expected to be a key investment area. Global spending on information security reached nearly $200 billion in 2023. A significant portion of this spending is allocated to security services (approximately $90 billion), followed by investments in infrastructure protection and network security equipment. The global managed security services (MSS) market is projected to grow, reaching $65.53 billion by 2028, compared to $31 billion in 2023. Additionally, the global market for information security technologies is expected to continue its growth, potentially becoming three times larger by 2030 compared to its size in 2017. The global Security as a Service (SECaaS) market is also forecasted to exceed $81 billion by 2032. These trends underscore the increasing recognition of cybersecurity as a critical investment for safeguarding business assets and ensuring compliance in an evolving threat landscape.

- **Creation of New and Improvement of Existing Regulations and Compliance** - governments worldwide are implementing regulations to protect personal data and ensure cybersecurity. Regulations such as the General Data Protection Regulation (GDPR) in the European Union and the California Consumer Privacy Act (CCPA) set standards for data protection that affect how companies handle consumer data. It is also essential to continually develop, adapt, and enforce new compliance regulations at the national level and on a global scale. This ongoing evolution of regulatory frameworks is crucial for addressing emerging data privacy and security challenges, fostering consumer trust, and ensuring that businesses remain compliant in a rapidly changing digital landscape.

- **Rise of BaaS (Blockchain-as-a-Service) for Establishing Trust and Digital Identity** - the increase in cross-border data flows and digital payment transactions for e-commerce globally highlights the importance of establishing trust online. In 2023, global losses from e-commerce fraud reached approximately $48 billion. As a result, there is a growing demand for cloud-based solutions and mechanisms for verifying digital identities using blockchain technology. Additionally, governments are expected to implement regulatory frameworks for developing and applying AI-based technologies aligned with established legal and ethical principles within the EU. The adoption and implementation of BaaS are on the rise, enabling SMEs to utilize this technology in their global supply chain operations without the need to build and maintain their blockchain infrastructure. The market value of blockchain technology is estimated to reach $26.91 billion in 2024, with projections indicating astonishing growth to nearly $1,880 billion by 2034.

5) **Ongoing Digital Inequality and Challenges for Inclusive Growth** - digitalization and globalization create numerous business opportunities but simultaneously deepen inequalities within and between countries. Digital inequality, defined as the gap between those with access to digital technologies and those without, remains a significant barrier to inclusive growth.

- **Access to Technology** - many regions, particularly in developing countries, still lack access to reliable internet connections, affordable digital devices, and digital literacy programs. As of July 2024, nearly 1 billion people in South Asia have never used the Internet. Despite India and China having the most significant online audiences in the world, they also lead in the number of people who remain unconnected. East Asia follows with nearly 370 million offline individuals. North Korea has the highest percentage of its population without internet access, as only a tiny segment of society can connect, while the rest face restrictions. Additionally, 364.3 million people in East Africa report never using the Internet as of July 2024, and 260 million in West Africa are similarly unconnected. In South Sudan, almost 93% of the population lacks internet access; in Somalia, the figure is around 90%. In contrast, the European region shows the best connectivity compared to other areas. Only 2.7 million people in Northern Europe lack internet access, while Western and

Southern Europe average around 10 million each, and Eastern Europe has approximately 33.5 million unconnected individuals. This disconnection hinders the participation of these people and regions in the information economy and limits their economic and social development.

- **Skills Gap** - rapid technological changes demand a workforce equipped with new skills, particularly in areas such as programming, data analysis, and digital marketing. Governments and businesses must address these challenges by investing in education and training programs. This can be achieved through initiatives that promote digital inclusion, such as investing in digital infrastructure, encouraging public-private partnerships, and ensuring equal access to education and lifelong learning opportunities.

6) **Greater Resilience and Green Information Economy** - the information economy is evolving toward greater sustainability, driven by both regulatory pressures and consumer demand. Digitalization offers opportunities to reduce carbon footprints, improve resource efficiency, and promote the principles of a circular economy. The global market size for green technologies and sustainability is projected to reach $19.76 billion by 2024 and is expected to grow to $89.97 billion by 2032 (Report ID: GMI6743 [22]).

- **Growing Use of Intelligent Green Technologies for Sustainability** - IoT, AI, digital twins, and blockchain are increasingly utilised to monitor and reduce energy consumption, optimise supply chains, and manage resources more efficiently. Smart cities, sustainable agriculture, green construction, and ecological logistics are prime examples of digitalisation supporting environmental goals. According to Future Market Insights in their report on the Green Technology and Sustainability Market Outlook (2022-2032) [23], **the share of cloud computing technology for carbon management** is expected to increase significantly over the next decade. Platforms facilitating carbon trading, emissions reporting, and sustainable investments are becoming increasingly important, allowing businesses to accurately track their carbon emissions and implement strategies to mitigate their environmental impact. The Asia-Pacific market is projected to grow the fastest in green technologies and sustainability by 2032, with significant economic players like China, Japan, Taiwan, India, and South Korea making substantial contributions to low-carbon renewable energy development programs. Europe is anticipated to be the second-largest market, driven by vital government initiatives focusing on low-carbon technological innovations.

- **Increasing Consumer Demand for Sustainable Products** - as consumer awareness rises, there is a growing demand for transparency and sustainability in the digital marketplace. Companies are leveraging digital tools to provide information about the environmental impact of their products, enhancing their appeal to environmentally conscious consumers. A recent survey by PwC, titled 2024 Voice of the Consumer Survey [24], which explored the perspectives of over 20,000 consumers from 31 countries and territories, found that nearly nine out of ten (85%) consumers experience the devastating effects of climate change in their daily lives. As a result, they prioritise sustainability in their purchasing practices, willing to spend an average of 9.7% more on sustainably produced or sourced goods. Additionally, around 35% of consumers actively try to travel less or use alternative transportation, reduce their overall consumption, and support local suppliers. Nearly 40% of respondents assess manufacturers based on their sustainability practices, such as recycling, using eco-friendly packaging, and conserving natural resources and water. This shift in consumer behaviour indicates a significant trend towards sustainability.

5. Conclusion

The information economy, driven by digitisation, is changing the basic principles of economic activity, creating new opportunities and challenges. Unlike the industrial economy, which relies on physical production and raw materials, the information economy produces primarily intangible products and relies on digitisation and rapid, disruptive innovation. Its main characteristics include information as a dominant resource and target result, digitalisation and globalisation of processes, transformation of business models and the labour market. The information economy is global, virtual and network in nature, allowing the internal and external exchange of information; it facilitates the decentralisation of economic activities, allowing direct interaction between producers and consumers on this base personalisation. Understanding these processes is critical to successfully navigating the modern economic environment and a high degree of dynamism and adaptation to future changes.

The information economy is developing rapidly due to digitisation, globalisation, and changing industries and business models. Key global trends include the ongoing digital transformation of business models based on unleashing the potential of data, as well as the rise of cloud computing and growing interest in AI technologies and automation; the rise of the platform economy and freelancers and the expansion of network effects and market dominance; increasing globalisation of digital markets, by expanding the market of e-commerce/m-commerce and global commerce and the scope of digital services and remote work. However, these trends also present significant challenges, including cybersecurity and privacy risks, the digital divide, the need for investment in continuing education for digital inclusion and the need for sustainable and green development. Navigating these dynamics will require businesses, governments and society to adapt continually, ensuring that the benefits of the information economy are widely shared and that risks are effectively managed.

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Testing causality between taxes and spending on five similar countries.

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Abstract

This paper examines the relationship between government revenues and expenditures from 1995 to 2023 using quarterly data for Greece, Spain, Italy, Portugal and Cyprus. Previous studies considered that countries with similar economic situation, for example, poor countries, present a fairly diverse picture as far as their macroeconomic performance is concerned. Antonio Afonso and Christophe Rault (2009), examined the relationship between tax causality and spend for Italy, France, Spain, Greece and Portugal. Authors present that some changes of the causality patterns can also be detected notably with countries like Greece, Italy and Portugal after the second half of 1980's which makes fiscal behavior adjustments to EMU imperative.

Furthemore, from a literature review, authors have studied that spending or tax and spending models in fiscal policy have an impact both on developing and developed countries. This paper examines empirically the relationship between government revenues and government expenditures for Greece, Spain, Portugal, Italy and Cyprus due to fiscal authority. This paper research work is carried out in the context of finding an appropriate fiscal policy which aims to find the correlation for the dynamic interdependence of the basic economic variables of the state economic system. More specifically, the main axe of the economy is the research on government public expenditures and revenues which aim in forming fiscal policy. In order to analyze the short term or long term forecasts for spend and tax policies or tax and spend policies time series observations are used. We usually use time series observations that follow a specific time period, for example an annually period.

In addition, we can classify time series based on observations which are monthly, quarterly etc. Furthermore, this model examines the relationship between revenues and expenditures, aiming to find a way to design an efficient fiscal policy. This study admittedly deals with the analysis of the causality between taxes and expenditures in order to examine whether revenues determine expenses or whether expenses determine revenues. This is crucial when countries draw up the budget. Thus, this paper examines the causality relationship between total revenues and public expenditures in a specific sample of countries, using eurostat's data. Clearly, this empirical analysis examines the stationary of time series, the cointegration, Johansen test and finally Granger's Causality test between revenues and expenditures. In contrast to other studies, the present paper also includes research on Cyprus. According to results in all countries we used a VAR model and Granger causality test. In the case of Portugal it is observed that there is no causality relationship between total revenues and total expenditures. In other countries, we observed that the logarithm of total expenditures causes the logarithm of total revenues. It is observed that Greece and Ireland plan their expenses at first and then they plan their taxes, while Spain and Portugal do the exact opposite. Finally, the results from Cyprus are similar to those of Greece and Ireland.

Key-words: total revenues, total expenditures, quarterly data, cointegration test, Johanen test, VAR, Granger-Causality test

1. Introduction

This paper examines empirically the relationship between government revenues and government expenditures for Greece, Spain, Portugal, Italy and Cyprus due to fiscal authority. This paper research work is carried out in the context of finding an appropriate fiscal policy which aims to find the correlation for the dynamic interdependence of the basic economic variables of the state economic system. The main axe of the economy is the research on government public expenditures and revenues which aims in forming fiscal policy. In order to analyze the short term or long term forecasts for spend and tax policies or tax and spend policies time series observations are used. We usually use time series observations that follow a specific time period, for example an annually period. In addition, we can classify time series based on observations which are monthly, quarterly etc. This model examines the relationship between revenues and expenditures. The aim is to find a way to design an efficient fiscal policy. This study deals with the analysis of the causality between taxes and expenditures in order to examine whether revenues determine expenses or whether expenses determine revenues. This is very important when countries draw up the budget. This paper examines the causality relationship between total revenues and public expenditures in a specific sample of countries. Countries are selected according to their similar economic situation and these countries are Greece, Spain, Italy, Portugal and Cyprus. In this study Cyprus is also investigated, a country which has not been researched in similar studies. In order to check the causal relationship according to Granger, the basic condition is that all used variables must be static in order to extract reliable results. Below, time series stagnation will be checked by using autocorellation–AC, Partial Correlation–PAC, Box-Pierce test and Augmented Dickey Fuller (ADF) test. Stagnation tests are very important because without them we cannot analyze causality relation and in addition, the stagnation control reduces the problem of apparent regression where parameters are considered statistically important while they are not in fact statistically important. Dickey Fuller test is used to check if there is stagnation at levels of each variable and if not, to convert it to stagnation using the first differences. According Augmented Dickey Fuller (ADF) test examines the unit root with intercept, with trend and intercept and with none of them. If variables are non-stationary then they are completed at cointegration level one as long as the first differences are stationary. According to Dritsaki (2004), if variables are non-stationary then a stable long-run linear relationship prevails between them. Before applying the cointegration test, it is necessary to determine the appropriate number of lags from the results of the analysis. Likelihood Ratio and the information criteria Akaike (AIC), Schwarz (SQ) and Hannan Quinn (HQ) are used for this reason. In this paper we used only AIC results in our table. Therefore, in this analysis the existence of cointegration between the used variables will be checked. Completion testing is performed with Johansen test. We find stagnation of the variable in their first differences.

2. Literature review

According to tax and spend hypothesis which is supported by Friedman (1978), tax revenues control spending decisions. Especially, high taxes lead to higher expenditures. Buchanan and Wagner (1977), support that government expenditures depend on tax revenues because revenue taxes increase public expenditures, a fact which happens because an increase on taxes leads to an increase of prices on goods and welfare. This has led to an increase in government spending. According to Narayan (2005), in a study for nine Asian countries supports the hypothesis tax and spend on Indonesia, Singapore, Sri Lanka and Nepal. In their empirical analysis, where the used data from World Bank for the period 1996-2000 using log of GDP, log of tax revenues and log of government expenditures.

Narayan (2005), finds that for Haiti government expenditure causes Granger on government revenue such as spend and tax hypothesis. About El Salvador conclusions show that government revenue causes Granger on government expenditures.

According to Raju (2008), there is a two way causality relationship between revenues and expenditures. Author's research used data from 1951 to 2004 for India. Baghestani (2004), confirm the causality between taxes and government spending in Egypt and he concluded that total revenues in Egypt are firstly gathered and lead government to expend.

Kollias and Makrydakis (2000), examine the relationship between government revenues and expenditures using empirical analysis for Greece, Spain, Ireland and Portugal as the poorest members of the European Union. Authors tested for unit roots, stationary tests and cointegration in order to test a causality between tax and spend. Finally, Kollias and Makrydakis (2000), conducted Granger causality test to examine the causal relationship between reveues and expenditures. In the case of Greece and Ireland, there is an interdependence between government spending and tax revenues. On the other hand, Spain and Portugal governments, firstly design tax revenues in order to spend. To conclude, Greece and Ireland spend and tax while Spain and Portugal tax and spend.

Koren Stephan and Alfred Stiassny (1995), checked the relationship between spending and taxation in Austria discriminating the rivaling spend and tax. They examine a Var model of Austria's public sector with expenditures, revenues and GDP. Authors used techniques to identify the causal relation between government outlays and receipts. Their empirical findings support that spend and tax influence budget decision making towards the expenditure side in Austria.

Provopoulos and Zambaras (1991), in view of alarming high levels of the deficit on public sector, tested causality between government spending and revenues on Greece. The findings supports that deficits of the Greek public sector are responsible for large public expenditures. Policies that aim to reduce spending will also aim to reduce deficits. Results also indicate that more tax revenues do not lead to increased spending.

Several studies have either confirmed or refuted conclusions for the relationship between tax revenues and expenditures using different econometric techniques. For example, in order to expand results to analyze tax and spend issues, the author used Vector auto regression model by using quarterly data. Other authors used co integration and error correct models using annual or quarterly data for different economies.

Oluwole Owoye(1995), investigates the causal relationship between taxes and expenditures in G7 countries from 19961 to 1990 by using cointegration and error correction models. Results showed that causality exists between taxes and government expenditures for all countries except from Japan and Italy. Annual data came from IMF's Yearbook and from IMF's Government finance statistics yearbook.

Antonio Afonso and Christophe Rault (2009), in their more recent survey than the previous, used bootstrap panel analysis and they studied causality between government spending and revenue for EU countries for 1960 to 2006. Their empirical results conclude that there is spend and tax causality for Italy, France, Spain, Greece and Portugal. For Germany, Belgium, Austria, Finland and the UK results showed that there is tax and spend causal. Bootstrap panel analysis of causality between government revenue and spending for EU countries allows contemporaneous correlation across countries and dispenses the need of pretesting variables for unit root test. This paper used Augmented – Dickey Fuller unit root test all the countries.

Antonio Afonso and Christophe Rault (2009), found tax causality for Italy, France, Spain, Greece and Portugal. Authors present that some changes of the causality patterns can also be detected notably with countries like Greece, Italy and Portugal after the second half of 1980's which makes necessary fiscal behavior adjustments to EMU.

William Anderson et al (1986), in their results concur with Barro theory that expenditures cause revenues. On the other hand, several issues used Granger's causality test to examine the relationship between taxes and expenditures.

Roshaiza Taha and NanthakumarLoganathan(2008), support that tax revenue has always become a major contribution to the sources of Malaysia's government revenue. Malaysia's tax revenues include direct and indirect taxes. This study empirically tests the causality between tax revenues and government spending for 36 past years. Results provide the evidence that there is a long-run relationship between tax revenues and government spending using VAR model for 1970-2006. In their study they used unit root tests ADF test, PP test and KPSS test, Johansen's Cointegration Test and finally Granger Causality test was estimated with VAR approaches. This study concludes that there was bidirectional Granger causality from direct tax revenues and indirect tax revenues to government spending. Malaysia's outputs indicate that reducing direct and indirect tax rates may lead to a fall in government spending in the future.

Tsangyao Chang et al(2002), examine tax and spend hypothesis and spend and tax hypothesis and also fiscal synchronization using cointegration and Vector autoregression models for ten countries using annual data over the period 1951 to 1996. Empirical analysis concerns ten countries using annual data on real GDP, real government expenditures and real government revenues. Their results from Granger causality tests suggest unidirectional causality running from Tax and Spend hypothesis for Japan, South Korea, Taiwan, UK and finally USA. On the other hand, according to their empirical analysis hypothesis Spend and Tax concerns only Australia and South Africa. To Fiscal Synchronization hypothesis, they found a feedback exists between revenues and spending for Canada.

Stephen Miller and Frank Russek (1990), examine the causality issue with the aid of co-integration and error- correction modeling. Their results, based on quarterly data which based on error- correction models, indicate that there is causality between taxes and spending.

3. Methodology

This section will present all data of the variables that will be used for the research.

In this analysis we examine two linear models. The first model uses only the logarithm of total revenues and logarithm of total expenditures. The second model uses the logarithm of total revenues, logarithm of total expenditures and logarithm of GDP. All results come from the statistical packpage e-views. All data came from governments finance statistics eurostat's database. Specifically, firstly in empirical analysis we analyze descriptive statistics of the variables, the correlation between variables and the diagrammatic representation of the variables. Empirical analysis uses quarterly time series data including 99 observations in order to characterize data as reliable from 1999 to 2023. After the analysis of the descriptive statistics, a stagnation test of the variables and Johansen covariance test will be performed to determine the number of lags in the var model. Finally, we examine Granger causality test for the relationship between tax revenues and public expenditures in the first model in order to exclude results for spend and tax or tax and spend policies in our countries sample.

Model based on vector autoregressive model which are the following:

$ltotexpt= \alpha_0 + a_3LTAXREV_{t-j} + a_4TAXEXP_{t-j} + u_{it}$ (1)

where a_0 = constant of the model

a_1=coefficient of the i variable ltaxrev

a_2= coefficient of the variable taxexp

ut= error

t= time of measure 1999q1-2023q3

j= lags of the model

4. Descriptive statistics

The following table will show descriptive statistics of the variables.

Tables include data on mean, maximum, minimum, standard deviation, Skewness and Kyrtosis. In addition Skewness and Kyrtosis are calculated. Asymmetry coefficient checks whether the distribution is characterized by negative, positive or neutral asymmetry. Coefficient of kyrtosis refers when distribution is thin, equal and intermediate. Based on the regularity Jarque –Bera test checked if variable follows the normal distribution.

Table 1: Descriptive statistics of LTOTREV

MEAN	3,731655
MEDIAN	3,718438
MAXIMUM	4,005513
MINIMUM	3,575151
STD.DEV.	0,090487
SKEWNESS	0,495094
KURTOSIS	3,010952
JARQUE - BERA	4,044951
PROBABILITY	0,132328

Based on the above table that appears the results of the descriptive statistics of the logarithm of totrev has mean 37,35 and an median of 37,60. According to asymmetry coefficient Ltotrev shows positive asymmetry. The coefficient ofkyrtosis is equal to 3,738>3 which shows that the distribution is wide. Jarque –Bera found that the variable does not follow the normal distribution.

Table 2: Descriptive statistics of LTOTEXP

MEAN	3,8249
MEDIAN	3,82864
MAXIMUM	4,16044
MINIMUM	3,61899
STD.DEV.	0,10856
SKEWNESS	0,40107
KURTOSIS	3,08091
JARQUE - BERA	2,681157
PROBABILITY	0,261694

Table3: AIC Information criteria

In order to decide the appropriate model of analysis VEC or VAR model we used the VAR lag Selection Criteria with four lags to include because we have quarterly data. We analyse Akaike information criteria (AIC). When we decide this we continue to Cointegration Test Specification.

	Greece	Spain	Italy	Portugal	Cyprus
lags	AIC	AIC	AIC	AIC	AIC
0	-2.6403	-3,1428	-4.2472	-4.3238	-2.2608
1	-3.1339	-3,4434	-5.4094	-4.2994	-2.2315
2	-3.3018	-46369	-5.5550	-4.3486*	-2.2989
3	-3.3310	-4,7126	-7.0448*	-4.3340	-2.4322*
4	-4.3949*	-5,6161*	-8,1969*	-6,0468*	-3,2697*

According to table which includes AIC information criteria the appropriate lags for VAR or VEC model are four for Greece, four for Spain, four for Italy, four for Portugal and four lags for Cyprus.

5.Cointegration- Johansen test

From the control for the existence of a unit root test we observe that the variables of the logarithm of income and logarithm of expenses remain stagnant in first differences for all the examined countries. Due to the above, cointegration test is considered necessary. Based on Johansen control, if there is a complete vector, then the error correction model is used to estimate the long-run or short run equilibrium relationship. If there is no complete vector and we accept the null hypothesis in Johansen control, then a self-regulating vector model without restrictions is used. According to empirical results, total revenues and total expenses in Greece are not summarized. Therefore, in the long run, the two indices do not move in the same direction, therefore a var model (1,2) will be used. In the case of Spain and the other countries based on Johansen's control, there is no integration relationship, so a var model will be used and then the causality between revenue and expenditure will be assessed.

6.Var model

According to bibliography, it is very important to check the relationship between the static model of the integration and an error correction model can be studied through the var models. In Var models all variables are endogenous. According to Jonansen Integration checklists for countries which are included in this paper we conclude that there is a complete vector and therefore a long-term equilibrium relationship for Greece. Table shows the results from the informational criteria according to AIC the appropriate umber of lags is three. Below Johansen's control will be analyzed to examine the existence of integration and to determine the appropriate var model. Finally, causality between taxes and expenses will be checked by using Granger's test.

Our estimation models for Greece are the following:

$LTOTEXP=1,8553+0,0543LTOTEXP_{t-1} +0,4670LTOTEXP_{t-2} + 0,095LTOTREV_{t-1} - 0,0901LTOTREV_{t-2}$

$LTOTREV=1,085-0,2839LTOTEXP_{t-1} + 0,3063LTOTEXP_{t-2} +0,5686LTOTREV_{t-1} +0,1225LTOTREV_{t-2}$

Our estimation models for Spain are the following:

$LTOTEXP=1,0124+0,019LTOTEXP_{t-1} +0,8567LTOTEXP_{t-2} + 0,2620LTOTREV_{t-1} – 0,4110LTOTREV_{t-2}$

$LTOTREV=1,18-0,079LTOTEXP_{t-1} +0,0619LTOTEXP_{t-2} +0,4403LTOTREV_{t-1} -0,1825LTOTREV_{t-2}$

Our estimation models for Italy are the following:

$LTOTEXP=2,326+0,099LTOTEXP_{t-1} +0,025LTOTEXP_{t-2} + 0,0572LTOTREV_{t-1}+ 0,1605LTOTREV_{t-2}$

$LTOTREV=0,7352-0,6128LTOTEXP_{t-1} +0,7263LTOTEXP_{t-2} +0,63406LTOTREV_{t-1} +0,0561LTOTREV_{t-2}$

Our estimation models for Portugal are the following:

$LTOTEXP=3,4181 +0,015LTOTEXP_{t-1} +0,4749LTOTEXP_{t-2} + 0,0148LTOTREV_{t-1}- 0,4082LTOTREV_{t-2}$

$LTOTREV=34181 +0,01577LTOTEXP_{t-1} +0,4749LTOTEXP_{t-2} +0,0148LTOTREV_{t-1} - 0,4082LTOTREV_{t-2}$

Our estimation models for Cyprus are the following:

$LTOTEXP= 3,381+0,3089LTOTEXP_{t-1} +0,2341TOTEXP_{t-2} -0,5560LTOTREV_{t-1}- 0,1375LTOTREV_{t-2}$

$LTOTREV=1,8190+0,12708LTOTEXP_{t-1} -0,1362LTOTEXP_{t-2} +0,1039LTOTREV_{t-1} +0,4389TOTREV_{t-2}$

7.Granger Causality Var models

According to the results of Johansen test for the countries of Greece, Spain and Italy Granger causality test is applied in order to examine whether a variable X is caused by a variable Y. Two variables can be related to each other but no causal relationship is established. In a model there can be two way or one-way causality. Based on Granger's table for Spain, Italy Greece, Portugal and Cyprus it appears that there is an important relationship between LTOTREV and LTOTEXP and also we conclude that LTOTEXP causes LTOTREV and LTOTREV causes LTOTEXP for Spain and Italy. Specifically, LTOTREV causes LTOTEXP for Greece and for Cyprus.

Table 5: Granger Causality Var models

	Greece		Spain		Italy		Portugal		Cyprus	
	Dependent variable		Dependent variable		Dependent variable		Dependent variable		Dependent variable	
Variables	LTOTREV	LTOTEXP	LTOTREV	LTOTEXP	LTOTREV	LTOTEXP	LTOTREV	LTOTEXP	LTOTREV	LTOTEXP
LTOTREV		8,2820*		14,237***		17,3809***		7,4006**		12,17***
LTOTEXP	0,5506		1,7034		23,747***		3,78166		2,8798	

***indicates significant at the 1% level

**indicates significant at the 5% level.

*indicates significant at the 10% level.

8. Conclusions

This paper examines the causal relationship between total revenue and total expenditure. The empirical analysis concerns Greece, Portugal, Italy, Spain and Cyprus. The majority of surveys dealt with results from different categories of countries with specific characteristics. This analysis uses countries that have shown high deficits including Cyprus which has not been assessed in other surveys. All data used in this paper has been extracted from the government finance statistics of Eurostat's database.

Firstly, this paper, in order to exclude reliably conclusions, used quarterly data from 1999 -2023. Paper results show that Johansen's control showed that for Greece, Spain and the other courties which are participate in this paper a VAR model will be used by using time lags which arose from the Akaike information criterion in order to check causality relationship. Our results showed that there is a causality relationship between total expenditures and total revenues except from Portugal.

Fiscal policy design depends on tax policy design and expenditures design. It is important that through Granger causality test we conclude what causes what specifically if taxes cause expenditures or expenditures cause taxes. The consequences of this research are very important about tax policy. There is a bidirectional causality relationship between taxation and expenditures. Greece, Spain and Italy do no present a bidirectional causality relationship.

From the results, it is obvious that total tax income cause total expenditures and total expenditures cause income. Therefore, there is a bidirectional causality relationship for Spain and Greece. The results of this paper agree with the research of Raju (2008), which claims that there is a bidirectional causality relationship between expenditures and tax income. The research of Kollias and Makrydakis (2000) is similar to this one because it also uses a specific number of countries which present specific characteristics (poorest in E.U.). It is observed that Greece and Ireland plan their expenses at first and then they plan their taxes, while Spain and Portugal do the exact opposite. Finally, the results from Cyprus are similar t those of Greece and Ireland.

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Human Resource Management in Cultural Organization. The Case of the Ephorate of Antiquities of Kozani

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Cultural organizations are faced with various challenges, which they will have to successfully address in order to ensure their survival and continuity. The role of Human Resources Management (HRM) is also very important; whose functions can determine the effective operation of all departments of an organization, the job satisfaction of the human resources and the meeting of their needs. Human Resources Management in cultural organizations follows the directions and conditions of Human Resources Management in general. With the particularities of the sector, the steps of human resource management from its planning and strategy, to training and evaluation, are also followed in this case as well. Western Macedonia consists of four prefectures. Each prefecture has the corresponding service that deals with and protects antiquities by region. Within this context, the opinions of employees of the Ephorate of Antiquities of Kozani regarding the functioning of the HRM in their organization are studied, using the research tool of the semi-structured interview.

KEYWORDS

Cultural Organizations; Cultural Institutions; Ephorate of Antiquities of Kozani; Human Resources Management; Administration; Marketing and Management.

JEL CLASSIFICATION CODES

BAD5 Business Administration

HR24 Human Resource
MAN30 Management
MAR32 Marketing

1. Introduction

The concept of Human Resource Management, from its appearance and its evolution over time, presents a set of characteristics and actions which as a theory are influenced by a group of factors such as globalization and technological achievements, the nature of the work itself and the human factor, economic challenges, and demo-graphic trends (Tzortzakis, M., K., 2019). The key elements of Strategic Planning in conjunction with the principles of Strategic HRM that present and list its benefits are those actual characteristics that a modern HRM manager will aptly use by leveraging each aspect of the characteristics.

Human Resource Management (HRM) is a very important function that can study, supervise, and implement various activities related to the development and management of the human factor of an organization or a business (Kefis, B., 2014). That's why, it includes the selection, utilization, adaptation, and attraction of all human resources within the workplace to be able to increase the efficiency of the business and their job satisfaction, always based on labor and legal relations that apply, social justice, safety, and hygiene (Bourandas., D., K., & Papalexandri., N., 2003).

2. Materials and Methods

People make up the core of a company. They form the basis of it as well. Human Resources are all the talents and willingness of the people working in a company to perform as much as possible, which can help on the one hand in the planning and on the other hand in the completion of the vision, strategy, goals, and mission that has been decided (Kefis, B., 2014).

2.1. The concept of Human Resource Management

According to Wayne Mondy & Joseph (2018) Human Resources Management is the process to design formal systems in an organization, so as to ensure the most efficient and effective use of the people working in it and to achieve its goals.

For Human Resource Management, employees are a key vital resource, which ensures the value of an organization and is its asset. For this reason, all organizations should invest in it to maximize their profits and fulfill a dual purpose, on the one hand to achieve the goals they have set and on the other hand to ensure the well-being, personal development, and the professional success of all employees [4]. In the modern era, the contribution that human resources can offer to ensure or maintain its competitive advantage is taken for granted. In addition, the experience, dedication, disposition, and qualifications of the employees in any organization are some of the main abilities that can lead to its success and survival (Armostrong, M., 2006).

Mostly, HRM goes beyond the areas of management, conditions, payment, dispute resolution and discipline and extends even further into the maintenance and development of employees through training, increasing productivity, performance and the quality of their work (Terzidis, P., K., & Tjortzakis, M., K., 2004).

Its role is to be able to direct and orient each employee, to offer him the valuable opportunity to acquire new skills to be able to undertake different tasks and finally to expand the existing ones he has in order to improve his performance. In addition, it can help him to develop his talents, something for which he will be rewarded, to develop his career, to plan his next steps in the work field, to further enhance his creativity and finally to satisfy his personal needs and the goals of the organization (Dessler, G., 2015).

All of the above proves that HRM can help maximize the efficiency of organizations by ensuring the necessary conditions to correctly identify their needs, to select, to attract, to retain, to adapt, to develop and to employ staff and finally to properly utilize all human resources. Due to the fact that the sustainability of organizations is directly related to the achievement of their goals, which is based on the human factor, the great importance of HRM can be understood [6]. Its content, therefore, concerns all the functions of human re-sources management and the way in which they are interdependent (Bourandas., D., K., & Papalexandri., N., 2003).

2.2. Opportunities of Human Resource Management

Human Resources Management can offer important opportunities to every organization, but it must face various challenges as well. Firstly, the most important is the attraction and the retention of any talent. Modern workers, due to the fact that they have many qualifications, also have increased demands from their working environment (Gary Dessker, 2022). This fact makes it much easier for them to move from one job to another, with the ultimate goal of being able to find the ideal working conditions for them. After all, there are very few who think about completing their career in the organization they started, something that used to be very common in the past (Dessler, G., 2015). In addition, the competition that prevails among companies to discover talented workers and the process of developing them, increases even more due to the globalization of the market, which creates more professional opportunities in foreign countries. Nowadays, it is much easier for any worker who wishes to migrate to another country to pursue his career and gain experience. This creates much more pressure on companies, which should increasingly increase their attractiveness towards employees through the proper management of their image (Iordanoglou, D., 2008).

Moreover, another challenge that the executives who make up the Human Resource Management will have to face in the coming years is the enormous technological development (Sharma, N. K., & Kumar, N., 2022). She has certainly helped in the field of work to save time and money, to have a better quality of life, to appear new ways of working and to develop e-Learning. Apart from these, however, it causes various issues related to the alienation of individuals, due to the fact that their daily contact is reduced and at the same time department managers are unable to properly exercise their leadership role or coordinate groups of individuals, parties who, in many cases, have different cultural origins and are located in different states (Wayne Mondy, R., & Joseph J., 2018).

2.3. Human Resource Management in Cultural Organizations

Cultural organizations have specific characteristics, which are also related to their mode of operation. Because of the increased cost of production and the low-cost reproduction of each cultural product, conditions are favorable for economies of scale to apply. At the same time, every investment made in cultural products is characterized by great risk, since it is not possible for their producers to know if any of them will experience failure or failure (Avdikos, B., 2014). In addition, most cultural organizations, unlike other businesses, are not nonprofit. This means that their profits are not passed on to their employees or owners but are used to enable them to continue their work. Many times, of course, there are also grants from the state (Kouri. M., 2007). This may also be one of the reasons why the human resources of the cultural and creative sectors decreased in the context of the crisis in many regions of Greece. The financial crisis greatly affected every political organization, since their resources were significantly reduced, and their operating expenses increased rapidly (Avdikos, B., 2014).

In the cultural and creative industries both abroad and in Greece, there is a growing tendency to adopt different practices regarding their management, mainly due to the need for cultural organizations to manage to survive in the modern competitive environment, which operates more and more according to the rules of the market and the economy (Byrnes. W.J., 2009). This fact is also connected with the tendency to apply a different public administration, based on which reforms need to be made in every public body, in order to be able to ensure the greatest possible efficiency and productivity (Console, N., 2006).

All cultural organizations, after proceeding with the planning of their structure, should connect, through the strategy they will follow, their actions and plans with the human resources they have, which is the most basic factor they provide. Because of this, HRM has undertaken a multifaceted and certainly demanding project, which needs the fruitful combination of art and knowledge. In addition, managers should be specialized and have acquired the necessary knowledge and experiences to be able to understand the needs of all employees (McKinlay, A., & Smith C., 2009). In this context, the functions that the human resources management department should perform in every cultural organization are also very important. The most important are the following:

2.3.1. Planning of human resources

Human Resources planning is primarily strategic in nature and helps to acquire and utilize the necessary number of employees who will have the qualifications to fill the jobs. At this stage, the experience gathered from the past, the current situation, the activities, but also the organization's environment are considered in order to be planned in line with the conditions prevailing in the labor market, with the changes in technology and the needs of the public (McKinlay, A., & Smith C., 2009).

2.3.2. Process to attract and select employees

At this stage, the goal is to find quality employees, who will have the inspiration and charisma required in the field of culture to be efficient and able to continuously improve. Once the candidates and the information needed by the organization have been collected, they will be evaluated and those deemed most suitable to meet the specifications of the positions offered will be selected through special procedures (Bourandas., D., K., & Papalexandri., N. A., 2016). The stages in this case are the implementation of the recruitment applications, the submission of Curriculum Vitaes and statistical letters, the interviews, and the practical training, the psychometric or various other tests that can be done, the confirmation of all the qualifications that the candidates have and the decision of their choice. This is a very important process, due to the fact that wrong decisions at this stage can be disastrous for any organization (Bourandas., D., K., & Papalexandri., N., 2003).

In the case of incorrect choices, disagreements and tensions can arise between employees or the most capable employees can leave, which can also have financial consequences for the organization (Bouradas., D., K., 2021). A very important factor in attracting and eventually hiring employees is the image that an employer has in the labor market. Certainly, the methods used to select personnel have both advantages and disadvantages and the methods should be combined with each other to be more effective (DeCenzo, D. A., Robbins, S. P., & Verhulst, S. L., 2016 and Farndale, E., Horak, S., Piyanontalee, R., & Vidović, M., 2023).

2.3.3. Development and Training of Human Resources

One of the most important functions that the HRM should perform is to train and develop each employee. In this way it will orient them so that they become familiar with the organization's vision and mission, as well as with its culture, values and aspirations (Alqudah, I. H., Carballo-Penela, A., & Ruzo-Sanmartín, E., 2022). Through the training they need they will acquire specific professional skills, they will improve their individual performance and that of the organization, they will be motivated and supported in terms of acquiring new behaviors and knowledge to be able to apply them in their work, they will manage their careers. Additionally, they will create and maintain their motivation and finally enhance their imagination and creativity (Da Silva, L. B. P., Soltovski, R., Pontes, J., Treinta, F. T., Leitão, P., Mosconi, E., ... & Yoshino, R. T., 2022).

It is a systematic process, which requires time and can give a significant advantage to any cultural organization, if it is implemented based on its needs and goals. In this way, the identification and analysis of the needs of the staff can be achieved and the appropriate programs can be adopted, so that they can acquire the skills that are considered useful for the future (Terzidis, P., K., & Tjortzakis, M., K., 2004). Although development is directly related to the experience, adaptability and skills of human resources, employees should develop their personality and all their characteristics that will help them to deal with situations and adapt to them, in taking initiatives, responsibilities and decisions with great responsibility, understanding human behavior, and introducing solutions, ideas and innovations (Dessler, G., 2015).

2.3.4. Remuneration package and evaluation of Human Resources

Paying and evaluating employees are two most important functions of Human Resource Management. Performances are assessed based on specific criteria, which are predetermined, in order to determine whether the goals are achieved, in relation to the tasks that the employees have (Mouza-Lazaridis, A., M., 2013). Moreover, the evaluation is a useful tool, according to which movements, transfers and promotions will be organized (Xirotiri-Koufidou, S., 2010). Assessment is an imperative process which helps to identify the training needs of employees and to determine if they are suitable for a job, to gain more motivation, to improve their performance and to improve communication between the ranks of the organizations (Terzidis, P., K., & Tjortzakis, M., K., 2004).

On the other hand, payment is the reward given to employees due to their performance and participation in the efforts made to realize the goals of an organization. It is the value of the services they offer to meet the requirements and at the same time it is a motivation, through attraction, retention and commitment of employees and a simultaneous factor to increase productivity and save costs (Gandzias, G., & Korres, G., 2011).

2.3.5. Subsubsection

The motivation of human resources is another important function of HRM, be-cause it is related to the behavior and performance of individuals. It is a psychological process that gives weight to human behaviors and leads them in specific directions (Patrinos, D., Th., 2003). In this way, the goal is to activate, motivate and direct people's behavior towards actions, so that the goals that have been set can be completed. Also, the commitment of employees to the organization can be increased. Through the provision of appropriate incentives on the part of management, staff will be able to identify with the mission and vision of the cultural organization and contribute as much as possible to achieve the goals sated (Trant, J., 2009).

On the other hand, motivation is a very important factor for employee performance, counting the fact that it can increase their efficiency. The recognition of their efforts, achievements and contribution will be able to contribute to the consolidation of a positive climate within a workplace and at the same time satisfy their individual and social needs (Armstrong, M., & Taylor, S., 2023). Therefore, they will perform better and contribute to the development of the respective cultural organization. Additionally, their autonomy will be strengthened and their dependence on superiors will be reduced, their responsibility will be improved, and they will be able to lead to self-control and self-awareness (Hart, P., D., & Gustavsson, J., C., 2002).

All the functions that must be performed by Human Resources Management which were mentioned are related to each other to a very large extent, with the result that the failed or successful execution of one of them has a direct effect on the effectiveness of the other (Bassett-

Jones, N., 2023). For this reason, it is necessary for all HRM staff to have the necessary emotional intelligence, so that they can properly motivate all employees and meet the needs and goals of the organization itself (Dessler, G., 2015).

Cultural organizations depending on the totality of their employees, the educational background of those exercising authority, the size of the service itself and the objectives of each superior authority are governed by conditions and follow the techniques defined at a more general level by the Human Resources Administration in greater or lesser degree. Specifically, in the Ephorate of Antiquities of Kozani, which is a regional agency far from the decision-making center and without self-governing rights, it is a micrograph of the organization, which operates in the best possible ways, achieving as many goals as possible, with the forces and the possibilities given to it.

Approaching the employees of the Ephorate of Antiquities of Kozani we aim to gain an insight into the way that the organization operates in the field of human factors. In addition, we seek to identify the existence of the use of techniques, and the exploitation of possibilities in relation to human resource management from the selection of personnel and the staffing of the organization to its training and the evaluation of its work.

2.4. Research Methodology – Purpose

The purpose of the research is to investigate the opinions of the employees of the Ephorate of Antiquities of Kozani regarding about Human Resources Management and its functions.

2.4.1. Method

This research was based on the qualitative methodology and more specifically on the research tool of the interview. Extensively, the semi-structured interview was chosen, in the context of which the participants were free to express their opinions and perceptions.

The total number of questions used in the data collection during the interview process was twelve. The first three questions addressed the educational level of the employee, the length of his working time and the responsibilities he exercises within the organization.

The contents of the remaining questions refer to two main thematic sections. The first thematic axis refers to the functions of Human Resources Management in the field of Cultural Organizations (Aguinis, H., Jensen, S. H., & Kraus, S., 2022). Particularly, good working relations and the development of collaborations between employees is an important issue that was raised. In addition, the planning of jobs, as well as the ways of selecting personnel in a cultural organization are important elements for an organization. They also reveal the capabilities of the organization itself.

New technologies and their influence, but also their use in the daily life of an employee, was considered an important topic (Chapano, M., Mey, M. R., & Werner, A., 2023). In addition, subject areas such as the evaluation and training of employees from the side of the Human Resource Management department are vital issues and were included in the interviews. The next issue that was asked to the interviewees is the choice of the strategy that shapes and organizes the Human Resources Management department.

The second thematic section concerns the educational background and the characteristics that must be possessed by those who are responsible for Human Resources Management (Batti, R. C., 2013). Finally, part of the research was the issue of the challenges they encounter and have to face.

2.4.2. Sample

The interview was attended by two employees of the Ephorate of Antiquities of Kozani, one of whom works in the field of Byzantine/Post-Byzantine Antiquities and the other in the corresponding field of Prehistoric and Classical Antiquities.

3. Results

Based on the responses of the interviewees, data was collected and categorized into two thematic axes. The first of them concerns the functions of the IHR in the context of cultural organizations. Regarding to the two participants initially referred to its contribution to the effort to establish a positive climate and to strengthen collaborations within cultural organizations. The first employee emphasized that such a thing can be achieved "...through unified management and a central strategic planning, with decision-making by the people in a position of responsibility" (I1). The second one agrees with this, adding that "Human Resources Management is one of the most basic departments in an organization as one of its main purposes is to secure important information with the aim of familiarizing employees with their duties. Ensuring compliance with legislation." (I2).

Consequently, a reference was made to another important function of the HRM, which is related to the planning of jobs within cultural organizations. Regarding to this question, one of the participants answered that “This is done through the central bodies of the organization"(I1), while the second emphasized that the specific process first depends on "...the available staff and then the distribution of responsibilities among the employees, recognizing the qualifications of each of them." (I2).

Subsequently, regarding to the way of selecting human resources, it was mentioned that this can be done "Through criteria (ASEP) and permanent employees who serve its chronic needs." (I1), while the persons in charge of the HRM in any case take seriously the "...skills, experience and previous service of the person." (I2).

Then it was discussed whether the Human Resources Management department has contributed to the integration of new technologies in the participants' workplace and if any such has been achieved, in the ways it has used to do so. Regarding this, the first respondent brings examples of various applications that facilitate his daily life. Particularly, he states "Yes, the electronic protocol and other applications of the new technologies (Archaeological Land Registry, Mobile Monuments Portal) have facilitated the work of the officials in practice." (I1). The second one agrees and emphasizes that "Technology has been included in the daily work as all cases are now carried out electronically without requiring a physical presence to process cases." (I2).

An issue of great importance, which was included in the interview, was the method used by the HRM professionals to evaluate the workers of the specifical cultural organization. Concerning it was initially emphasized that it is implemented "on an annual basis with evaluation by the Heads of Departments and the Heads of the Organization." (I1). The second participant disagreed with this point of view, who emphasized that "There is no written evaluation specifically by the human resources department." (I2).

Finally, the last topic that was touched on was the way in which the strategy of the organizations is shaped by the HRM. Regarding this, the first employee stated that "the department manages the placement of employees in specific regional and central services, therefore it directly shapes the capabilities of the specific services and consequently the strategy of the organization." (I1). Accordingly, the second one emphasized that the whole process is completed "By allocating tasks to the staff based on the availability and skills of each person." (I2).

The second thematic axis concerns the educational background of the persons in charge of the HRM in the cultural organizations and the challenges they will encounter. Regarding this and more specifically with the characteristics that the director of every cultural organization should have, the first participant emphasized that "He should have certified knowledge of the subject and have handled relevant organizations (except of the narrow Public Sector)." (I1). The second one added that the director "Should provide opportunities for staff training, freedom of creativity and have objectivity in his selection, properly evaluating his capabilities." (I2).

Regarding the challenges that the first participant may encounter, he states that very serious are "Pressures from various factors (political, self-administrative, internal) to serve specific persons and personal needs, with the result that the human resources of the Regional Services are weakened and the strategic planning of the Organization." (I1). On the other hand, the second participant refers that the biggest challenge is the "...understaffing of the Services." (I2).

It is characteristic that the first employee closes his interview by giving his own comment; by showing his dissatisfaction with the way the Human Resources Management department operates in the organization to which he belongs. For this reason, he states that "Human Resources Management in the Organization in which I work has not received the importance of the role it could perform and is largely considered a simple part of handling a bureaucratic process, while it could co-shape the Organization's planning.".

4. Discussion

Through this research, an attempt was made to investigate the perceptions of the employees of the Ephorate of Antiquities of Kozani regarding the responsibilities and the effectiveness of the Human Resources Management department of their organization. Regarding the main functions, which should be handled by the specific department, both participants emphasized that HRM helps to reshape the entire culture of the organization through proper strategic planning, responsible decision-making, compliance with legislation and the familiarization of the Commissioners with the tasks they have undertaken. Wayne Mondy & Joseph (Wayne Mondy, R., & Joseph J., 2018), also agree with this, emphasizing that HRM is a very important resource of any organization, since it can help to achieve the goals that have been set, but also to ensure the development and well-being of each employee. According to Armstrong (2016) an organization can secure a significant competitive advantage and at the same time achieve employee loyalty to it through the existence of the specific department.

In addition, the interviewees referred to the fact that the HRM can help in the planning of jobs within the organization mainly through the distribution of responsibilities according to the qualifications that each employee has and their abilities.

On the subject, DeCenzo et al. (2016) emphasize that through the planning of the HRD, all employees are utilized, and the existing jobs are effectively covered, depending on the actions that need to be implemented and on the abilities that they have themselves.

Correspondingly, the research emphasizes that the employees are also selected by the HRM managers according to their experience and the qualifications they have to fill the positions with their knowledge. After all, the selection process is very important and for this reason, all the necessary specifications should be met, to confirm the qualifications of the candidates and ultimately judge whether they can fill the positions or not. All of these can be achieved through the HRM (Bourandas., D., K., & Papalexandri., N., 2003).

In the modern era, all cultural organizations should be able to follow the developments of society and adapt to existing needs. For this reason, it is reported that the HRM department is increasingly introducing new technologies into the daily lives of the employees of the Ephorate of Antiquities of Kozani, to improve their performance and make it easier for them to carry out their daily duties. Finally, disagreement was observed among the interviewees regarding the way the HRM department uses to evaluate employees. In this respect, while the first one states that the evaluation is carried out by the Heads of Departments and the Heads of the service, the second one emphasizes that no evaluation process is implemented in his organization. This fact is opposed to what Mouza-Lazaridis (2013) claims, according to which the HRM constantly assesses the performance of employees based on certain criteria, which have been determined in advance, to see whether they can cope with their tasks. After all, the evaluation is required to find and meet the needs of the employees, so that they can improve more (Terzidis, P., K., & Tjortzakis, M., K., 2004).

With reference to the skills that the director of the HRM department in cultural organizations should have, it is emphasized by both the two participants that he should stand out for his specialized knowledge and experience. The results of the re-search carried out by Batti (2013) also agree with this, in which it is emphasized that the skills of the director of the HRM are very important to achieve all the goals that have been set and for each organization to function effectively. Finally, reference was also made to the challenges that this department may face.

Regarding this, the first participant emphasizes that a big challenge might be the need to serve specific interests, which he considers weakening regional services and, in general, the strategic planning of each cultural organization. Stone & Deadrick (2015) agree with this as well, where, in their research on the opportunities and challenges that HRM managers may encounter, is also the need to serve specific interests or ideologies, which can disorient employees and thus harm their productivity.

Finally, the second participant states that the biggest and the most important challenge is the understaffing of organizations, which can create many problems to themselves. According to Batti (2013), the absence of the appropriate executives in the organization can reduce their competitive advantage and at the same time limit the opportunities they have to meet the goals that have been set.

5. Conclusions

A set of theories that have been scientifically documented in the past appear conclusively in the present research. Human Resource Management helps to re-shape the entire culture of the organization. Also, the correct strategic planning leads to the correct decision-making, compliance with the legislation and the familiarization of the managers of the Cultural Organizations with the tasks they have undertaken.

Human Resources Management can help to plan jobs within the organization mainly through the distribution of responsibilities according to the qualifications and abilities that each employee has. Employees are selected according to their experience and the qualifications they have so they can fill in the positions with their knowledge.

The Human Resources Administration is increasingly introducing new technologies into the daily lives of the employees of the Ephorate of Antiquities of Kozani. This option helps to improve their performance and make it easier to carry out their daily tasks. The evaluation of the employees is carried out by the Heads of Departments and the Heads of the Organizations on an annual basis. The director of the Human Re-sources Management department in cultural organizations must stand out for his specialized knowledge and experience.

Regarding the challenges that may be faced by the one who exercises management in a personnel department, it may be necessary to serve specific interests, which he considers weakening the regional services and in general the strategic planning of the respective cultural organization. Finally, the understaffing of organizations is a fact that creates many problems for the organization itself.

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CURRENT HIRING REQUIREMENTS IN CONSTRUCTION INDUSTRY

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Abstract:
Everyone's goal is to start their ideal job as soon as they graduate. Some students, however, begin working even before they finish their studies. They do this in order to gain hands-on experience that could help them land their desired career after graduation. These students are frequently preferred by employers over graduates with no work history. This is true because skill sets have been added. The problem here is that graduate students without experience frequently only draw their knowledge from books and not from real-world experiences. The practical knowledge required to enter the workforce is not taught in schools. Understanding the numerous hiring factors, a corporation uses when looking for young graduates is the goal of this study. This study is based on a number of factors, including the skill sets needed, degree of experience, sexual orientation, country of origin, undergraduate background, soft skills, etc. The study combines case studies with business survey data. The goal of this research is to aid students by compiling a database of hiring standards, tactics, and priorities.

Keywords: Hiring practices, Construction Industry, Graduates, Skillset, Experience.

Introduction:
With numerous advancements in building materials, computer technology, project delivery, and human resource management, the construction sector has seen significant transformation during the

last 20 years. Furthermore, the status of the economy has increased competition for jobs in the construction sector. Due to these circumstances, it is critical to utilize the information imparted to students and to develop extra abilities that will give them a competitive edge in the employment market. Focusing on developing relationships and other soft skills, including communication, has been demonstrated to be a crucial trait for people joining the contemporary workforce. There is a growing need for graduates with the abilities required to work in transdisciplinary and multi-cultural environments as industry continues to expand internationally. Soft skills enhance the creation and maintenance of connections among the broad collection of experts required to execute projects. Because of the nomadic nature of the construction industry, the capacity to create and sustain connections might be particularly crucial. These talents are more important for students to have in a challenging market so they can stand out. Employers are starting to focus more emphasis on new graduates' abilities, especially their practical experience in the construction sector, in addition to these soft talents. The educational programs for construction engineering are intended to assist students get ready for available jobs in the sector. Many of these curricula offer minimal flexibility for courses that go beyond the confines of the conventional classroom's current paradigm. Program curriculum must devise a solution to develop graduates who can provide businesses with more than simply technical expertise.

Literature Review

The aim of the First paper survey is to study the employment of graduates of the direction Construction for the period 2017-2018. The methods of systematic, logical and comparative analysis, the results of the public opinion survey on the employment of the graduates, the results of the authors 'own research on identifying employers' preferences and the needs of the construction industry in the region, taking into account the development of new technologies in construction, were used. The aspects are shown and the content of the curricula determining the priorities in the training of personnel for the construction industry in the region is disclosed. The indexes of employment of graduates analyzed as a criterion of the effectiveness of the activity of an educational institution. It is shown that practical orientation is an integral part of bachelors training, which is a special feature of the personnel training for the construction industry in the Kaliningrad region(Shershova, Nuzhina, & Kurochkin, 2018). The results of graduate's employment monitoring are published. Priority profiles of personnel training for the construction industry in the region have been underlined. A comparative analysis could become an important area of results application for fine tuning of territorial labor and employment policy techniques.

Second paper highlights about how construction is a dynamic industry that requires continuous focus on academic curriculum to meet the current workforce demands. Educational institutions that are responsible for developing undergraduate students require a strategic plan to adequately prepare future construction managers to be able to better manage the ever-increasing complexity of the construction industry. This paper investigates the most important skills that today's construction industry requires from graduating construction management students. This research examines a skill set determined by an initial preliminary survey. This skill set was then addressed through structured surveys sent to various industry stakeholders in order to identify the key skills desired by the industry from today's graduating construction management students. The significance of the study is it identifies the key knowledge areas; personal and professional attributes; skills; and expertise that academic curriculums in construction management programs need to focus on to adequately prepare graduating students entering today's modern and complex construction industry (Ahmed, Yaris, Farooqui, & Saqib, 2014). The study concludes that knowledge of health and safety regulations, interpreting contract documents, listening ability/ giving attention to details, knowledge of building codes and regulations, and time management are the five most important skills desirable in a new hire in construction management.

Third paper aims to assess the perception of the Ghanaian construction industry of the performance of entry-level building technology graduates (Ayarkwa, Dansoh, Adinyira, & Amoah, 2011). Also, other non-technical skills or attributes expected from building technology graduates are to be compared with the actual proficiency of the graduates.

In the fourth paper the industry experts who took part in this study selected the skills they believed students needed to succeed in the workplace and earn better starting salaries. strong attention on finishing projects. The literature as well as this study's findings demonstrated how important soft skills are to employers when hiring new employees. Many programs lack the flexibility to include formal opportunities for cultivating and refining students' soft skills due to restrictions on curriculum material (Short, Pearce, Fiori, Bulbul, & McCoy, 2014). Utilizing experiential learning opportunities, particularly involvement in an internship program, is one way to address this problem. Participating in internships would also give students a competitive advantage because practically all industry participants saw internship participation as work experience. Students that take part in internships get the chance to work alongside those in higher positions.

Malaysia is experiencing rapid development, as evidenced by the numerous construction projects that are now underway, particularly in the state of Johor, where the third quarter of 2016 had the largest value of construction work completed. This obviously calls for many skilled workers, particularly among the locals, as it has been stated that Malaysia's construction sector is experiencing issues due to a lack of locally available skilled labor. Additionally, it has been stated that the local labor force is unable to meet the demand of the building industry (Manap, Noh, & Syahrom, 2017). As a result, the contractor was forced to import foreign workers to meet the demands of the construction industry's labor market. This study has two goals: to identify the standards that construction companies use when hiring locally qualified laborers and to investigate the tactics that can entice local talent to work in the sector.

To accomplish the goals of this study, a questionnaire has been issued to G7 contractors in the state of Johor. The SPSS 20.0 software was used to assess the dependability of the collected data before it could be analyzed to determine the mean value, frequencies, and percentages. The findings of this study suggest that the potential employer wants to deal with men and that they are looking for individuals who are youthful, experienced, knowledgeable, and skillful.

Most of the tactics, such as wage increases, bonuses, allowances, and overtime compensation, as well as improving worker welfare and offering better housing, are mostly financial in nature. This study can serve as a reference for both contractors and skills institutions to improve where they fall short to attract locally trained skilled labor to the business (Oshoniyi, 2014; Rohini & Keerthikar, 2018).

In German-speaking nations, entry to apprenticeship training is particularly difficult for children of immigrants from non-EU countries (Imdorf, 2017). When employing new apprentices, how do recruiters at small and medium-sized businesses (SME) consider applicants' national and racial backgrounds? The theory of justification put out by Boltanski and Thévenot is suggested by the author as a way to conceptualize racial discrimination in hiring. As a result, the social body of a firm is made up of various interconnected "worlds" of social coordination and justification (industrial, household, and market). These worlds assert various personnel assessment principles, some of which penalize candidates of certain ethnic origins, to avoid organizational difficulties and to ensure the continued existence of the company. Empirically, the essay discusses the hiring of apprentices in Germany and Switzerland. It demonstrates that when recruiting school dropouts they see as foreigners, SME employers anticipate problems both domestically and in the company's market environment. Therefore, to minimize problems when employing apprentices, discriminatory criteria like ethnicity are exploited as symbolic.

The next study was conducted to comprehend the value of the hiring and selection procedures at construction firms. The company's websites, handouts, journals, books, and questionnaires were used to collect the data. External and internal selection processes are the two sources of recruiting. The internal selection procedure consists of a selection interview, a psychological exam, an ability test, an achievement test, an intelligence test, an aptitude test, and an aptitude test. The external selection procedure involves screening of the application form, selection tests and interviews, technical tests, group discussions, panel interviews, final interviews, medical examinations, and letters of appointment (Rohini & Keerthikar, 2018). Finding the Right Candidates, Candidate Competition, Speed, Misalignment, and Narrow Focus are further recruiting issues identified by the author. The author suggests job posting, training, background checks, including credit, educational, criminal, and reference checks, to boost the efficiency of hiring.

This another study intends to provide weighted ratings to evaluate how a student's performance and participation in different higher education activities affect their career prospects after graduation. This report highlights developments in the construction industry's employer demographics related to Career identity, personal flexibility, and social and human capital are the three characteristics that make up an individual and contribute to their employability. The results of this study demonstrate the value of students having some professional experience to enhance their career progress (Gomes, Celik, & Abraham, 2022). To improve their capacity to become successful construction managers, some practical understanding of the duties performed by personnel on-site may prove helpful. According to the author, employability is a conceived version of active, work-specific adaptability that helps employees to recognize and seize career possibilities (Imdorf, 2017). They might not realize how highly they appreciate the industrial experience they claim to be the deciding element in the recruiting process when they are presented with a resume that lists an outstanding number of academic accomplishments. Testing companies to determine if they adhere to their claims that experience is the primary factor in a fresh graduate's employability may prove fruitful.

The goal of this last study is to evaluate the most common hiring and hiring-selection methods used by construction organizations, as well as the most popular and successful sources for hiring and hiring-selection in the construction sector. This study employed a cross-sectional survey using a closed-ended questionnaire for the data gathering process. It also used the quantitative descriptive research approach(Dosumu et al., 2021). According to the study's findings, hiring well-known individuals, such as previous interns, internal applications, recommendations from educational institutions, and internal staff promotions are among the best ways to fill open positions in construction organizations.

Methodology:

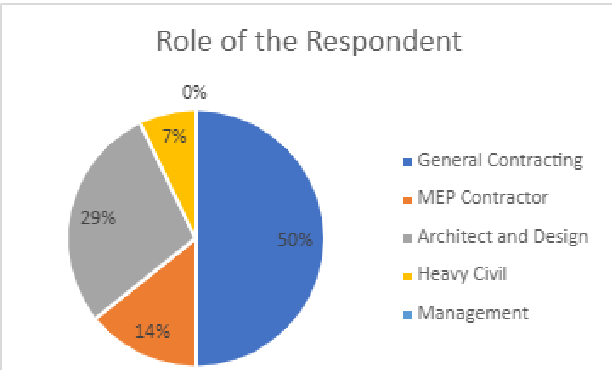
Given the research aimed to understand the numerous hiring factors a corporation uses when looking for young graduates is the goal of this study, they used a Literature Review and survey method as it could identify and determine the trends at the point of the study. The research used an online survey method as most have internet access, a likelihood of prompt responses. The general population of the study was US construction industry professionals working in construction companies possessing knowledge on the strategies used in their respective company. The online survey was generated in Qualtrics and consisted of both multiple-choice and open-ended questions. The survey consisted of three sections, including a) respondent demographics; b) Hiring factors. The survey questions were designed in such a manner that the respondents could complete the study within 10 minutes. After the generation of survey development, it is shared through Mail. The final number of respondents using the filter of complete responses was 20.

Survey Questionnaire:

1. What area of construction your company is specialized in?
2. How big is your company?
3. If a graduate student with a different discipline other than construction is applying for a job, how much experience is expected from them in the area of CM?
4. What are the skills that you prefer from a graduate student joining your team?
5. Level of the education that you acquire from someone to join your team in the CM Field?
6. What is your hiring cycles? How often do you give promotion?
7. What are the resources that you use for recruiting?
8. Is your company flexible to transfer employees from one department to another if they show interest?
9. What software do you use?
10. Do you sponsor work Visa?

Results and Discussion:

Below are the results of the survey conducted on Qualtrics



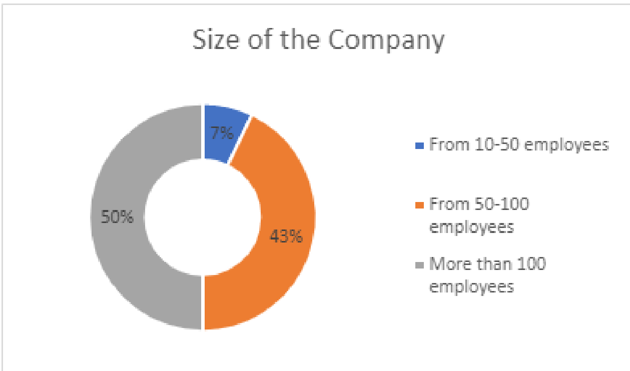
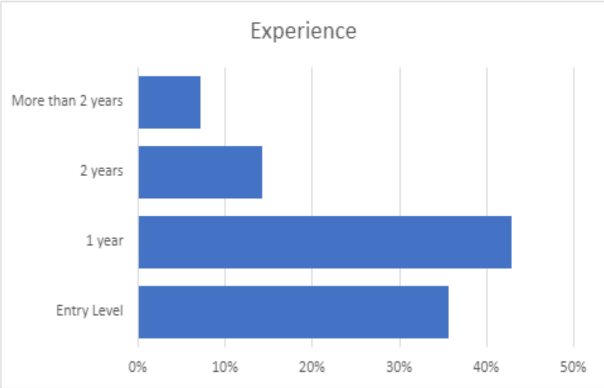


Fig 1: Role of Respondents

Fig 2: Size of the Company



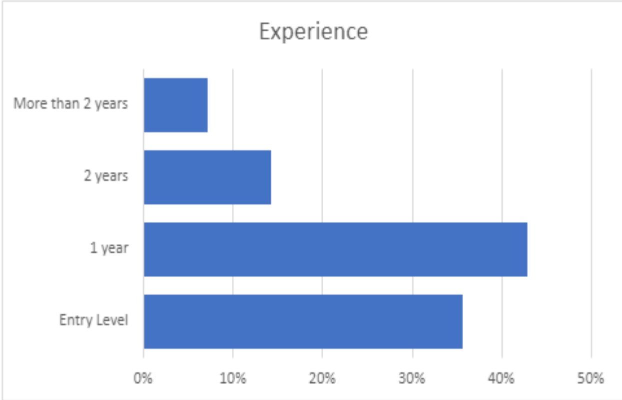
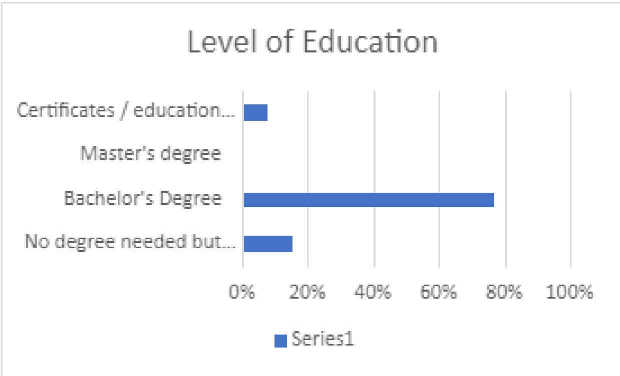


Fig 3: Experience expectations

Fig 4: Expertise of the Respondent



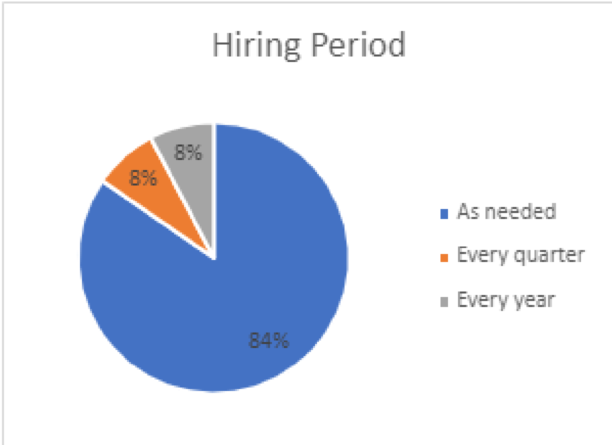
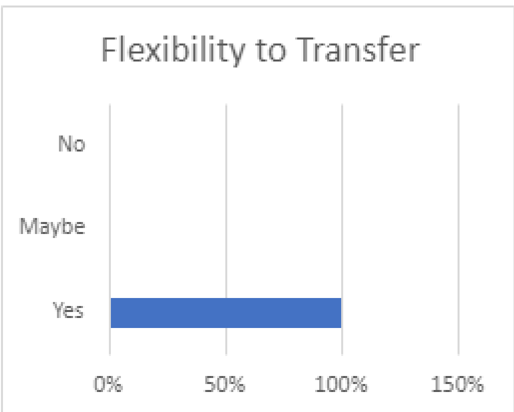


Fig 5: Level of Education requirements

Fig 6: Hiring Cycle of a company

Fig 7: Resources used for hiring

Fig 8: Promotions Offered



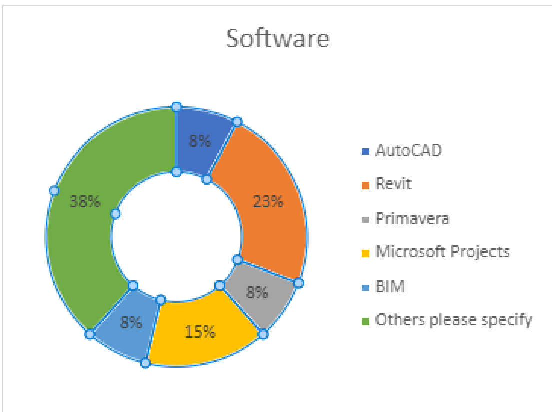


Fig 9: Flexibility to transfer Departments

Fig 10 : Software's used in Company

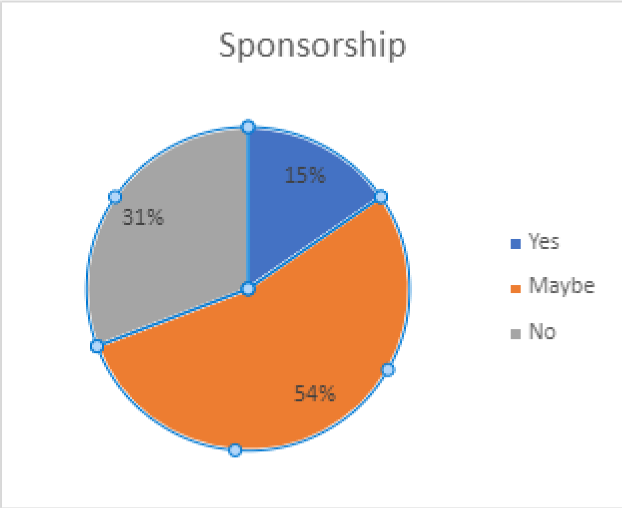


Fig 11: Sponsorships provided by Company

Conclusion:

The companies use different strategies for hiring the employees and the findings of the study show that Hiring is done whenever there is a need of an employee mostly through the career fairs and then the internets and websites. Coming to the promotions most of the companies offer whenever they are qualified after starting with a basic salary. Also, most of the companies provide the flexibility to transfer between the departments present in the country. Most software used by the construction companies in the US construction industry are Revit and the Microsoft projects. Coming to the sponsorship of the Visa for the international students, 50% of them provide for the employees.

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Exploring Income Inequality: Pathways of Explanation and Policy Responses

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Abstract

Income inequality has increased in developed economies over recent decades. This has been attributed to a number of factors, the importance of which varies according to the theoretical approach adopted. This article examines empirically these approaches and identifies the factors influencing the rise in inequality and, consequently, the policies to reduce it. We distinguish two main categorizations: a) mainstream approaches focusing on technology, education, growth, and globalization, and b) heterodox approaches focusing on financialization, labor market institutions, the public sector, and functional income distribution. By juxtaposing these approaches and using fixed effects models, we assess their explanatory power regarding the observed changes in inequality. The analysis covers the EU-15 countries for the period 1980-2020. The findings indicate that reducing inequality requires more than just educational policies aimed at limiting the skill premium driven by technology. Specifically, alternative policies could be implemented to strengthen labor market institutions, expand the public sector, and control financialization. These findings are significant for economic policy-making, as the literature frequently notes that rising inequality has contributed to the sluggish average growth rates observed in Europe over recent decades. This article contributes to the ongoing debate on finding effective policies to address inequality.

Keywords
income inequality, technology, education, labor market institutions, financialization, wage share

JEL classification codes
D31, D63

1. Introduction

In recent years, the issue of income inequality has been at the center of public discourse. This is due to its significant increase and the political impact it has caused, owing to the growing discontent among citizens. Furthermore, a series of studies show that the rise in inequality negatively affects growth rates, making the issue of inequality crucial not only from an ethical/political standpoint but also from a purely economic perspective. It is not coincidental, therefore, that a large number of studies in recent literature attempt to investigate the factors influencing inequality in order to find ways to reduce it.

However, this is not an easy task. The theoretical approaches attempting to explain inequality are not satisfactorily verified in empirical studies. Each one of them provides only a partial understanding of the factors that potentially influence this complex phenomenon. The dominant approach explains inequality based on differences in productivity, concluding that inequality is a “race between technology and education”. Based on this, it focuses on educational policies to reduce inequality. Other approaches, distinct from the previous ones, which fall under heterodox economics, focus on different factors, such as labor market institutions and financialization. According to these approaches, interventions are needed in both labor and financial markets. The purpose of this paper is to explore these approaches and examine the extent to which they interpret reality. The remainder of this paper is organized as follows: Section 2 provides a brief theoretical overview of the factors influencing inequality. Section 3 outlines the methodology, describes the data, and presents the econometric specifications employed. Section 4 reports the empirical results. Finally, Section 5 concludes the paper.

2. Literature Review

In this brief literature review, we present the key determinants of inequality. As different schools of thought focus on distinct factors, we will first discuss the determinants highlighted by mainstream economics and then expand our analysis to include those emphasized by heterodox economics.

Mainstream economics primarily focuses on technology, globalization, growth, and education. From the perspective of the dominant neoclassical school, technology is considered skill-biased (Acemoglou, 2002), favoring high-skilled workers, who are more productive, and significantly contributing to the rise in inequality. According to human capital theory, skills reflect individual preferences regarding the level of investment in education. The broader the diffusion of education across the population through educational systems, the more individual preferences are homogenized, thereby contributing to the reduction of inequalities (Mincer, 1958; 1974, Becker, 1967)

Globalization is reported to have differing effects on developed and developing countries. The primary theoretical framework for analysis is the Stolper-Samuelson theorem (Stolper and Samuelson, 1941), which posits that trade benefits the factor of production that is relatively abundant in each trading country. In developed countries, skilled labor is relatively abundant, while in developing countries, unskilled labor prevails. Consequently, globalization increases inequality in developed countries by widening the existing wage gap between skilled and unskilled labor.

Finally, within the neoclassical framework, economic growth is considered a reliable path to reducing inequality. This belief is rooted in the Kuznets curve and is reflected in trickle-down economics. The Kuznets curve (Kuznets, 1955) suggests that in the early stages of development, as workers transition to new sectors with greater wage disparities, inequality rises. However, as the economy reaches more advanced stages of development, inequality declines as the wealth generated is distributed across society. Similarly, trickle-down economics argues that the benefits of growth eventually spread throughout the entire society and are not confined to higher-income groups (Aghion and Bolton, 1997).

On the other hand, heterodox economics focuses on entirely different factors, primarily the functional income distribution, financialization, labor market institutions and public sector activity. Rooted in classical political economy, it places strong emphasis on class-based analysis. In this context, the functional income distribution is considered a key factor in rising inequality. The functional income distribution operates through various macroeconomic channels. In a typical post-Keynesian framework, an increase in the capital share reduces consumption, as the labor share has a relatively higher propensity to consume (Kaldor, 1955). Any positive effects of the capital share on investment fail to offset consumption losses, leading to a decline in aggregate demand, growth rates, employment, and ultimately, an increase in inequality. In the same vein, Dafermos and Papatheodorou (2015), incorporating firms' indebtedness into the aforementioned mechanisms, demonstrate that, in most cases, a rise in the labor share reduces inequality, even in the long run. Furthermore, it is often emphasized that an increase in the capital share exacerbates inequality, as capital income is more unevenly distributed than labor income (Piketty, 2014).

In these approaches, financialization is considered a decisive factor in increasing inequality. The focus on shareholder profitability not only raises the profit share but also elevates the managerial class (Dunhaupt, 2014), widening inequality within the labor force, as the (very high) income of managers is classified as labor income. Moreover, financialization enhances capital mobility, further expanding its income share (Lin and Tomaskovic-Devey, 2013).

Labor market institutions, such as trade unions, are also considered effective in reducing inequality. Trade unions play a dual role: they strengthen labor's bargaining power against capital and promote more equal wages within the workforce (Freeman, 1980), contributing to lower inequality through both channels. Similarly, the expansion of public sector employment has a comparable effect, as the public sector operates on a non-profit basis and standardizes employee wages by design (Hein, 2015).

At the empirical level, numerous studies support either mainstream or heterodox perspectives. Key contributions in the first category include studies by Barro (2000), the IMF (2007), and the OECD (2011). In the second category, representative works come from Dafermos and Papatheodorou (2013), Dunhaupt (2014), and Darcillon (2016).

3. Methodology, econometric specification, and data

In this section, we explore the factors influencing inequality, testing the hypotheses of the two main approaches outlined in the theoretical review. For this purpose, we apply two models. The first includes the factors emphasized by mainstream approaches, namely technology, globalization, education, and economic growth. The second includes the factors highlighted by heterodox approaches, namely the functional income distribution, globalization, labor market institutions, and public sector employment. Functions (1) and (2) describe the two approaches, respectively.

$$\text{inequality}^{\text{m}} = \text{f}(\text{technology}, \text{globalization}, \text{education}, \text{economic growth}) \quad (1)$$

$$\text{inequality}^{\text{h}} = \text{f}(\text{functional income distribution}, \text{globalization}, \text{labor market institutions}, \text{public sector employment}) \quad (2)$$

The scope of the study includes the EU-15 countries[93], for which sufficient long-

[93] EU-15 countries are: Austria, Belgium, Germany, Denmark, Spain, Finland, France, Greece, Ireland, Italy, Luxemburg, Netherlands, Portugal, Sweden, and the United

term data are available and which follow a relatively common trajectory within the framework of the European Union. The period under study is 1980-2020. Thus, our data form a panel dataset.

A common practice in the literature is to estimate panel data using fixed or random effects estimation methods. Both methods control for time-invariant, unobservable country-specific characteristics, although they make different assumptions regarding the correlation of these characteristics with the other variables in the model[94]. Although the countries we study are relatively homogeneous within the EU framework, it is reasonable to assume that each has some fixed, unique characteristics that affect the evolution of inequality. For this reason, we estimate both fixed and random effects models, while also including time fixed effects to account for potential common shocks, such as international economic crises, that affected the countries during these years. The choice, as the most appropriate model, between fixed and random effects model is based on an overidentifying restrictions test[95] which indicates that the random effects model is more suitable for the specification of function (1) (mainstream approach), while the fixed effects model better fits the specification of function (2) (heterodox approach). As a robustness check for our models, we also estimate the same models without time fixed effects. The equation to be estimated is equation (3):

$$\ln\left(\mathrm{inequality}_{i,t}\right) = c + \beta \ln\left(X_{i,t}\right) + \gamma_i + \delta_t + u_{i,t} \quad (3)$$

where i represents the countries under examination, t the years, c the constant term, X a vector of independent variables, β the vector of coefficients of the independent variables, γ the country-specific effects, δ the time fixed effects, and u the error term.

One issue worth noting is the choice of the inequality variable. Among the many available inequality indicators, the literature commonly selects the Gini index, which is more sensitive to changes in the middle of the income distribution. Following the literature, we select the Gini index as a measure of income inequality. The immediate question that arises is which income should be considered, pre- or post-tax and transfer payments (market income or disposable income)? To answer this question, we turn to identity (4):

$$\text{Disposable Gini} = \text{Market Gini} - \text{Redistribution} \quad (4)$$

Equation (4) is an identity, as redistribution is defined as the difference between the two Gini indices (market Gini minus disposable Gini) and shows the reduction in market Gini achieved through government redistributive intervention. Running the regression (4) (using log-transformed variables and the fixed effects

Kingdom.

[94] Fixed effects method assumes correlation while random effect method assumes no correlation between the time-invariant unobservable country-specific characteristics and the other regressors.

[95] The Hausman test is the most commonly used method for choosing between fixed and random effects models in specifications without robust standard errors. However, in the presence of robust standard errors, the Hausman test becomes inappropriate. Therefore, we rely on the alternative test of overidentifying restrictions. The fixed effects estimator uses the orthogonality conditions that the regressors are uncorrelated with the idiosyncratic error while the random effects estimator uses the additional orthogonality conditions that the regressors are uncorrelated with the group-specific error (the "random effect"). The overidentifying restriction test examines whether the data are consistent with the validity of these additional orthogonality conditions.

estimation method), and based on the resulting regression coefficients, we can calculate the contribution of market Gini and redistribution to the shaping of disposable Gini. From this exercise, it is found that 80% of the average annual change in disposable Gini in the EU-15 countries is attributed to the corresponding change in market Gini, and the remaining 20% is due to the average annual change in redistribution. Furthermore, we can reasonably assume that changes in redistribution are greatly influenced by social policy and government decisions regarding the size of taxes and social spending. Based on this, we focus our attention on the market Gini, which exerts by far the greatest impact on changes in the disposable Gini. In this way, we focus more on market forces, macroeconomic factors, and economic institutions that shape initial inequality, while abstracting from the government redistributive effects in the analysis.

The variables used and the sources of our data are as follows: for the Gini indices (market and disposable), the WID.world database. For technology and GDP per capita, we use the capital-to-labor ratio and the real GDP to population ratio from the Penn World Tables database. From the same source, we also obtain the income share of labor. For trade globalization, we use a corresponding index from the KOF Globalisation Index. The financialization variable is derived from the IMF's Financial Development Index Database. For education, we use the Barro and Lee (2013) database. The union density rate is obtained from the OECD/AIAS ICTWSS database. Finally, public employment data come from the Comparative Welfare States Dataset (Brady et al., 2020) and the OECD Government at a Glance 2021.

All variables are in logarithmic form. Finally, in all regressions, we employ Driscoll-Kraay standard errors, as the corresponding tests indicated the presence of cross-sectional dependence in our data.

4. Results

Equation (3) is examined within two distinct frameworks defined by functions (1) and (2). Regarding function (1), which represents the mainstream approaches, the results are presented in Table 1. Columns (1) and (2) display the fixed and random effects estimates, respectively, incorporating time fixed effects. A robustness check is conducted in columns (3) and (4), which present the same models without time fixed effects.

Table 1: Determinants of inequality – function (1)

	(1)	(2)	(3)	(4)
	Fixed effects	Random effects	Fixed effects	Random effects
Technology	0.076** 0.030	0.078** 0.029	0.057* 0.029	0.067** 0.032
Education	-0.060* 0.035	-0.073* 0.041	0.007 0.032	0.002 0.034
GDP per capita	0.028 0.019	0.015 0.018	0.074*** 0.019	0.070*** 0.018
Globalization	0.040** 0.017	0.032** 0.015	0.029* 0.017	0.027* 0.015
Constant	2.437***	2.602***	2.124***	2.069***

	0.315	0.320	0.273	0.307
Obs	600	600	600	600
Time dummies	yes	yes	no	no
R^2	0.46	0.16	0.39	0.02

Dependent variable: Market Gini. Reference period: 1980-2020. Countries: EU-15. Driscoll-Kraay std errors for cross sectional dependence. Symbols ***, **, * indicate 1%, 5%, and 10% significance level respectively.

Based on the results of the overidentifying restrictions test used to choose between fixed and random effects models, the model in column (2) appears to be the preferred specification. However, its explanatory power is relatively limited. Examining all columns, the most robust finding is the positive effect of technology on inequality. The same applies to globalization, which consistently shows a positive impact.

The effect of education is less definitive. While initial estimates that include time fixed effects suggest a statistically significant negative impact, this relationship reverses, and the statistical significance disappears when time fixed effects are excluded. This raises questions about the effectiveness of educational policies in reducing inequality.

In contrast, the findings concerning economic growth are clearer. Contrary to mainstream claims, growth does not reduce inequality. In fact, all coefficients are positive, and those in columns (3) and (4) are statistically significant, directly opposing mainstream narratives.

Overall, mainstream approaches explain only a small portion of inequality's variability, primarily through the effects of technology and globalization. There are some indications that education might serve as a balancing factor, but the evidence is weak. Finally, economic growth does not reduce inequality, making it difficult to translate "growth" in a purely economic sense into "development" from a socio-economic perspective.

Turning to heterodox approaches, equation (3) now reflects function (2), with the corresponding results presented in Table 2. As before, columns (1) and (2) display fixed and random effects estimates, respectively, including time fixed effects. A robustness check is conducted in columns (3) and (4), which use the same models without time fixed effects.

Table 2: Determinants of inequality – function (2)

	(1)	(2)	(3)	(4)
	Fixed effects	Random effects	Fixed effects	Random effects
Financialization	0.017** 0.007	0.015** 0.007	0.039*** 0.004	0.038*** 0.005
Union density	-0.023* 0.013	-0.025* 0.013	-0.052*** 0.012	-0.054*** 0.013
Public employment	-0.146*** 0.019	-0.136*** 0.017	-0.130*** 0.018	-0.120*** 0.016
Wage share	-0.121*** 0.025	-0.115*** 0.028	-0.183*** 0.038	-0.179*** 0.043
Constant	4.658*** 0.113	4.619*** 0.128	5.046*** 0.155	5.015*** 0.184

Obs	513	513	513	513
Time dummies	yes	yes	yes	yes
R^2	0.64	0.33	0.56	0.31

Dependent variable: Market Gini. Reference period: 1980-2020. Countries: EU-15. Driscoll-Kraay std errors for cross sectional dependence. Symbols ***, **, * indicate 1%, 5%, and 10% significance level respectively.

Based on the overidentifying restrictions test used to choose between fixed and random effects models, the preferred model is that of column (1), which also demonstrates the highest explanatory power. Regardless of the estimation method, Table 2 clearly highlights the effects of the explanatory variables. In all regressions, variables display expected signs: Financialization positively impacts inequality. Functional income distribution is significant, with labor's share negatively affecting inequality. Unionization and public sector employment also have negative effects on inequality. These findings remain robust even when time fixed effects are excluded.

Overall, heterodox approaches explain changes in inequality relatively well. The expansion of the financial sector and the decline in labor's share, observed in recent decades, have contributed significantly to rising inequality. Additionally, labor market institutions and the public sector have been increasingly targeted by policy measures. The empirical results suggest that such policies exacerbate inequality.

5. Conclusions

In this paper, we attempted to empirically examine the main theoretical approaches regarding the factors that have contributed to the rising trajectory of inequality in developed countries, specifically within the EU-15, since 1980. The study focuses on initial inequality, i.e., before state redistributive intervention, which constitutes the primary component of inequality in disposable income. We distinguished and categorized two major theoretical strands, summarized as mainstream and heterodox approaches.

The mainstream approaches shape public discourse and applied economic policy. According to these perspectives, inequality reflects differences in individuals' productivity, which depends on their skills and education. Technological change, according to this view, favors highly skilled workers and widens the wage gap they already have compared to others. This disparity, however, can be mitigated by the broader dissemination of education, which enhances skills across a larger share of the population. This perception is encapsulated in the well-known phrase "the race between technology and education." Similarly, globalization affects inequality in developed countries in a similar way.

This approach places individuals and their choices regarding education at the heart of the inequality narrative. Since the primary channel through which inequality is driven is technological progress—largely intertwined with human advancement—inequality is considered an inevitable outcome. The scope for policy intervention, therefore, is perceived as limited, primarily focusing on education. Other policy measures are deemed incapable of significantly reducing inequality. Worse still, according to this perspective, such interventions may have a negative impact on growth, potentially exacerbating inequality over time, since economic growth itself is seen as a potential factor for reducing disparities.

The findings of this study do not confirm the absoluteness of this view. Technology indeed increases inequality, and educational policies may contribute to its reduction, although the latter is debatable. However, the theoretical framework encapsulated in the phrase “race between technology and education” has limited explanatory power when juxtaposed with real-world data. Furthermore, the focus on pure economic growth cannot be seen as a viable solution for reducing inequality, as growth does not negatively affect inequality. This observation, already emphatically highlighted in Piketty's (2014) influential work, is empirically reaffirmed in our study.

The study’s findings suggest that heterodox approaches offer much more in explaining the persistent upward trend in inequality over recent decades, although they fall short of fully accounting for changes in inequality. According to these approaches, the rise in inequality is a result of policies implemented under the influence of the neoliberal paradigm. These policies have weakened labor protection institutions, facilitated the expansion of the financial sector, and led to a decline in labor’s share of income relative to capital. The findings of this study show that these factors indeed play a decisive role in driving inequality. In this sense, there is scope for reducing inequality by implementing policies that strengthen labor’s bargaining power and regulate the financial sector more effectively. Moreover, greater involvement of the state in economic activity could further contribute in this direction, as public employment tends to create more equalized remuneration structures.

These findings are particularly significant for economic policymaking. Their importance is not confined to mitigating the ethical issues arising from inequality but extends to its narrowly economic dimension. Increasingly, even within the mainstream framework, voices are being raised claiming that inequality hinders economic growth (OECD, 2015). In this sense, the continuation and deepening of the academic discourse on this issue could have a positive economic and social impact.

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Convergence of the Digital Economy in the Balkans

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Abstract
Temporal evolution of digitalization and its influence on the indicators of the real economy is of great interest. This paper examines the progress of the Information and Communication Activities (ICA) index and its contribution to the national Gross Domestic Product (GDP) regarding four Balkan countries. The methodology employed is time series analysis and more specifically Autoregressive Integrated Moving Average (ARIMA) models. Furthermore, this research forecasts the development of the ICA index in the future and examines the convergence of the digital sector among the employed countries. The outcomes claim a clear stable increase of the ICA index regarding Bulgaria and Romania and a flat progress or a possible slight growth regarding the Croatian ICA. These results demonstrate an increasingly higher contribution to the ICA to the national GDPs. On the contrary the Greek ICA seems to have a flat progress or a slight decrease mainly due to the financial crisis that the country faced. Finally, there is a high convergence of the digital index between Bulgaria and Romania, a slight one among Croatia and the other two Balkan countries and a divergence among Greece and the other Balkans.
Keywords: Digital Economy; Information and Communication Activities; Gross Domestic Product; Balkan countries; ARIMA models; Bivariate correlations

1. Introduction
One of the most important changes over the last decades is the transfer to a society based on the internet and digitalization (Limna et al. 2022). As a matter of facts, this daily use of the internet, Information Technology (IT) (both software and applications) and telecommunications over the last decades created a new economic aspect known as the “Digital Economy” (Wang 2022; Williams 2021).
The significance of the internet, telecommunications and digital economy is clearly recorded in the data. More specifically, in 2000 only 44% of the U.S. citizens were using the internet daily (Barefoot et al. 2018) while last year this proportion grew up to 91.8% (Statista 2024). Furthermore, in 2018 each U.S. citizen was spending on average 6.30 hours per day on the internet (Brynjolfsson and Collis 2019) and 8.40 hours per day in 2023 (Smart1marketing 2024). In 2023, the U.S. IT industry contributed to the national GDP and created more that 12.1 million job openings (Select USA 2024). The social websites “we are social” (We are social 2024) and “bank my cell” (Bank my cell 2024) claim that in 2024 there are 5.35 billion internet users and 7.21 billion active subscriptions for smartphones worldwide. Finally, the online product sales in 2020 reached the value of $14.4 trillion (Bulturbayevich and Jurayevich 2020).

While the increasing use of the internet and digitalization in everyday life and their contribution to the economy are recognized, their influence on official statistics remains undefined (Brynjolfsson and Collis 2019). This absence is mainly explained by the non-measurable cost of most digital products which in return does not affect classical economic indicators like Gross Domestic Product (GDP) (Brynjolfsson and Collis 2019). Considering all the above, the question arises about the real evolution of the digital economy and its influence on economic indicators. The aim of this paper is to fill this gap by examining the progress of the Information and Communication Activities (ICA) index and to forecast its future development within four Balkan countries. Finally, this research intends to evaluate the contribution of digitalization to national GDPs and the convergence of the digital index among the countries.
More specifically, this research investigates the evolution of the digital economy in four Balkan countries: Bulgaria, Croatia, Greece and Romania. The selection of these countries was based on the geographical location as they all belong in the Balkan Peninsula and the quantity and quality of data. The under-examination period extends from 1995 to 2022. The paper employs time series and more specifically Autoregressive Integrated Moving Average (ARIMA) models (Chatfield 2003) to process the data. All the necessary data is downloaded from the official website of Eurostat (Eurostat 2024) and processed by the R 4.4.1 software (R Core Team 2024). Regarding the future development of the ICA index from 2023 to 2027, this study employs the forecast package for R (Hyndman et al. 2024). The ICA index considers the proportion of digital activities (like computer manufacturing, telecommunications, electronical and optical products, software, information services and programming) as a percentage of total GDP. The main conclusions support that there is stable growth regarding the ICA index and digital convergence among most of the countries.
This research contributes to academic background as it offers an understanding regarding the impact of digitalization on economic indicators. This investigation is accomplished by focusing on the ICA index across four Balkan countries. More specifically, this paper is an initial attempt to examine the impact of digital economy in the Balkans while most of the studies employ as under-examination countries U.S.A. and China (Barefoot et al. 2018; Collis 2020; Wen and Wang 2024). Furthermore, this research introduces methodologies to forecast the future progress of the ICA index, and it uses bivariate correlations to investigate the digital convergence among the countries. Finally, it must be mentioned that the ICA index is a non-widely used measure of digitalization which has been employed in only a few researches so far (Fernandez-Portillo et al. 2020; Magoutas et al. 2024; Tsachtsiris et al. 2022). However, it provides a comprehensive aspect on how digitalization contributes to national economies.
The structure of this study is as follows: the following part presents the definitions and methods of measuring the digital economy. Moreover, it states the connection between digitalization and national GDPs so far. The third chapter presents the data and the employed methodology while the next section refers to the results. Moreover, the fifth part presents the conclusions and the discussions of the research. Finally, the last chapter shows the employed references.

2. Literature Review

2.1. Definitions and methods of measuring Digital Economy

Digital Economy is based on technological progress. As technology evolves, so does digitalization. As a matter of fact, due to technological evolution, digital economy is a dynamic variable which has many definitions over time (Bukht and Heeks 2017). The primary definitions were connecting digital economy with the broad concept of the internet (Tapscott 1996; Lane 1999). However, the most recent and complex definitions claim that digitalization consists of many pillars like the digital infrastructure (hardware and software), e-commerce, digital media, innovations and process optimization (Barefoot et al. 2018; Sakawa 2020).

As there are many definitions regarding the digital economy it is reasonable that there are also various ways to quantify digitalization. The measurement of digitalization is a challenging process due to the digital products and services which have a non-measurable cost (Brynjolfsson and Collis 2019). One of the most common measurements of digital economy is the Information and Communication Technologies (ICT) (Barefoot et al. 2018). The ICT sector considers activities related to computer manufacturing, programming, telecommunications, software, information services, electronic and optical products (Bukht and Heeks 2017).

The European Union employs another measure to quantify digitalization. This measure is called Digital Economy and Society Index (DESI) (European Commission 2024). This index measures the digital performance of a European country in comparison with the digital sector of other European countries. It considers four pillars: how familiar the human capital is with digitalization, connectivity, digital integration and digital public services.

2.2. Digitalization and national Gross Domestic Products

Digital economy based on information and communication technologies has emerged as one of the most important development factors regarding the national economies worldwide (Oloyede et al. 2023). The development of digital economy and information and communication technologies has a lasting and long-term impact on the evolution of the economy (Mattalia 2013). As a matter of fact, the countries must take advantage of the opportunities that arise from the digital economy (Limna et al. 2022).

The positive connection between digital economy and national economic progress is reported in recent studies. However, the digital infrastructure of each country affects significantly the influence of digitalization on national macroeconomic indicators (Tayibnapis et al. 2018). The already developed countries argue that the digitalization of the national economy has a primary role in their agendas (Mahmudov and Mullabayev 2020). On the other hand, the impact of digitalization on the national economies is supposed to be reduced to approximately one-third to one-half in the emerging countries compared to the developed ones (Bukht and Heeks 2017). More precisely the internet is estimated to constitute approximately 20% of the GDP of developed countries, 10% of the GDP of BRICs (Brazil, Russia, India, China) and only 5% of other developing counties GDP (Manyika and Roxburgh 2011). Moreover, the digital economy is recorded to contribute by 5.5% to the total GDP of developing countries, 4.9% of China’s GDP and 6% of Russia’s GDP (Borremans et al. 2018). In a global level the digital economy contributes around 5% of the global GDP (Bukht and Heeks 2017; Williams 2021). In other papers, pillars of the digital economy like the “Internet Economy”, the mobile sector and the “Collaborative Economy” are estimated to contribute by 3%, 1.5% and 0.002% to the global GDP respectively (Rausas et al. 2011; Manyika et al. 2013; Petropoulos 2017). Furthermore, there

are estimations that in 2019 e-commerce constituted 30% of global GDP which is equivalent to $26.7 trillion (UNCTAD 2021).
Regarding the U.S. digital economy, it is estimated that it has contributed by 6.5% to the U.S. GDP in 2016, which is equal to $1.209,2 billion (Barefoot et al. 2018). Facebook, on its own, is estimated to contribute to the U.S. GDP by 0.11% on average annually from 2004 to 2017 (Collis 2020). In the developed European countries, the development of the digital economy contributes to the increase of GDP (Fernandez-Portillo et al. 2020). A 10% increase in the growth rate of investments in information and communication technologies would develop the European GDP by 0.92% on average (Tsachtsiris et al. 2022). In the case of Chinese province of Zhejiang, a 1% increase in the level of digital economy results on a 0.4694% in the level of high-quality economic development (Wen and Wang 2024). The investment in the Indonesian digital sector contributes to the growth of the country's economy by 0.048% (Barata 2019).
The connection between digitalization and GDPs becomes increasingly important mainly due to virtual environments, such as the metaverse, which are still in primary stages (Dwivedi et al. 2022). Consequently, the digital economy and innovations can be used as development strategies (Magoutas et al. 2024).

3. Data and methodology

This paper employs four Balkan counties: Bulgaria, Croatia, Greece and Romania. The selection of the above countries was based on two main criteria. The first one is the geographical location of the above-mentioned countries as they are established in the Balkan Peninsula along with Albania, Bosnia & Herzegovina, Serbia, Kosovo, Montenegro and North Macedonia. The second criterion is based on the data availability of the countries as only Bulgaria, Croatia, Greece and Romania have the necessary quantity and quality of data. The under-examination period extends from 1995 to 2022. "National accounts aggregates by Information and Communication Activities" is the employed variable. ICA counts the proportion of activities related to digital economy such as telecommunications, information service activities, computer programming, publishing activities and consultancy as a percentage of total GDP. Consequently, the unit of measure is the percentage of total. All the necessary data are provided by the website of Eurostat (Eurostat 2024). More precisely, on the above-mentioned website, "National accounts aggregates by industry (up to NACE)" is the variable selected while in the frame of "Geopolitical entity" the four Balkan counties "Bulgaria, Croatia, Greece and Romania" are chosen. The "Time" frame is filled with the years from 1995 to 2022, and the "Percentage of total" fills the "Unit of measure" filed. Moreover, the field of "Statistical classification of economic activities in the European Community" is filled by the "Information and communication" industry while the "Value added, gross" is selected in the "National accounts indicator" frame. The data selected were processed for further processing while R software was employed for graphics and statistical results (R Core Team 2024). The methodology employed is time series analysis and specifically the ARIMA models.

4. Results

This section presents the results of this research. The first subsection shows the descriptive statistics while the second part demonstrates the predictive models used.

4.1. Descriptive Statistics

This subsection demonstrates the descriptive statists of the time series. More precisely the next figure shows the time series plots for each Balkan country employed.

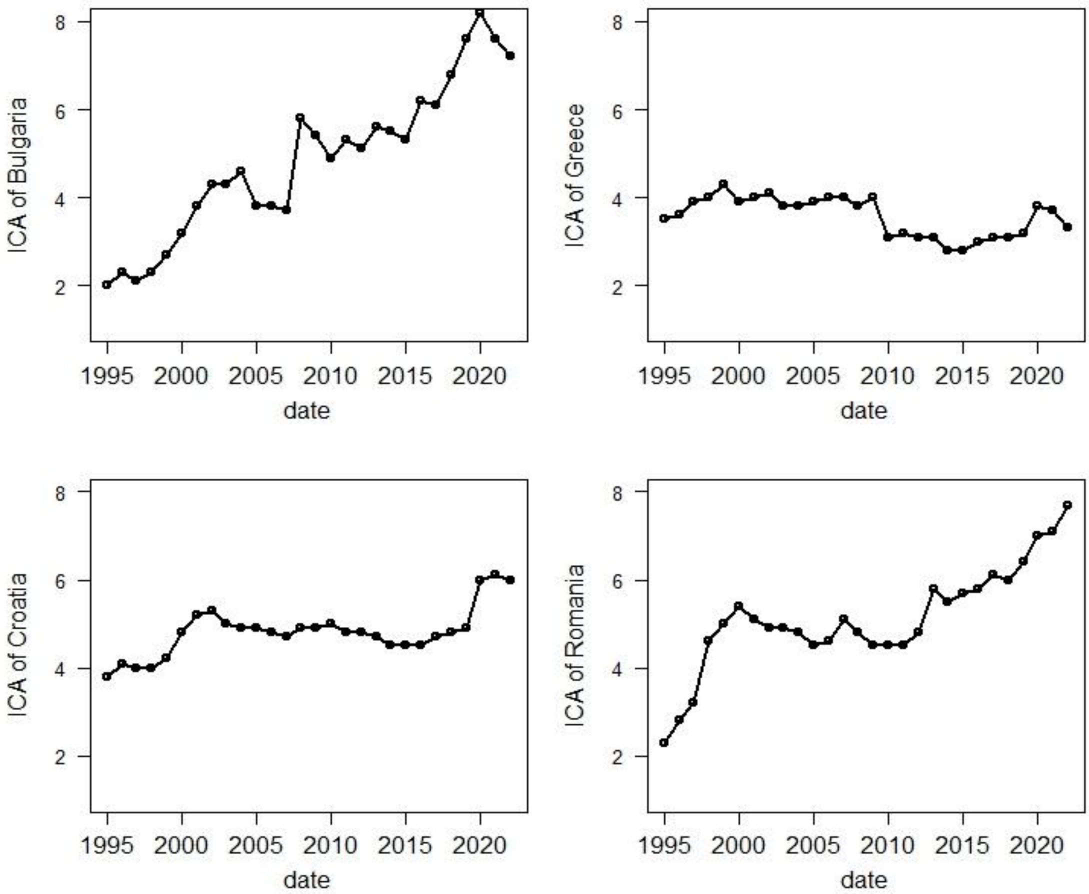

Figure 1. Time series plots of the ICA indexes for Bulgaria, Croatia, Greece and Romania.

The outcomes present a similar evolution of the ICA index for Bulgaria and Romania which have the steepest increasing trends over time and the highest ICA values among the countries. More precisely, the maximum ICA value of Bulgaria reaches up to 8.20% in 2020 while, regarding Romania, the highest value is up to 7.70% in 2022. Croatia seems to have a flat progress for most of the under-examination period followed by a great growth from 2020 and on. During that year Croatia's ICA is equal to 6.0%. Finally, the ICA of Greece has a slight decline over time. Its value fluctuates from 2.80% in 2014 and 2015 to 4.30% in 1999. The serious financial crisis that the country faced from 2010 and on has probably affected the evolution of the digital sector. Figure 2 demonstrates the box plots of each country. It is clear the Bulgaria and Romania have the greatest development of the ICA index. Furthermore, according to Figure 2, Croatia has the lowest interquartile range among the countries as the value of the ICA fluctuates around 5% for most of the years. However, Croatia's box plot has greater values than the Greek box plot in general. It should be mentioned that the median of Croatia's ICA is equal to 4.80% while the Greek median is up to 3.75%.

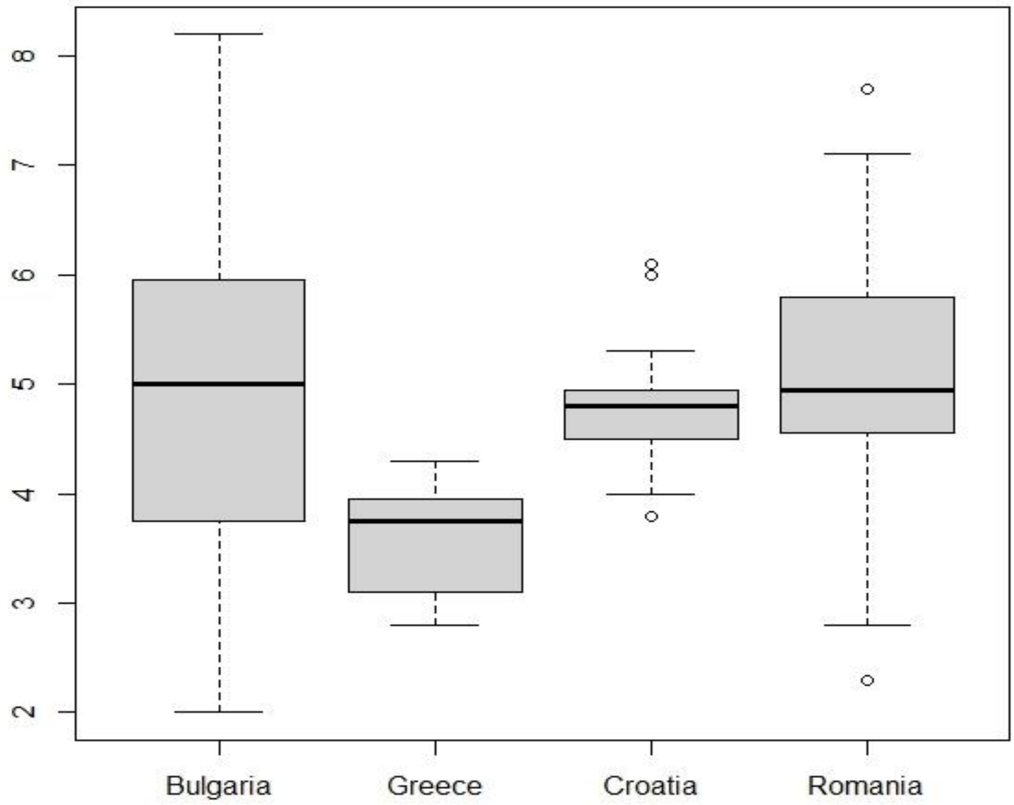

Figure 2. Box plots of the ICA index for Bulgaria, Croatia, Greece and Romania.

4.2. Predictive Models

To model the ICA index times series and to forecast the future evolution of the index ARIMA (p, d, q) models are employed (Chatfield 2003; Chatfield and Xing 2019). The Akaike's Information Criterion (AIC) (Hyndman and Khandakar 2008) is employed to identify the parameters p, d, q which minimize the AIC value. As shown in Figure 1 there is a lack of stationarity and a presence of a trend without a constant mean over time regarding the ICA indexes especially for Bulgaria and Romania. Furthermore, Figure 3 presents the declining values of the autocorrelation function (ACF) of the countries' time series which indicates non-stationary characteristics. To check whether the data of each entity is stationary or non-stationary Dickey-Fuller test (Dickey and Fuller 1979) is used. The p-values of all the Balkan countries are greater than 5% which demonstrates that all the time series are non-stationary. Table 1 presents the results of the Augmented Dickey-Fuller test.

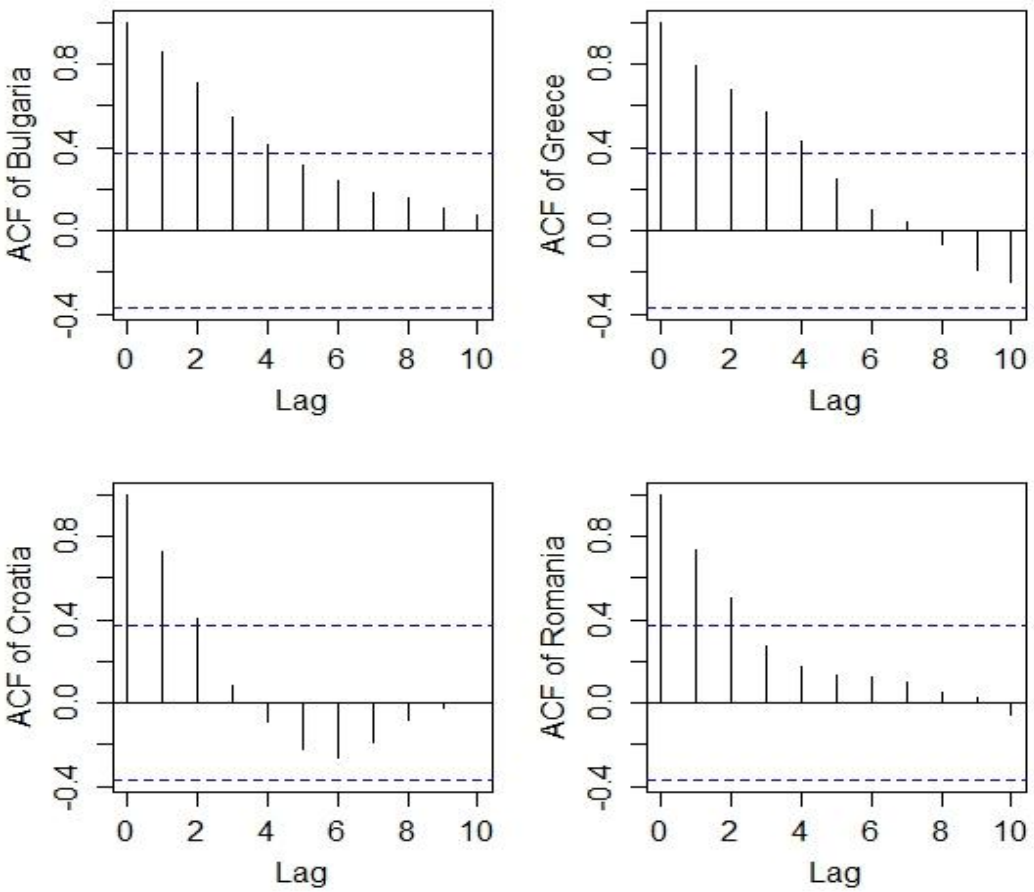

Figure 3. Correlograms of the ICA index for Bulgaria, Croatia, Greece and Romania.

Table 1. Results of the Augmented Dickey-Fuller test (lag order = 3).

Country	Dickey-Fuller statistic	p Value
Bulgaria	-3.0493	0.1711
Greece	-1.9200	0.6100
Croatia	-2.6294	0.3318
Romania	-1.2740	0.8503

Figure 4 indicates the evolution of the ICA over time and presents the forecasts of the index from 2023 to 2027. The forecast package (Hyndman et al. 2024) is used to predict future values. For each country the black lines indicate the raw data, the red circles show the fitted data while the gray areas reflect the forecasts of ICA. To fit the ARIMA models and to forecast the ICA values of the countries from 2023 to 2027 with a 95% confidence level the forecast R package was employed.

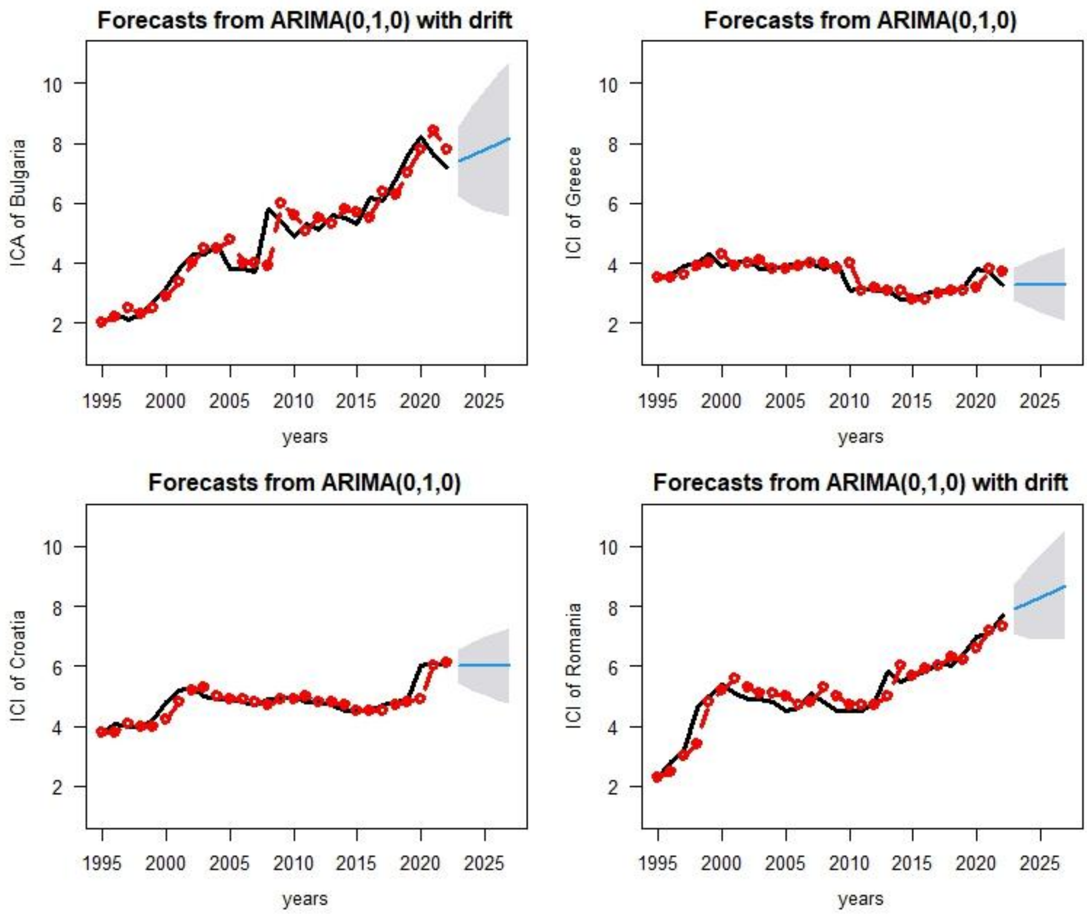

Figure 4. ARIMA fitted models and forecasts of the ICA index from 2023 to 2027 for Bulgaria, Croatia, Greece and Romania.

As demonstrated in the above figure Bulgaria and Romania continue to have upward trends during the years of forecasts. More specifically, as quoted in Table 2, which presents the forecasts for all the Balkan countries, ICA forecasts for 2027 regarding Bulgaria and Romania are 8.16% and 8.70% respectively. These estimates demonstrate that the activities related to digital economy are expected to exceed by far the proportion of 8% of the national GDPs. For these two Balkan countries digitalization can be used as a development strategy for their national economies if we consider that approximately in the early 2000s the value of the index did not even exceed 4% regarding Bulgaria and 5% regarding Romania. On the other hand, the general stable evolution of Croatia's ICA index during the under-examination period affects the future values of the variable which are more likely to remain constant or to increase slightly from 2023 and on. The estimates claim that the value of Croatia's ICA index will equal to 6%. In comparison to the past values of the index there seems to be also a slight increase. Finally, the forecasts regarding Greek's ICA will be equal to 3.30% for all the forecasting years. Once again, the slightly decreasing value that dominates from 1995 to 2022 seems to have affected the predictions regarding the country. It should be mentioned that these predictions are even lower than the values that the Greek ICA index had during the decade 2000-2010.

Table 2. ICA forecasts for Bulgaria, Croatia, Greece and Romania.

Country	Year	Lo 95	Average	Hi 95
Bulgaria	2023	6.2344	7.3925	8.5507
	2024	5.9472	7.5851	9.2230
	2025	5.7717	7.7777	9.7837
	2026	5.6540	7.9703	10.2866
	2027	5.5732	8.1629	10.7526
Croatia	2023	5.4379	6.0000	6.5620
	2024	5.2051	6.0000	6.7948
	2025	5.0265	6.0000	6.9734
	2026	4.8759	6.0000	7.1240
	2027	4.7433	6.0000	7.2566
Greece	2023	2.7560	3.3000	3.8440
	2024	2.5306	3.3000	4.0693
	2025	2.3577	3.3000	4.2422
	2026	2.2119	3.3000	4.3880
	2027	2.0835	3.3000	4.5164
Romania	2023	7.0846	7.9000	8.7153
	2024	6.9468	8.1000	9.2531
	2025	6.8876	8.3000	9.7123
	2026	6.8692	8.5000	10.1307
	2027	6.8767	8.7000	10.5232

Ljung-Box tests (Ljung and Box 1978; Hassani and Yeganegi 2020) are employed for validating the quality of the fitted and the forecasting models based on residual analysis. The p-values of all the under-examination countries are above 5% with a lag of five time periods. This means that the null hypothesis that the residuals are independently distributed cannot be rejected. Consequently, there is no autocorrelation among the residuals. More specifically, the p-values of Bulgaria, Croatia, Greece and Romania are 0.7072, 0.8894, 0.9404 and 0.7385 respectively.

Figure 5 presents the bivariate correlations of the countries' ICA evolution over time.

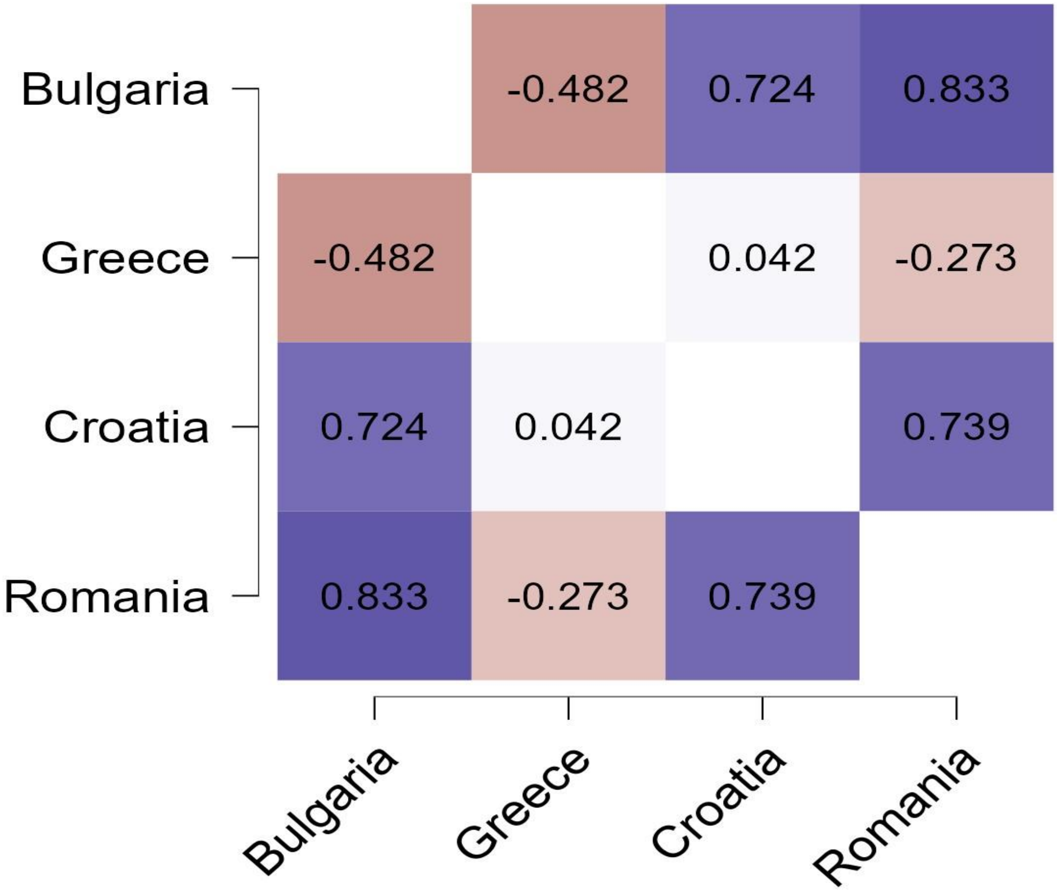

Figure 5. Bivariate correlations of the ICA index for Bulgaria, Croatia, Greece and Romania.

The above figure indicates the strong positive bivariate correlation regarding the evolution of the ICA index for Bulgaria and Romania as the bivariate correlation coefficient is equal to 0.833. Moreover, the evolution of Croatia's ICA index seems also to have a positive relation with Bulgaria and Romania as the bivariate correlation coefficients are 0.724 and 0.739 respectively. In contrast with the other three Balkan countries which have positive bivariate correlation regarding the evolution of ICA, Greece demonstrates insignificant or even negative bivariate correlations with them. More specifically, the bivariate coefficient between the Greek and Croatia's ICA is equal to 0.042. Furthermore, Greece's ICA seems to have negative bivariate correlations with Bulgaria and Romania as the bivariate coefficients are equal to -0.482 and -0.273 respectively. In conclusion there is a strong convergence regarding the evolution of the Bulgarian and Romania ICA index. However, the Croatian index does not achieve the same convergence with the other two Balkan countries. On the contrary, the Greek ICA index shows a clear divergence with the Bulgarian and Romanian index as due to the serious Greek financial crisis which has clearly affected the development of the digital sector.

5. Discussion and Conclusions

Over the last decades more and more countries consider the digital economy as one of the most important development pillars. However, there is a lack of researches on how the digital economy affects the official economic indicators. Moreover, regarding the already existing papers the vast majority of them examine on the impact of digitalization on the U.S. and Chinese economy (Barefoot et al. 2018; Collis 2020; Wen and Wang 2024). As a matter of facts, the purpose of this paper is to address this gap by examining the evolution of the ICA in four Balkan countries (Bulgaria, Croatia, Greece, Romania). This paper contributes significantly to the academic field it examines the digital economy's impact on GDP regarding the Balkans. Moreover, the research forecasts the progress of the ICA in the future, and it compares its evolution among the countries. Most of the recent studies employ one pillar of digitalization like "Internet Economy", mobile sector, "Collaborative Economy", e-commerce or Facebook (Rausas et al. 2011; Manyika et al. 2013; Petropoulos 2017; UNCTAD 2021; Collis 2020). ICA is a non-widely used index which counts the proportion of the digital activities as a percentage of total GDP. This index provides a comprehensive aspect of how digitalization contributes to national economies.

The outcomes of the study indicate a clear increase in the value of ICA regarding Bulgaria and Romania. On the other hand, Croatia seems to have a flat progress for most of the time period examined followed by a great growth from 2020 and on. Finally, the serious financial crisis that Greece has faced from 2010 and on seems to have affected the evolution of the digital economy as the Greek ICA demonstrates a slight decline over time.

The predictions have the same progress for all the countries as the time period from 1995 to 2022. More specifically, Bulgaria and Romania continue to present an increasing trend during the forecasting period. This fact indicates that regarding Bulgaria and Romania there is an increasingly higher contribution of the ICA to the national GDP. Consequently, digitalization can lead to national economic growth for these two Balkan countries. These outcomes are aligned with previous researches which support the positive effect of digital economy on national GDPs (Barata 2019; Barefoot et al. 2018; Bukht and Heeks 2017; Collis 2020; Fernandez-Portillo et al. 2020; Tsachtsiris et al. 2022; Wen and Wang 2024). It is crucial to mention that regarding Bulgaria and Romania the predictions estimate that the proportion of ICA indexes will exceed by far the 8% of the national GDPs in 2027. At this point it should be kept in mind that both Bulgaria and Romania have among the lowest scores regarding the DESI index which records the digital performance of the members of European Union. Consequently, the contribution of the ICA index to the total GDP of countries with higher ranking in the DESI index may be greater than the corresponding values of the two Balkan countries. Croatia's ICA forecasts remain stable as the index did for most of the under-examination years. Finally, the Greek ICA demonstrates a stable evolution in the future with values lower than those during the decade 2000-2010. Especially in case of Greece there is an urgent need for decisions that will contribute to the growth of the digital sector and will eliminate potential risks.

Finally, the bivariate correlations confirm the above results as they indicate positive relations among Bulgaria, Croatia and Romania. These bivariate correlations are based on the upward trend that Bulgaria and Romania have in most of the under-examination period and the great growth in Croatia's ICA index from 2020 and on. On the contrary, the negative bivariate correlations of the Greek ICA with the Bulgarian and Romanian ICAs confirm the opposite declining

evolution of the Greek index in comparison with the other two Balkan countries. The implications of this research try to verify whether or not these four Balkan countries have exploited the most of the advantages of the digital economy in order to use digitalization as development strategy of their national economies. It can be concluded that Bulgarian and Romanian governments could prioritize the digital sector to enhance economic growth. In case of Croatia this slight increase in the ICA should be supported by further measures. Finally, the Greek government has to take hard decisions and to make targeted efforts to stabilize and support the development of the country's digital economy.
The limitations of this research are that, regarding the Balkans, only these four countries have available data and that the paper employes only one digital index. As a matter of facts, future research could employ more digital variables to investigate the progress of digitalization. Finally, the effect of digital economy on more aspects of the national economy like productivity, employment and disposable income would be an interesting field to explore.

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