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Economic Development and Growth

Foundations and Frontiers

*Edited by Pantelis C. Kostis, Paraskevi Boufounou
and Theodoros Papadogonas*



Economic Development and Growth - Foundations and Frontiers

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Aims and Scope of the Series

This series will provide a comprehensive overview of recent research trends in business and management, economics, and marketing. Topics will include asset liability management, financial consequences of the financial crisis and covid-19, financial accounting, mergers and acquisitions, management accounting, SMEs, financial markets, corporate finance and governance, managerial technology and innovation, resource management and sustainable development, social entrepreneurship, corporate responsibility, ethics and accountability, microeconomics, labour economics, macroeconomics, public economics, financial economics, econometrics, direct marketing, creative marketing, internet marketing, market planning and forecasting, brand management, market segmentation and targeting and other topics under business and management. This book series will focus on various aspects of business and management whose in-depth understanding is critical for business and company management to function effectively during this uncertain time of financial crisis, Covid-19 pandemic, and military activity in Europe.

Meet the Series Editor



Prof. Choudhry holds a BSc degree in Economics from the University of Iowa, as well as a Masters and Ph.D. in Applied Economics from Clemson University, USA. In January 2006, he became a Professor of Finance at the University of Southampton Business School. He was previously a Professor of Finance at the University of Bradford Management School. He has over 80 articles published in international finance and economics journals. His research interests and specialties include financial econometrics, financial economics, international economics and finance, housing markets, financial markets, among others.

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Preface

Economic development and growth have always been central in economic science, as evidenced by the last two Nobel Prizes in Economic Science. In 2024, Daron Acemoglu, Simon Johnson, and James A. Robinson were honored “for their studies of how institutions impact the path of prosperity for nations”. Their work has advanced our understanding of why some nations achieve long-lasting development and growth, and others remain stuck in underdevelopment. Moreover, in 2025, the Nobel Prize was awarded to Joel Mokyr, Philippe Aghion, and Peter Howitt “*for having explained how advances in technology can drive a sustained process of economic growth*”, based on the fact that long-term prosperity is about technological progress and creative destruction. In combination, these revolutionary works reaffirm the twin cornerstones of development and growth, effective institutions and constant innovation, which are the theoretical basis for this volume.

This edited volume, entitled *Economic Development and Growth – Foundations and Frontiers*, reflects a diverse array of perspectives on how economic development and growth may be facilitated. The book offers a theoretical analysis and empirical evidence, along with country and regional perspectives, to enrich our understanding of the patterns and determinants of sustainable development and growth. It seeks to bridge the developing theory and the emerging realities of the 21st century, with a focus on topics such as innovation, inclusiveness, digitalization, and green transition.

The book consists of five major sections that cover distinct but interrelated elements of economic development and growth:

The first section, entitled “Foundations of Economic Development and Growth”, lays the theoretical groundwork for understanding the key determinants of economic performance. Chapter 1, “Why Some Places Do Better in Economic Growth and Other Do Not? Entrepreneurial Difference: An Essay”, by David Audretsch and Maksim Belitski, provides a comprehensive overview of current scientific knowledge on entrepreneurship and innovation, as well as the impact of entrepreneurship on regional development and growth. Chapter 2, “Analyzing the Megacycles of the Economy”, by Ioanna Atsalaki and George Atsalakis, illustrates key megacycle data, demonstrating that this information not only provides a holistic view of the evidence but also offers insights into policy-making, enabling more prudent investment decisions. Chapter 3, “Reasons for Change in Personal Income by Country in the Twenty-First Century and Evaluations of OECD Countries” by Ahmet Yüzbaşıoğlu, examines income dynamics and structural changes within advanced economies.

The second section, entitled “Inclusion, Inequality, and Human Development” addresses the human and social dimensions of development. Chapter 4, “Information Literacy Model for Economic Development” by Mijo Knezović and Tihana Babić, introduces an integrated model of knowledge and information literacy outcomes in

development. Chapter 5, “Assessing Financial Inclusion Progress in Nigeria: Exclusion Gaps, Policy Strategies, and Implications”, by Olayinka Adegbite, reviews policy initiatives and progress towards inclusive finance in one of Africa’s largest economies. Chapter 6, “Macroeconomic Performance and Its Influence on Education, Investment, and Economic Growth in Sub-Saharan Africa” by Isaac Abekah-Koomson, Eugene Chinweokwu Nwaba, Chatief Kunjaya, Abdul Ghofar, and Kwame Asante, extends the connection between macroeconomic stability and education investment among developing countries.

The third section, entitled “Finance, Innovation, and Growth Dynamics”, explores how financial systems, innovation, and investment interact to shape growth trajectories. Chapter 7, “Finance, Innovation, and Growth” by Danmo Lin, revisits the traditional link between financial development and technological change. Chapter 8, “Evaluating Alternative Creative Accounting Mining Techniques: Empirical Evidence from Greece” by Kanellos Toudas, Paraskevi Boufounou, Dimitra Tsogka, Konstantinos Kollias, and Marios Tsakas, explores the consequences that accountancy practices may have on financial transparency and economic productivity. Chapter 9, “Carbon Finance: Empowering Carbon Emission Reduction with the Power of Finance” by Xiaojing Yi, showcases how new financial approaches can expedite the transition to low-carbon world economies. Chapter 10, “The New Silk Route for Chinese Foreign Investment” by Adelina Quintero Sanchez and Pastora Melgar Manzanilla, discusses China’s outward investment strategies and their influence on global growth patterns.

The fourth section, entitled “The Digital and Sustainable Transformation Frontier”, looks to the future of growth in the digital and green eras. Chapter 11, “The Age of Twin Transition: The Case of MENA and Turkey” by Canan Ozkan, Yusuf Yildirim, and Abdullah Sultan Al Shammre, emphasizes how digitalization meets with sustainability in reshaping economic systems. Chapter 12, “Unlocking Economic Growth: Digital Customer Experience in Grocery Retail – From Traditional via Unmanned to Humanized Unmanned Supermarkets” by Simon Georg Fauser, Marco Schmäh, Svend Hollensen, Anna Marie Dyhr Ulrich, and Susanne Gretzinger, demonstrates how digital innovation can significantly transform the retail landscape and consumer behavior.

Finally, the fifth section, entitled “Regional and Sectoral Perspectives”, provides comparative analyses across specific countries and industries. Chapter 13, “Critical Factors Influencing Economic Growth: A Case Study of Vietnam” by Lu Phi Nga and Phan Thanh Tam, highlights critical policy and structural determinants of sustainable growth in Vietnam. Chapter 14, “The Impact of Trade Openness on Economic Growth in Rwanda: An Empirical Analysis” by Mutemberezi Fidele, Habumugisha Placide, and Ngomije Tete Flora revisits the role of openness in small developing economies like Rwanda. Chapter 15, “Impact of Climate Change on Agriculture in Sub-Saharan Africa: Quantification of Price Bias in Econometric Approaches” by Jérôme Verny, Ouail Oulmakki, and Youssef Bouazizi, considers how climate variability is affecting agricultural productivity. Chapter 16, “COVID-19 Mortality Rate Variability Linked to Healthcare Expenditures in European Countries” by Bilal Kargi and Bekir Cihan Uçkaç, examines the relationship between healthcare investment and resilience in various European economies.

In total, the chapters of this volume provide a mosaic for economic development and growth in the 21st century, one that richly incorporates crucial aspects, such as institutions, innovation, equality, and sustainability, into an interrelated development and growth policy approach. This book serves as a validation of existing theories and analyses of new frontiers that are guiding global prosperity.

We want to thank all contributors for their rigorous involvement with the book. Their diverse perspectives and theoretical and empirical contributions contribute to the international debate on inclusive and sustainable economic development and growth. We would also like to thank our publishing partners for their assistance during the editorial process.

We trust that this book will serve as both a reference and an inspiration for future research, policy design, and teaching in the ever-evolving fields of economic development and economic growth.

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Section 1

Foundations of Economic Development and Growth

Chapter 1

Why Some Places Do Better in Economic Growth and Other Do Not? Entrepreneurial Difference: An Essay

Maksim Belitski and David Audretsch

Abstract

What matters for economic growth? How we can facilitate economic growth via entrepreneurship? Policy makers needs to invest in culture for creativity, better education, physical capital, digital technologies to create more conducive environment for growth and entrepreneurship. We apply endogenous growth theory to understand how investment into knowledge can and should be translated into productivity, growth, society, creating a better economy. We also discuss why some assumptions of endogenous growth models fail, talking about the European paradox of knowledge - high investment in human capital, training, cultural awareness but this does not translate into growth, jobs and startups. It is not enough to have those investments, but there is a missing link for knowledge to spill over and this is entrepreneurship activity and creating a well-functioning entrepreneurial ecosystems.

Keywords: economic growth, knowledge frontiers, endogeneous growth theory, entrepreneurship policy, startup, innovation

1. Introduction

Entrepreneurship plays a crucial role in facilitating economic growth. Historically, the European Union has highlighted the need to transition towards a knowledge-based economy, with the Lisbon Council of Europe [1] recognizing this as a strategic path forward. Despite high investments in knowledge, science, and human capital, there remains a gap in effectively translating these assets into economic benefits, which is sometimes referred to as the “European paradox.” This paradox emphasizes the necessity of entrepreneurship as a conduit to translate knowledge into economic outcomes. This chapter examines how entrepreneurs facilitate economic growth drawing on endogenous growth theory [2, 3], drawing from theory, empirical observations, and policy perspectives, focusing on the critical role of entrepreneurship in mobilizing knowledge to drive productivity, employment, and innovation [1, 4].

The Lisbon Council of Europe made a commitment to moving Europe forward, to improving economic performance through a key strategy of positioning Europe as a global leader in knowledge. However, when the president of the European Union visited Madrid more than a decade ago, he acknowledged that this alone was not enough. President Prodi highlighted what he called Europe's "lacuna," a deficit in entrepreneurship that needed urgent attention. He emphasized mounting evidence that the key to economic growth and productivity lies in an economy's entrepreneurial capacity. While President Prodi wasn't necessarily criticizing the Lisbon Council of Europe's strategy, he added that knowledge, ideas, science, and technology may not be enough. Someone needs to act on this knowledge and bring it to market.

At that time, an emerging body of econometric evidence linked various measures, such as startup rates, shares of small business, and self-employment rates across countries, regions, and even within the Organization for Economic Co-operation and Development (OECD), to entrepreneurship. These studies consistently found that places with higher levels of entrepreneurship seemed to do better, as measured by productivity, employment, creation, and exports. This link between entrepreneurship and performance was becoming increasingly clear to me as well.

Around that same time, I was called to a meeting in Stockholm, hosted by Sweden's Ministry of Economics. Like much of Europe, Sweden had endured a decade of economic stagnation, with slow growth and rising unemployment. By the end of the twentieth century, the country had had enough. The Ministry called together a group of experts to ask, "What can Sweden do?"

Having read the literature, I felt I knew the answer. At the time, my colleagues and I referred to it as the new economic growth theory. Now, it is more commonly known as endogenous growth theory. Paul Romer [5] argued that while physical capital matters, ideas and knowledge are equally, if not more, important. This is more obvious today than it was at the turn of the century.

The Lisbon Council of Europe had already reflected this shift in economic thinking, emphasizing that while factories and physical capital are essential, so too are ideas, knowledge, science, and technology. With this in mind, I arrived in Stockholm and confidently proposed a solution: invest in knowledge, research and development (R&D), patents, education, human capital, and even culture.

However, the Swedish Minister of Economics was unsure. By any OECD measure, whether R&D investment as a percentage of GDP, patents per capita, or levels of education and labor skills, Sweden ranked at or near the top. Yet, despite these investments, the expected economic outcomes such as growth, jobs, and productivity were not materializing. This disconnect was referred to as the "Swedish paradox."

The paradox highlighted a critical flaw in the models of endogenous growth: knowledge and innovation do not automatically translate into societal benefits. President Prodi liked this characterization so much that he adapted it for the European Union, coining the term "European paradox." Despite high investment in knowledge, R&D, education, human capital, and cultural awareness, these efforts did not seem to be translating into the desired economic outcomes.

I walked out of that meeting in Stockholm with the same realization that President Prodi had: investments in knowledge, science, and technology are very important, but they are not enough. There is still a missing link because that knowledge does not automatically spill over into tangible societal benefits.

2. Theory

Theoretical perspectives on economic growth have evolved over time, transitioning from an emphasis on physical capital and labor to a focus on knowledge and innovation. Early economic growth theories, such as those proposed by Robert Solow [6, 7], highlighted the significance of capital accumulation (physical and labor) in driving economic output. Solow's model, however, contained a residual component, which he termed "technological change," implicitly acknowledging that knowledge and ideas play a role in growth. However, these residual factors were seen as unpredictable and external to the economic system—akin to "manna from heaven"—and therefore not considered directly actionable through policy.

This perspective shifted with the emergence of endogenous growth theory, particularly through the work of Paul Romer. Romer's theory [5, 8] emphasized the importance of ideas and knowledge as core drivers of economic growth, suggesting that they are not externalities but endogenous to the economic process and can be influenced by deliberate investments in R&D, human capital, and education. Knowledge, in this framework, could generate positive spillovers that enhance productivity and growth across firms and sectors, especially when in close geographic proximity.

As cases like the Swedish paradox illustrate, high levels of investment in knowledge do not guarantee economic returns. This theory assumes that knowledge spills over naturally and is readily absorbed and commercialized by businesses. The reality, as observed in the experiences of countries like Sweden and Germany, suggests that these spillovers often face barriers. These barriers, conceptualized as the "knowledge filter," highlight the challenge of transferring knowledge from its point of origin—whether within firms like IBM or institutions like universities—into economically productive activities. This gap points to the critical role of entrepreneurship in facilitating economic growth by bridging the knowledge filter and translating innovation into marketable goods, services, and technologies.

Entrepreneurship serves as a mechanism to capitalize on knowledge spillovers and convert them into new ventures, market opportunities, and innovative products. In instances like the founding of SAP, Facebook, and Google, entrepreneurs took nascent ideas, often unrecognized by larger institutions, and created globally influential companies. These examples underscore the importance of individuals or small teams who identify and act on knowledge that otherwise might remain uncommercialized or underutilized within the bounds of existing organizations.

Entrepreneurship as a catalyst for economic growth is not solely about starting new businesses. It is about the ability of entrepreneurs to identify, adapt, and commercialize knowledge in ways that contribute to regional, national, and global economies. This section discusses the mechanisms through which entrepreneurs drive economic growth, such as mobilizing knowledge spillovers, enhancing regional competitiveness, and creating employment.

3. Mobilizing knowledge spillovers

Knowledge spillovers refer to the process by which ideas, innovations, and expertise generated within firms, universities, or regions become accessible to other entities, which can then use this knowledge to enhance their productivity and develop new technologies. Romer's endogenous growth theory posits that knowledge is a

non-rivalrous good, meaning that one entity's use of knowledge does not diminish its availability to others. However, without mechanisms to mobilize these spillovers, much of the knowledge generated can remain underutilized.

Entrepreneurs play a vital role in overcoming the knowledge filter by identifying viable business opportunities within existing knowledge pools and driving the commercialization of these ideas. The case of SAP's founding exemplifies this: despite the idea for new software emerging from IBM engineers, it took the entrepreneurial drive and risk-taking of these individuals to create a standalone company that transformed their idea into a leading global enterprise.

Similarly, university spinoffs like Google and Facebook illustrate how academic research and knowledge can be transferred into high-impact commercial ventures. However, universities themselves, being nonprofit and often bureaucratic institutions, are not equipped to drive entrepreneurship directly. Instead, students and academics who act entrepreneurially become the bridge, enabling knowledge to spill over and reach markets effectively.

4. Enhancing regional competitiveness

Entrepreneurship contributes to regional economic development by fostering innovation clusters and ecosystems that are conducive to growth. Clusters, as described by Michael Porter [9], are geographic concentrations of interconnected firms, suppliers, and associated institutions within a particular field. The presence of dense networks of related firms and industries facilitates knowledge exchange, labor market pooling, and supply chain efficiencies.

Regions with strong entrepreneurial ecosystems, like Silicon Valley, benefit from high levels of knowledge spillovers, collaboration, and access to financial and human capital. This creates a self-reinforcing cycle where successful entrepreneurial ventures attract talent, investment, and further innovation. The comparison between Silicon Valley and the Boston area in Annalee Saxenian's *Regional Advantage: Culture and Competition in Silicon Valley and Route 128* [4] underscores how regional networks, cultural attitudes towards risk and collaboration, and social capital can significantly affect a region's entrepreneurial capacity and economic performance.

Entrepreneurship also plays a pivotal role in diversifying regional economies. According to Jane Jacobs [10], economic diversity within a region fosters the cross-fertilization of ideas and innovation, leading to dynamic growth. Diverse economic activities provide fertile ground for entrepreneurship to take root, enabling the region to be resilient to economic shocks and better positioned for sustainable growth.

5. Creating employment and productivity

Entrepreneurs are pivotal in job creation and enhancing productivity, contributing to overall economic development. New ventures, especially those in high-growth sectors, generate employment opportunities and can lead to the reallocation of resources towards more productive uses. The process of "creative destruction," as described by Joseph Schumpeter [11], characterizes how entrepreneurial ventures disrupt existing markets and practices, driving efficiency and spurring innovation.

High-growth ventures, sometimes called "gazelles," contribute disproportionately to job creation compared to small or large firms that are not experiencing high

growth. Furthermore, entrepreneurial activity fosters competition, pushing existing firms to innovate, improve efficiency, and adapt to changing market conditions, all of which contribute to higher levels of economic productivity.

6. Discussion

This section will introduce you to the This narrative exploring the vital role of entrepreneurship in transforming knowledge into economic growth, using real-world examples such as SAP, Facebook, and Google to challenge traditional models of innovation and development. It begins with the story of SAP's founding to illustrate how ideas often face institutional resistance and require entrepreneurial action to become commercially viable. The discussion then traces the evolution of economic thought—from Solow's view of knowledge as a passive spillover to Romer's model of knowledge as an intentional investment—highlighting the importance of geographic and institutional context. Along the way, it examines how clusters, ecosystems, and localized resources enable or constrain innovation, revealing a shift from resource-based to knowledge-driven economic strategies. Readers will gain insight into how entrepreneurship bridges the “knowledge filter,” why proximity still matters in the digital age, and how history, place, and policy interact in shaping the dynamics of regional development.

Let us take the example of the founding of SAP, a European multinational software company based in Germany.

In 1971, a group of IBM engineers approached their employer with an idea for a new kind of software. Decisionmakers within IBM dismissed the idea, saying that it would not work. The five young innovators and co-founders—Dietmar Hopp, Hasso Plattner, Claus Wellenreuther, Klaus Tschira, and Hans-Werner Hector—passionate and committed, thus took it to other companies. They approached Siemens and Nokia, yet the idea was repeatedly rejected.

In the end, they considered starting their own company. They approached Germany's major banks, including Deutsche Bank, Dresner Bank, and Commerzbank, but the banks were skeptical. Their reasoning: if IBM had not pursued the idea, it likely lacked merit. Fortunately, the team finally secured startup.

The point of this story is to illustrate that knowledge does not simply “spill over” as assumed in traditional models of endogenous growth. In this case, knowledge transfer and commercialization required entrepreneurship, the active effort to move an idea beyond the boundaries of the firm and transform it into a marketable product.

Solow's [7] growth model suggested that technical change contributes to economic performance as a residual factor, alongside physical capital and labor. Solow famously remarked that “knowledge falls like manna from heaven,” implying an unpredictable and seemingly divine process. However, this perspective leaves policymakers with little actionable guidance.

Romer's endogenous growth model, however, offered a more explicit view. He argued that innovation could be fostered by investing in knowledge, R&D, and human capital. Unlike Solow's model, Romer emphasized that knowledge could spill over and benefit other companies and individuals, especially in proximity to the source of the innovation.

Consider the example of companies like Facebook and Google, whose origins lie in ideas generated by students at Harvard and Stanford University, respectively. These institutions facilitated the creation of groundbreaking concepts but lacked the

structure to transform them into market-disrupting companies. It was the student entrepreneurs who turned their ideas into a reality.

This dynamic between institution and entrepreneur is depicted in the movie *The Social Network*. In one scene, Harvard's president, Larry Summers, dismisses the claims of the Winklevoss twins that Mark Zuckerberg stole their idea for Facebook. Summers responds, "This is Harvard. Get another one." This reaction underscores the inherent uncertainty and undervaluation that often accompany new ideas. Even renowned economists, like Summers, may not recognize the long-term potential of early-stage concepts. This phenomenon is referred to by scholars as the "knowledge filter."

To combat this knowledge filter requires entrepreneurship to bridge the gap between creation of an idea and its practical application. Whether it's Facebook's development at Harvard or Google's proximity to Stanford's innovation hub in Silicon Valley, the geographic and institutional context plays a critical role. Policymakers have increasingly recognized the significance of fostering such ecosystems, as they anchor economic activity and attract talent. Entrepreneurs, therefore, are vital for translating knowledge into transformative businesses, catalyzing regional economic growth.

In the case of SAP, Germany's investments in education and an open, free society fostered a culture that empowered IBM's engineers to innovate and pursue entrepreneurship. The founders of SAP were able to transform an idea into a successful enterprise because they operated in an environment with fewer barriers to finance and resources. Had they'd been in the more restrictive society of East Germany, for example, they would have had a difficult time pursuing their entrepreneurial ideas.

This illustrates the inherent challenges organizations face when evaluating ideas. Companies like IBM, for example, cannot feasibly pursue every innovation or idea. Thus, entrepreneurship becomes vital, allowing individuals to act on uncertain concepts outside the confines of traditional organizational structures. This also allows societies to reap the benefits of investments in knowledge and human capital due to spillover effects.

The importance of this dynamic is further reflected in the development of clusters, as explored by Paul Krugman in his work on the spatial concentration of economic activity. Inspired by Porter's discussions on clusters at Harvard, Krugman analyzed why industries tend to thrive in concentrated geographic regions. This research highlights the relationship between innovation, entrepreneurship, and the local economies that sustain them.

Economic activity in vast countries like Canada tends to cluster in cities such as Toronto, Vancouver, and Montreal, driven by the localized nature of knowledge spillovers. Investments in knowledge often remain geographically anchored, requiring proximity for access. This reinforces the role of entrepreneurship in transforming localized knowledge into economic growth.

David Ricardo's emphasis on natural resources reflects a historical period when such factors played a crucial role in economic development. For example, Bilbao in Spain thrived as a hub for shipbuilding due to its natural harbor, which facilitated the concentration of physical capital. Similarly, Detroit, once the wealthiest city in the United States, owed its success to its geographic proximity to the Great Lakes and nearby coal supplies. This access enabled the flourishing of industries reliant on physical capital, an aspect central to Solow's Nobel Prize-winning work on economic growth.

These examples highlight how access to natural resources shaped the spatial concentration of economic activity. For instance, the Ruhr Valley in Germany became a center for the steel industry due to its proximity to essential resources like coal. This relationship between natural resources, physical capital, and geographic advantages highlights the foundational elements of economic geography in earlier eras.

Historically, economic strategies have evolved from reliance on natural resources to more knowledge-based approaches. Some regions, however, continue to derive competitiveness from physical capital or natural resources. For example, the economic success of Switzerland's ski resorts, Colorado's mountain towns, or southern European coastal areas is based on leveraging their natural assets rather than contemporary knowledge or creative industries.

This contrast illustrates how strategies vary across regions. While earlier approaches emphasized investing in physical capital like factories and infrastructure, by the late 1990s and early 2000s, much of the West had shifted their strategies. Influenced by Romer's endogenous growth theory [8, 12] and frameworks like the Lisbon Council, emphasis turned towards knowledge, ideas, and innovation.

Recent discussion differentiates between human capital (the people behind innovation) and knowledge (R&D). Thinkers like Richard Florida [13] popularized the concept of the "creative class," highlighting the role of human ingenuity in driving growth.

Edward Glaeser [14], in his review of Florida's *The Rise of the Creative Class* [13], evaluates the book using three criteria: correctness, writing quality, and novelty. Glaeser acknowledges that the book is correct in asserting the importance of human capital and praises its engaging writing and examples. However, he criticizes it for lacking novel insights, arguing that the significance of human capital was already well established.

This raises an interesting debate on the evolving definition of human capital. Florida broadens the concept by emphasizing not only traditional measures like years of education but also creativity and the "creative class" as important contributors to economic performance. For example, my colleague, Paula Stephan, once had to wrestle with the apparent contradiction of her son, who dropped out of university yet founded and sold a successful software company. This suggests that human capital extends beyond formal education to include entrepreneurial ability and innovative capacity.

These discussions align with broader themes about factors of economic performance. Whether considering natural resources, physical capital, or human capital, the key lies not only in their abundance but also in their configuration and application. Romano Prodi and others emphasize the significance of organizing these resources effectively, a notion endorsed by Porter [9] in his work on clusters. Porter argues that economic success depends not merely on the quantity of resources but on the spatial and structural organization of economic activity.

This idea is further refined by Kenneth Arrow's focus on specialization and economies of scale, as well as Jane Jacobs's emphasis on diverse, dynamic urban economies [10]. Together, these perspectives highlight the relationship between factors, their structure, and the spatial strategies that drive regional and global economic performance.

Jacobs, a sociologist from Toronto, argued that it is actually diversity, rather than specialization, that drives economic performance. She suggested that knowledge spillovers, which are crucial to innovation, emerge from exchanging and combining distinct ideas. A homogeneous economic or social structure limits this potential

because shared thinking stifles the generation of new ideas. Jacobs emphasized the need for complementary yet diverse economic activities and populations within a place to foster growth.

This notion was later tested by Glaeser et al. [15] in “Growth in cities”. They examined whether specialization or diversity benefits cities more and assessed the impact of monopoly power versus localized competition. Their findings, based on US data and subsequent replications in contexts like Spain, concluded that diversity and localized competition foster economic vibrancy. Competition within input markets, such as talent and ideas, enables individuals to move between firms or start their own ventures, encouraging dynamic innovation and entrepreneurship.

These insights tie into the broader importance of entrepreneurship as a mechanism for regional and national growth. Entrepreneurship thrives in diverse, competitive ecosystems, allowing communities to adapt and innovate. However, as regions strategize, balancing these elements remains a central challenge in fostering sustainable economic development.

7. Conclusion

Entrepreneurs are instrumental in facilitating economic growth by serving as conduits for the commercialization of knowledge, enhancing regional competitiveness, and creating jobs and productivity improvements. While traditional economic growth theories emphasized physical capital and labor, contemporary perspectives recognize that knowledge, ideas, and human capital are key drivers of growth. However, without the mechanisms to mobilize and commercialize this knowledge—namely through entrepreneurship—these assets may fail to translate into economic performance.

Entrepreneurial activity helps to overcome the knowledge filter by bridging the gap between knowledge creation and its application in markets. Furthermore, entrepreneurs contribute to regional development by forming and strengthening clusters of economic activity, fostering diversity, and spurring innovation and competition. The strategic management of places, therefore, must not only focus on enhancing factors and resources such as knowledge but also on creating conditions that enable entrepreneurship to thrive.

As economic growth strategies have evolved over time, there has been a transition from focusing on attracting physical capital and large firms to investing in knowledge and fostering entrepreneurial ecosystems. While these strategies are complementary and context-dependent, entrepreneurship remains a critical factor in transforming knowledge into economic growth and ensuring that regions, nations, and societies can capitalize on their investments in human capital, research, and technology.

Entrepreneurship, therefore, is not just about creating new businesses but about creating a dynamic process that allows places to adapt, innovate, and grow sustainably. Policymakers should recognize and support entrepreneurship as a key driver of economic growth, ensuring that investments in knowledge, human capital, and technology are accompanied by an environment conducive to entrepreneurial activity. By doing so, economies can unlock their full potential for innovation, competitiveness, and sustainable development.

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Analyzing the Megacycles of the Economy

Ioanna Atsalaki and George Atsalakis

Abstract

A long-term economic megacycle, lasting 56 years, consisted of 28 years of stagnation or recession, with decreasing deviation of energy consumption from the sigmoidal curve. During this time, deep and extensive changes occur due to the emergence of new technologies that bring disruptive changes to the economy and society, increasing productivity and triggering the next 28-year upward cycle, where energy consumption increases. The start of each economic cycle is linked to the emergence of new fundamental technologies (technological-industrial revolutions), which leads to a new, cheaper energy source, a new transportation infrastructure, a new means of transport, and a multitude of new technological applications. These appear and develop during the first 28 years. It takes several years for the new technologies to spread widely enough to significantly increase productivity, thereby creating the next 28 years of growth. Different transportation infrastructures are developed in each cycle: In railways, highways, and airlines, magnetic train lines are emerging as the new transportation infrastructure of the next cycle. In each cycle, a new country emerges as a rising power. The upcoming megacycle of 2024–2080 is approaching, and the changes expected to occur are presented based on the dynamics of the evolution of previous megacycles.

Keywords: megacycles, economy cycles, new technologies, disruptiveness, economy trend, technological change

1. Introduction

Economic history, traditionally perceived as the study of past events, transcends this narrow view. It is more accurately an exploration of changes—examining how events unfold, adapt, and reshape societies over time. This perspective is crucial today, as we confront unprecedented shifts that are reshaping our world in profound ways. The year 2024 stands at a crossroads, marking the end of a global economic megacycle and the dawn of a new era. Understanding the mechanisms of historical change is more vital than ever in comprehending and navigating these shifts [1].

The concept of historical change encompasses both continuity and transformation. History is not merely a record of what was but a guide to understanding how and why things evolve. As we move toward a new financial era, the dynamics of change in the past offer valuable lessons. Economic cycles, which have historically dictated economic stability and prosperity, reflect broader shifts in political power, technological

innovation, and societal priorities. By studying the mechanisms that govern these cycles, we gain insights into potential future outcomes and challenges [2].

The current global economic megacycle, marked by prolonged economic expansion and interconnected markets, is now reaching its conclusion. This transition heralds a period of uncertainty and potential upheaval as we adapt to new economic realities. Year 2024's significance lies not only in marking this shift but also in its role as a litmus test for our understanding of historical patterns. How we interpret and respond to these changes will shape the coming decades [3].

Economy history is indeed the study of change, of understanding how and why transformations occur. As we stand on the brink of a new financial era, a deep grasp of historical mechanisms offers us a compass. This understanding is crucial as we seek to navigate a world in flux, where the past informs us about not only where we are but also where we are heading [4].

The concept of long-term economic cycles, often termed megacycles, has captivated economists and researchers for more than two centuries. These cycles, characterized by prolonged periods of expansion and contraction in economic activity, offer a framework for understanding macroeconomic fluctuations over extended periods. Early proponents of these cycles include Jevons [5], who linked business cycles to solar activity, and Moore [6], who associated economic fluctuations with climate variations. The enduring influence of these theories illustrates humanity's enduring fascination with finding patterns in complex economic phenomena.

Among the most prominent theories of long waves in economics is that of the Russian economist Kondratieff [7]. In the 1920s, Kondratieff identified a cycle spanning approximately 50 years, driven by economic indicators alone. His theory, known as the Kondratieff Wave, proposed that these long waves were inherent in capitalist economies, characterized by alternating periods of prosperity and stagnation. Although Kondratieff's work initially garnered attention, it was later expanded upon by the Austrian economist Schumpeter [8], who attributed these cycles to clusters of major technological innovations. Schumpeter argued that these innovations spurred economic growth, thereby creating identifiable waves.

2. Theoretical background

The study of Kondratieff waves (K-waves) or long waves (LWs) has intrigued scholars for decades, as they offer a framework to understand economic cycles spanning roughly 50–60 years. Originally proposed by Russian economist Kondratieff [7], these cycles suggest that economic growth and decline follow a regular, oscillating pattern over long period.

The large-scale processes—like energy consumption—might naturally follow an exponential or logistic growth curve due to population increase and technical progress, one would expect a relatively smooth trajectory over time. However, in practice, real-world data often diverge from these neat progressions, showing booms, slowdowns, and other cyclical irregularities. As the global economy expands or contracts, energy usage tends to fluctuate accordingly—major industrial expansions require more energy, while recessions can curb demand. Over many decades, this results in an undulating pattern rather than a smooth curve. When graphed, these cycles can look like a smoothed sine wave, particularly over long intervals. Although real data are never perfectly sinusoidal, the approximation holds well enough to suggest cyclical behavior. Relevance to pendulum motion: A simple pendulum moving under gravity exhibits simple harmonic

motion, which is mathematically expressed as a sine (or cosine) function over time. The reference to a pendulum underscores the repeating, oscillatory nature of economic expansions and contractions. Although economies are far more complex than mechanical pendulums, the analogy highlights how cyclical feedback mechanisms (investment, innovation, saturation, recession, and new investment cycles) can generate repetitive up-and-down movements. Like a pendulum, economic systems may “swing” away from an equilibrium (boom periods) and then move back, often overshooting in the other direction (recessions). While actual data can be jagged, sinusoidal curves capture recurring peaks and troughs where there is cyclical acceleration and deceleration. In practice, an ideal sine wave is a simplified approximation that helps analysts interpret underlying cyclical forces and compare different cyclical patterns (e.g., short business cycles vs. long-wave Kondratieff cycles). Recognizing sinusoidal-like cycles offers one way to anticipate future peaks or troughs in global demand for resources like energy. It can guide long-term investment strategies or policy initiatives (e.g., infrastructure planning, R&D priorities). However, timing the exact peaks and troughs is notoriously difficult. External shocks—wars, pandemics, technological breakthroughs—can shift cycles.

Research in this area has expanded to explore not only economic indicators but also biological, social, and geopolitical factors that may drive these cycles.

A unique perspective on K-waves is offered by Devezas and Corredine [9], who investigated biological determinants, suggesting that these cycles may be influenced by “natural human biological clocks.” This concept implies that collective human behavior, shaped by generational learning processes, imposes a rhythm on economic and social dynamics. Supporting this notion, Modis [10] argues that such rhythms could indeed influence broader economic trends, reinforcing the idea that K-waves may have a biological basis that affects how societies evolve over time.

Furthermore, scholars like Goldstein [11] delve into the dynamics of K-waves through causal relationships among critical factors such as war, production, and innovation. Stein and Russett [12] posit that wars, particularly those involving major global powers, can dramatically affect investment patterns, price levels, and real wages within economies. These changes can either stimulate or hinder economic growth, leaving long-lasting impacts on socioeconomic structures. War, in this context, functions as an agent of social change, with Russett [13] suggesting that wars carried out by powerful nations can result in permanent changes, both positive and negative, in interdependent economies. The analysis of war economies, along with the consequences of conflict, sheds light on the interplay between military activities and economic cycles. Scholars in Refs. [14, 15] argue that understanding the economic impact of wars—especially those of great magnitude—can provide insights into the principles governing economic, social, and technological change.

The typology of wars and their potential impacts on K-waves are further explored by Wilmshurst [16], who classifies conflicts into categories such as interstate armed conflicts, internal conflicts, minor conflicts (with 25–999 deaths per year), and major conflicts (with over 1000 deaths per year). Major wars, according to Goldstein [11], are integral to the “hegemonic cycles” of nations with global influence. These hegemonic cycles, lasting approximately 150 years, reflect periods of global leadership by powerful nations, interspersed with phases of conflict and competition. Historically, these cycles of dominance and the wars that punctuate them—such as those studied by [17]—align with broader K-wave patterns, underscoring the cyclical nature of economic and political hegemony.

The study of Kondratieff waves reveals a complex interplay between biological rhythms, economic dynamics, and the influence of war. While economic factors like

production and innovation play significant roles in driving these cycles, the broader patterns of K-waves are also shaped by social and biological influences, and periodically punctuated by conflicts that reshape the global economic landscape. By examining these factors, researchers continue to expand our understanding of long-term economic cycles, offering valuable insights for anticipating future shifts and challenges in the global economy.

Kondratieff wave has since attracted both ardent supporters and vocal critics. On the one hand, modern researchers, such as in Refs. [18, 19], have explored the relationship between innovation cycles and Kondratieff's long waves, finding correlations in global invention activity. These findings lend credibility to the idea that waves of economic activity may be tied to innovation and technological advancement. On the other hand, critics such as Refs. [20–24] have challenged the validity of Kondratieff's cycle, questioning the periodicity of business cycles and the use of monetary indicators as evidence. Reference [25] claims that long waves are rooted in war that generates technological and economic change in society.

Despite its contested status, the Kondratieff Wave continues to resurface in economic discourse, particularly in periods of economic upheaval. Some researchers have turned to physical variables, such as energy consumption, as more objective measures to validate the existence of these cycles. For example, Refs. [26, 27] have identified cyclical variations in energy use that align with Kondratieff's proposed waves. By examining such unambiguous variables, these scientists attempt to bypass the speculative nature of monetary indicators and provide a more empirical basis for understanding megacycles.

The study of megacycles remains a contested yet intriguing field within economics. While the Kondratieff Wave and similar theories offer a framework for interpreting long-term economic trends, they are often challenged by the limitations and subjectivities inherent in economic data. However, as new methodologies and data sources emerge, the quest to understand the nature of economic megacycles persists, reflecting a broader human desire to find order within the complexities of economic history.

While much research has been conducted on K-waves, scholars still debate their underlying mechanisms. As some researchers suggest, alternative hypotheses might offer additional insights into the factors driving these economic cycles and help address gaps left by existing theories.

One such avenue of inquiry is the relationship between K-waves and the clustering of basic innovations. According to Ray [28], the evolution of K-waves is closely tied to innovation cycles, particularly during the downturn and bottom of a K-wave. This phase, often referred to as a period of "creative destruction" [29], is marked by clusters of basic innovations that fundamentally disrupt existing economic structures. They argue that during these phases, new technologies emerge, leading to significant structural changes that eventually fuel the recovery and prosperity phases of the economic cycle. The widespread adoption of these innovations and their integration into markets can thus trigger the subsequent upswing, as seen in the works [27, 30].

Another perspective, presented by Modelski [31], views K-waves as the rise and fall of dominant industrial or commercial sectors within the global economy and suggests that these waves are essentially endogenous to the economy, driven by clusters of basic innovations that lead to the growth of new sectors. This process results in structural change and the reshaping of the global economic landscape. Moreover, Modelski [31] highlights the importance of considering external factors, such as political, social, and cultural influences, which interact

with these economic cycles to create a complex, multi-faceted pattern of growth and decline. This understanding of K-waves as processes of “creative destruction” aligns with the broader view that technological and economic changes are closely interconnected.

A key component of this innovation-driven cycle is the role of General Purpose Technologies (GPTs), which have significant and lasting impacts on the economy. Lipsey [32] and Lipsey et al. [34] define GPTs as technologies that offer a broad scope for improvement and wide applicability, becoming integral to various sectors and often spurring new technological advancements. Examples of such technologies include the steam engine, electric motors, and semiconductors, each of which has been pivotal in reshaping entire industries and catalyzing economic growth. These technologies often lead to “destructive creation” [33], making existing products obsolete and driving the development of new products and processes. As they evolve, GPTs not only contribute to increasing returns-to-scale but also encourage complementarities with other emerging technologies, resulting in cumulative advancements across multiple fields.

The diffusion of GPTs plays a crucial role in driving long-term economic cycles, as their impact often extends beyond national borders, permeating interconnected economic systems. Scholars such as Refs. [21, 25, 34–36] note that the spatial and temporal spreads of these technologies generate ripples of change across industries, economies, and societies. This ripple effect promotes corporate and industrial evolution, economic growth, and even social transformations, underscoring the pervasive influence of GPTs on the global economy.

The drivers of long waves are complex and multifaceted. The clustering of basic innovations, the influence of GPTs, and the rise and fall of industrial sectors all play significant roles in shaping these economic cycles. The framework provided by existing studies, while valuable, may benefit from further exploration of these alternative hypotheses to enhance our understanding of the mechanisms driving long waves. By considering these factors, scholars can develop a more comprehensive understanding of how and why these economic cycles occur, potentially offering insights that can inform future economic policy and strategy.

3. Understanding technological development through production revolutions

The theory of production principles, developed over nearly three decades, provides a framework for understanding the evolution of technology within the context of human history. This theory, extensively discussed in Refs. [37–42], offers insights into the logic of technological development by identifying key stages or “production revolutions” that signify shifts in productive forces and technological paradigms. According to this theory, three major production revolutions have defined the course of human progress: the Agrarian Revolution, the Industrial Revolution, and the Cybernetic Revolution.

Each of these production revolutions represents a transformative period that fundamentally alters the production system and enables a new level of societal development. The Agrarian Revolution marks the transition from hunter-gatherer societies to settled agricultural communities. This shift enabled humans to produce surplus food, which supported population growth, urbanization, and the development of complex social structures. The transition to agriculture also laid the foundation for future

technological advancements, as societies became more interconnected and began to experiment with new tools and techniques for farming.

The Industrial Revolution, beginning in the late eighteenth century, introduced mechanized production and transformed economies from agrarian-based systems to industrial powerhouses. This revolution was characterized by the development of steam engines, mass production, and the rise of factory systems. It not only accelerated production capabilities but also fundamentally changed the nature of work and the organization of society. The Industrial Revolution catalyzed urbanization, as people moved to cities to work in factories, and it spurred technological innovations that would later give rise to new industries and economic growth.

The Cybernetic Revolution, which began in the latter half of the twentieth century, represents the current stage of technological evolution, marked by the advent of digital technologies, automation, and information systems. This revolution has led to the development of computers, the Internet, and artificial intelligence, reshaping industries, economies, and even personal lives. The Cybernetic Revolution is distinguished by its emphasis on information and communication technologies that have enabled unprecedented levels of connectivity and have transformed traditional production systems into complex, global networks. This stage continues to evolve, with ongoing advancements in fields like biotechnology, nanotechnology, and robotics.

Each production revolution, as Grinin [24–37, 43, 44] and his collaborators argue, introduces a new set of production principles that redefine the relationship between humans, technology, and the environment. These principles establish the foundation for new technological paradigms and reflect a historical progression in which each stage builds upon the previous one. For example, the technological advancements of the Industrial Revolution were made possible by the agricultural surplus generated by the Agrarian Revolution, which freed up labor for industrial pursuits. Similarly, the Cybernetic Revolution has been facilitated by the infrastructure and industrial base established during the Industrial Revolution.

Moreover, the theory of production principles suggests that each revolution marks a transition to a new stage of development for the world's productive forces. This transition is not merely technological but also involves shifts in social organization, economic structures, and cultural norms. For instance, the shift from agrarian societies to industrial ones brought about changes in family structures, social hierarchies, and political systems, as nations grappled with the demands of industrialization. The Cybernetic Revolution has similarly brought about significant changes in work patterns, social interactions, and even concepts of identity, as digital technologies become integral to daily life.

The theory of production principles provides a valuable lens through which to view the historical trajectory of technological development. By framing human progress in terms of production revolutions, this theory emphasizes the transformative impact of technology on society and underscores the interconnectedness of technological, social, and economic changes. As we continue to navigate the complexities of the Cybernetic Revolution, understanding these historical patterns can offer insights into the future directions of technological evolution and their potential implications for humanity [38].

Following are some examples of innovations that moved from experimental stages to broad acceptance.

Microprocessor breakthrough: Intel's 4004 microprocessor (1971) symbolized a leap forward, as it combined the essential CPU elements on a single chip. This made computers smaller and more affordable, fostering the rise of personal computing.

Emergence of personal computer brands: In the mid-to-late 1970s, companies like Apple (Apple II), Commodore (PET), and Tandy (TRS-80) introduced consumer-friendly personal computers. These machines—though still relatively expensive—were sufficiently affordable and user-friendly to attract hobbyists, small businesses, and educational institutions.

Academic and defense roots: The Advanced Research Projects Agency Network (ARPANET) in the late 1960s and 1970s was initially a government project aimed at creating a robust communication network. Over time, universities and research institutes used ARPANET to collaborate on projects, paving the way for the modern Internet.

4. Megacycles based on energy consumption: A 56-year rhythm in historical data

The historical data on U.S. energy consumption, which extends back to 1800, reveals intriguing insights into long-term economic cycles through the lens of energy use. Analysis of the evolution of energy consumption over time, with data sampled at five-year intervals up to the end of 2015, suggests a stepwise growth pattern characterized by two phases: an uptrend and a downtrend. S-curves provide a more accurate representation of these growth phases, according to Modis [45].

The work of Stewart [26] provides a historical context for this analysis, as previous models had suggested the presence of two main growth steps, with a third anticipated in a manner similar to the previous two. In Modis [45] analysis, deviations from the overall S-curve trend have been isolated by examining the ratio of the actual data to the trend, revealing a consistent pattern of oscillation. When the same method is applied to U.S. electrical energy consumption and worldwide per capita energy consumption, the resulting trends align with a sinusoidal wave of roughly 56 years, further suggesting the presence of a long-term cyclical pattern [45].

This pattern, known as Kondratieff's economic cycle, is evidenced by recurring oscillations in energy consumption that impact economic conditions. The data indicates that energy consumption can be as much as 20% higher or lower than expected during certain periods, with higher consumption generally correlating with economic growth and prosperity, and lower consumption correlating with economic downturns. The regular 56-year oscillation observed both in the U.S. and global data highlights a link between energy consumption and economic cycles, providing independent evidence for Kondratieff's theory [45].

One notable finding is the phase difference observed between the U.S. and global energy consumption cycles. While the U.S. experiences booms and busts approximately 7 years earlier than the rest of the world, there are also significant deviations in the timing and amplitude in the U.S. data, starting around 1990. This suggests that while the general cyclical pattern remains, local factors in the U.S. economy may influence the timing and intensity of these cycles differently from other regions. Such deviations highlight the complexity of these economic cycles and suggest that while energy consumption provides a general indicator, additional factors must be considered to fully understand regional variations [45].

To quantify the relationship between the observed patterns and the idealized 56-year sinusoidal wave, correlation coefficients were calculated for U.S. total energy, U.S. electrical energy, and worldwide energy per capita. The correlation coefficients for these variables, when squared (r^2), indicate that the regular sine-wave pattern explains 39, 62, and 51% of the variance in their respective data patterns. These values

indicate that while a significant portion of the cyclical pattern can be attributed to this 56-year rhythm, other influences are also at play [45].

The alignment of these long-term energy consumption patterns with Kondratieff's cycles suggests that energy consumption is an important factor in economic development. The recurring oscillations observed in both U.S. and global energy consumption underscore the cyclical nature of economic growth and recession, where periods of heightened energy demand align with economic expansion, and periods of reduced demand coincide with economic downturns. Understanding this relationship can offer valuable insights into the underlying forces that shape economic cycles and provide a basis for anticipating future economic shifts.

Marchetti [27] claims that a pulsation of about 50 years pervades many aspects of human activity, with social communication systems likely mediating this signal. Physical indicators, excluding money indicators, show clear cyclical patterns that economists have debated for over a century. Infrastructure development, such as canals, railways, and paved roads, follows a 50-year cycle with consistent saturation parameters. Metro system construction starts clusters in three groups about 54 years apart, suggesting a coordinated pattern beyond individual decision-makers. Various indicators such as homicide rates, suicide patterns, and weapon preferences show cyclical behavior aligned with the 50-year energy/activity wave. Economic activities, inventions, energy market shares, and prices demonstrate remarkable tuning to this cycle. Infrastructure construction, particularly for railways and metros, tends to be anticyclical, occurring mainly during recession periods. The cycle affects deep social behaviors, as evidenced by homicide rates and weapon preferences, changing with economic booms and recessions. This pulsation suggests that human society behaves like a homeostatic body, a concept long perceived but now quantitatively demonstrated. The findings de-emphasize central causes of economic activity, instead viewing it as one of many manifestations of social information trading following biological rules.

Modis [45] suggested that various physical, economic, and social phenomena may exhibit cyclical patterns that align or resonate with the Kondratieff cycle, despite the fact that the strength of these correlations varies, and causal relationships are not always clear. Innovations and patent trends seem to synchronize with the 56-year cycle, peaking during economic hardship. This observation challenges Schumpeter's [8] explanation of the Kondratieff cycle being caused by innovation clustering. Bank failures in the U.S. tend to peak near the troughs of the energy consumption cycle. This suggests a correlation between economic downturns and financial instability. The discovery of basic chemical elements shows some resonance with a 56-year cycle, although the correlation is weak. Sunspot activity exhibits both an 11-year cycle and a longer periodic variation, similar to the energy consumption cycle. A 55-year cycle in sunspot intensity has been detected over a 300-year period. The U.K. Wholesale Price Index, when smoothed over a 27-year period, reveals a wave pattern with an average periodicity of 55.8 years. This provides some evidence for the Kondratieff cycle in economic indicators.

The methodology for linking energy consumption cycles to economic booms and recessions typically involves: (a) collecting comprehensive, long-term data on energy use and economic indicators, (b) identifying periodic behavior in the energy data via smoothing or spectral methods, (c) quantifying how closely peaks and troughs in energy demand correlate with known periods of growth or contraction using cross-correlation coefficients and time-shift analyses. This methodology often find that energy consumption tends to be higher during times of economic prosperity and

lower during downturns, reinforcing the notion that energy demand can serve as a valuable proxy for overall economic activity. By illuminating this relationship, the research not only highlights an empirical pattern but also contributes to the broader conversation about the drivers of economic cycles—offering a nuanced tool for both academics and policymakers in forecasting and analyzing long-term trends [45].

5. Megacycles, new technologies, and economic growth

The historical data on energy consumption provides compelling evidence for a long-term economic cycle of approximately 56 years. While deviations in timing and amplitude, particularly in the U.S. data, indicate that local factors may influence these cycles, the overall pattern aligns closely with Kondratieff’s economic theory. By recognizing the interplay between energy consumption and economic growth, researchers and policymakers can gain a deeper understanding of the drivers behind these cycles and better prepare for the economic fluctuations that lie ahead.

Figure 1 below shows the long-term economic megacycles lasting 56 years, as analyzed by Modis [45], extended to figure out the supposed next 56-year megacycle, starting from 2024 to 2080.

Figure 1 shows the deviations from a logistic growth trend of annual energy consumed data that forms a regular oscillation every 56 years.

Each megacycle consists of 56 years. The first 28 years are characterized by stagnation or recession with a decreasing deviation of energy consumption from the sigmoid curve, where deep and extensive changes take place in the economy due to the emergence of new technologies. These bring about drastic changes in the economy and society, increasing productivity and triggering the next upward part of the cycle of 28 years, where there is an increasing deviation of energy consumption

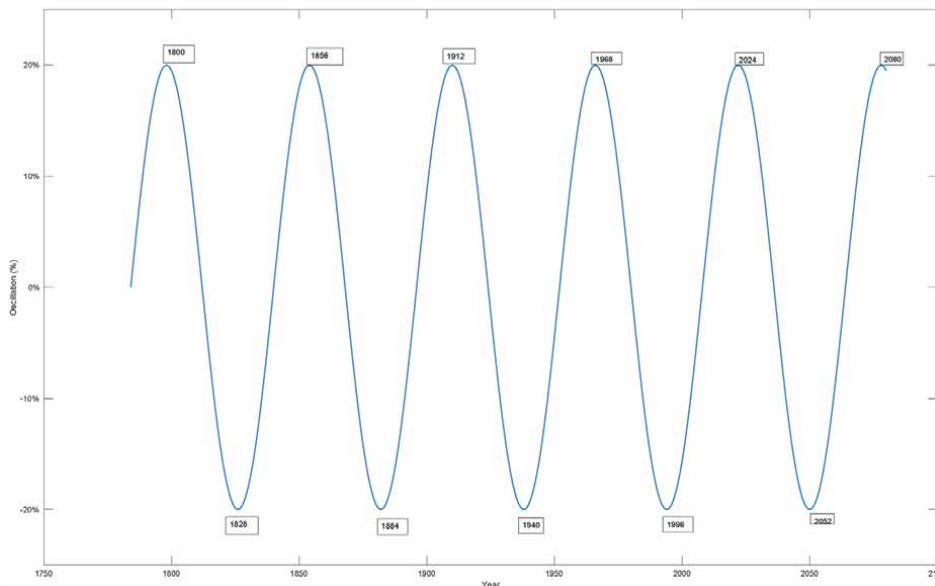


Figure 1.
Regular oscillation of energy consumed from 1800 to 2080 with a 56-year period (deviations from a logistic-growth trend for annual energy consumption).

from the sigmoid curve. During the 28 years, there are smaller sub-periods in the economy of about 7 years.

The start of each economic cycle is associated with the emergence of new key technologies (in the form of technological-industrial revolutions). These lead to a new cheaper source of energy, a new transport infrastructure, a new faster means of transport, and a host of new technological applications emerging and developing in the first 28 years, where the economy is dominated by stagnation, stagflation, and/or anemic growth. It takes almost 28 years for new technologies to become widespread enough to increase productivity by leaps and bounds, creating the next 28 years of growth.

For the past megacycles, an analysis follows, describing the new technologies, the energy source, the transportation infrastructure, the main transportation means, and the country that had emerged in each cycle.

1800–1856: Before 1800, people burned wood and dried manure to heat homes and cook food, while relying on muscle power, wind, and watermills to grind grain. The emergence of new technologies in 1800–1828 allowed the production of energy from water and wind, the construction of factories, the horse-drawn carriage, etc. England emerged as a powerful force.

1856–1912: The emergence of new technologies in the period 1856–1884 with the widespread use of steam engines and coal yielded the development of the economic cycle 1884–1912 where the main fuel was coal with 50% in the energy mix. Railways became the transportation infrastructure and trains the main transportation means. The USA emerged as a new power.

1912–1968: The emergence of new technologies in the period 1912–1940 with the widespread use of internal combustion engines and oil yielded the development of the economic cycle 1940–1968 where oil participated in the energy mix with approximately 40%. Asphalt roads became the transportation infrastructure and cars the main transportation means. Europe and Japan emerged as new powers.

1968–2024: The widespread diffusion of information systems, communication systems, computers, Internet, and its myriad applications during the stagnation of 1968–1996, together with the emergence of cheap natural gas, fueled the new growth cycle until 2024. Airlines are the main infrastructure, and airplanes remain the fastest transportation means. In 2022, the energy mix consisted of about 27% coal, 31% oil, 24% natural gas, and 12% renewable sources. China emerged as a new power.

After 1996, companies appeared that did not exist before and marked new economic sectors, such as: iPhone, Facebook, YouTube, Instagram, Twitter, TikTok, Android, Bitcoin, Tesla, iPad, Gmail, Netflix, Reddit, WhatsApp, Messenger, Google maps, Snapchat, LinkedIn, Skype, Airbnb, etc.

Incorporating new technologies into the global economy is not a single-step process but rather an integrated chain of events spanning R&D, infrastructure development, policy formulation, and societal acceptance. Effective technology integration relies on close cooperation between governments, private sector innovators, academic institutions, and international organizations. Key enablers include well-funded research, robust digital and physical infrastructure, coherent regulatory environments, and a strong emphasis on education and workforce development. Equally important are global collaborations that streamline technology transfer while considering ethical and cultural dimensions. By embracing these processes—supported by continuous monitoring and adaptive frameworks—nations can foster inclusive economic growth, enhance productivity, and drive human progress in an increasingly interconnected world.

6. Forecasting scenario: 2024–2080

Scenario writing involves developing detailed narratives about possible future states based on varying assumptions about key driving forces so that organizations can prepare for a range of potential outcomes and enhance their strategic flexibility.

Figure 1 shows that the previous four major cycles, each lasting 56 years, oscillated precisely from 1800 to 2024. If the oscillation continues with the same precision, it will depict the next megacycle, lasting 56 years, for the period 2024–2080.

Forecasting scenario: 2024–2080: As we look ahead from 2024 to 2080, several transformative shifts are anticipated in technology, energy, and the global economy. Following historical patterns, this period is likely to witness a new wave of innovation, societal change, and the emergence of new global powers as the world transitions from fossil fuels toward renewable and advanced energy systems. The projected era will be shaped by the key technological advancements and the continual evolution of energy sources that drive economic cycles.

2024–2080: The rise of renewable and decentralized energy systems: From 2024 to 2052, the energy sector is expected to undergo significant transformation. Renewable energy sources such as solar, wind, and hydropower are anticipated to dominate the energy mix, further accelerated by breakthroughs in energy storage and grid technology. By 2035, it is projected that renewables will make up over 50% of global energy consumption, displacing fossil fuels as primary energy sources.

Decentralized energy systems will emerge, allowing individual households, communities, and businesses to generate and store their own power, thereby reducing dependency on centralized grids. Innovations in battery storage, such as lithium-sulfur and solid-state batteries, will facilitate this shift. Meanwhile, energy generated from hydrogen fuel cells, especially green hydrogen, will likely see significant growth, contributing to decarbonizing sectors such as heavy industry and long-haul transportation.

This period will also witness the continued development of autonomous transportation systems. Electric vehicles (EVs) will become more affordable and prevalent, while the rollout of autonomous vehicles (AVs) will reshape urban mobility. As electric and autonomous technologies merge, smart cities with integrated transportation networks and sustainable infrastructure will become the norm. The countries are expected to regain economic momentum during this period, driven by advancements in AI, biotechnology, and sustainable infrastructure.

Nuclear fusion holds the promise of becoming a groundbreaking energy source because it has the potential to provide virtually limitless, clean, and safe energy. Unlike current nuclear fission reactors, which split heavy atoms to release energy, fusion works by combining light atomic nuclei—typically isotopes of hydrogen such as deuterium and tritium—to form a heavier nucleus. This process releases a tremendous amount of energy, similar to the reactions that power the sun and stars.

Research projects like International Thermonuclear Experimental Reactor (ITER) in France and private ventures such as Commonwealth Fusion Systems and Helion Energy are making strides toward achieving practical fusion power. ITER, for example, aims to demonstrate sustained fusion reactions and net energy gain by the 2030s. Advances in materials science, plasma physics, and magnetic confinement are driving progress.

If successful, nuclear fusion could revolutionize the global energy landscape by providing a sustainable, high-output energy source that could meet the demands of an ever-growing population. It holds the potential to drastically reduce dependence

on fossil fuels, minimize carbon emissions, and ensure energy security for future generations.

2052–2080: The quantum and artificial intelligent-driven economy: Between 2052 and 2080, quantum computing and artificial intelligence (AI) will redefine the technological landscape, driving a new economic cycle. By the early 2050s, quantum computing will be mature enough to solve complex problems that are currently intractable, leading to advancements in fields such as materials science, pharmaceuticals, and climate modeling. The fusion of AI and quantum computing will accelerate innovation, enabling real-time data processing on a massive scale and enhancing decision-making across industries.

This era will also mark the rise of biotechnology and synthetic biology as dominant forces. Genetic engineering, advanced medical therapies, and personalized medicine will revolutionize healthcare, extending the human lifespan and improving quality of life. At the same time, synthetic biology will enable the creation of bio-based materials, fuels, and products, furthering the shift toward a sustainable and circular economy.

Space exploration and colonization efforts are expected to gain traction during this period, as reusable rocket technology and advancements in life support systems make long-term human habitation on the Moon and Mars viable. Space mining of asteroids and other celestial bodies will potentially yield new resources, such as rare minerals, essential for advanced technologies back on Earth.

The global economic balance is likely to shift once again, with India, Brazil, and regions in Africa emerging as major economic powers, fueled by rapid population growth, resource availability, and technology adoption. These regions will lead in renewable energy production and advanced agricultural technologies, addressing both energy and food security concerns.

Energy mix and infrastructure: By 2080, the global energy mix will be dominated by renewable sources, potentially exceeding 80% of total consumption. Fossil fuels will have largely been phased out, retained only in niche applications or as backup sources. Energy storage and transmission technologies, such as superconducting grids and wireless power transfer, will eliminate most losses in energy distribution, resulting in highly efficient, resilient, and scalable energy systems.

Transportation infrastructure will continue to evolve, with hyperloop systems and advanced maglev trains offering rapid intercity travel, reducing the need for air travel. Autonomous drones and electric vertical takeoff and landing (eVTOL) vehicles will be widely used for short-distance passenger and cargo transport, especially in urban areas.

Sociopolitical and economic implications: The era from 2024 to 2080 will see substantial geopolitical shifts as nations adapt to the new economic landscape. With energy systems becoming increasingly decentralized, smaller nations with abundant renewable resources may gain influence, while traditional energy-exporting nations face economic restructuring. Climate resilience and environmental sustainability will be central to economic strategies, with nations competing on their ability to innovate and implement green technologies.

Technological advancements will likely increase economic inequality within and between countries, as those with access to advanced technologies gain a competitive edge. The widespread use of AI and automation may lead to significant changes in labor markets, necessitating new education and training systems to prepare the workforce for an AI-driven economy.

The trajectory of economic megacycles is inextricably linked to geopolitical realities. Tensions, conflicts, and rivalries can stall or severely disrupt global growth, while

collaboration, shared standards, and concerted policy efforts can spark or extend major periods of economic expansion. Examining historical precedents—from post-World War II reconstruction to contemporary trade disputes—reveals the enduring impact of political dynamics on trade flows, technological innovation, and global prosperity. Looking to the future, the interplay between conflict and cooperation remains crucial. With today's multipolar world and swift technological advancements, nations may face a tapestry of partial alliances, fragmented supply chains, and shifting trade regimes. Maintaining stable, inclusive megacycles will likely depend on multilateral dialog, balanced regulatory frameworks, and pragmatic approaches to climate change and resource management.

7. Discussion

The period from 2024 to 2080 is anticipated to be one of profound change, as humanity transitions to a sustainable and technologically advanced future. The forecasted developments in renewable energy, AI, quantum computing, biotechnology, and space exploration will not only reshape industries but also redefine global power structures and societal norms. By embracing these changes and fostering collaboration across nations, humanity will be better equipped to address global challenges, from climate change to resource scarcity, building a more resilient, equitable world.

The year 2024 is the most important year of the present century. It is the beginning of new exponential changes that will shake the world. During the stagnation that will follow in 2024–2052, humanity will discover and implement new technologies that, when widely spread to every business and every household, will lead to the new cycle of economic growth in the years 2052–2080. Just as after 1996 (1968–1996), information technology and telecommunications had come to be used by all businesses and households, driving the growth of the last 3 decades, so will, over the next three decades, other new technologies like artificial intelligence, be spread and adopted by every business and every household to create the next development cycle.

Some of these new technologies will allow for widespread dissemination and integration into the global production infrastructure of the cheap, “clean” and inexhaustible energy production fuel from nuclear fusion (already in November 2022, the first successful test was made by the U.S.). The 2040s will see the commercial use of nuclear fusion. Without cheap energy, there can be no development of states and decent survival of households and businesses. The hope for cheap, stable, and environmentally friendly energy is nuclear fusion. Its appearance will weaken many important countries as they will lose the huge revenues they had from fossil fuels.

At the same time, we are at the end of the debt cycle, many currencies will depreciate and demand for gold will increase as a storage shelter for existing wealth.

As had already happened repeatedly for thousands of years, the much greater economic demands for money, rather than actual money, led the world to capital flight, selling money and buying gold. This leads to inflation; debt payments will be made in devalued currency. Each cycle was part of the creation of a cycle of geopolitics, and the new power that will emerge in the new cycle will be India.

In the new cycle, new sectors of the economy will be developed based on the high technology of microchips, which will sideline or bring to the fore new partners, economies, and countries. Japan in the 1990s had 32 companies in the world's 50 largest companies. But recently, it only had Toyota in 42nd place. Such tectonic changes will occur in the new economic cycle starting in 2024. New partners have already appeared (Nvidia, OpenAI, etc.). Artificial intelligence (AI), 3D printing,

new material technologies, biotechnology, and quantum computing, among others, will transform economies and societies in the coming decades. By the end of this decade, there will be two kinds of companies: those that are fully using artificial intelligence (AI) and those that are not. Children will have personal AI tutors with vast knowledge, professionals will have personal AI advisors-assistants, and every person will have an assistant to increase their effectiveness. We will be able to create an abundance of intelligence for the world and an abundance of energy that will help us create and develop amazing ideas; our children will be educated more than ever before, people will be more productive, and there will be better health care. All of this will educate and make societies wiser, develop abundance in everything, and with the help of cheap energy, create the next megacycle of economic growth. But there will also be negative use made of technology that may harm humanity.

The new cycle will occur in an environment where the cross-cultural conflict between democratic systems of government and illiberal regimes (sometimes with religious characteristics) is becoming increasingly evident. States with illiberal regimes, no matter what economic prosperity they achieve, do not spread it to the people to increase their standard of living; the wealth is either reaped by oligarchs or channeled into military equipment, threatening democratic countries and creating geopolitical risks. On the other hand, inside many countries, the internal conflict between extreme politicians from both the right and left is becoming more and more evident. The two extremes fight without moral barriers and inhibitions feeding each other, but both have a common goal of conquering the power of the state to attack individual liberties and the institutions of democracy. All this, however, affects the countries, but does not affect the megacycles of the economy that normally evolve with extreme precision, approximately every 5.5 decades.

All countries have an excellent opportunity to dynamically enter the next megacycle through new technologies, to create innovative services and products that are internationally tradable, to develop their economies, to accumulate wealth from international trade, to improve their education, to strengthen their defense, and by making good use of their cultural heritage and cultural diplomacy, to take the position they deserve in the international environment.

Economies need to modernize and introduce new technologies. The influx of cheap labor only temporarily benefits the economy. In the long run, cheap labor slows down the modernization of economies.

An increase in wealth is achieved by an increase in productivity, and an increase in productivity means the same product being produced by fewer hands. This is achieved by machinery and automation, not by introducing workers.

While to date, innovations have increased our muscle power, now with artificial intelligence, our mental power will also increase.

Different transport infrastructures are developed in each cycle: First, canals between rivers were developed, then train lines, highways, airlines, and today magnetic train lines, which appear to be the new transport infrastructure of the next cycle. Similar changes have been seen in means of transportation in land areas: riverboats, trains, cars, airplanes, and today, the appearance of the maglev trains that develop a speed of 600 km per hour. In each cycle, a new country emerges as a rising power.

Incorporating graphs and statistical models is a powerful way to demonstrate the link between energy consumption and economic growth. By selecting robust datasets, employing relevant visualization techniques, and interpreting the findings in a broader policy context, analysts and stakeholders can gain deep insights into how

energy fuels growth—and how strategic decisions can shape a more sustainable and efficient future. These visuals not only make the argument more compelling but also serve as a basis for nuanced policy discussions on how to balance economic development with the environmental stewardship.

8. Conclusion and limitations

The analysis of long-term economic megacycles, as discussed by Modis [45], presents a compelling argument regarding the interrelation between energy consumption economic cycles and technological innovations. The 56-year economic megacycles, sometimes referred to as Kondratieff cycles, are evident in the oscillations of energy consumption deviations from a cumulative sigmoid curve. These cycles, based on the fluctuations in energy consumption over time, underscore how the global economy reacts to and depends upon varying levels of energy demand.

The data analyzed by Modis [10, 45] reveals an intriguing pattern, wherein there is a rhythmic oscillation in energy consumption. Modis's [45] study demonstrates this oscillation, illustrating that energy consumption can be as much as 20% higher or lower than anticipated during certain periods. Such deviations suggest that there are phases where energy consumption surges, reflecting heightened economic activity, and periods where it subsides, signaling economic downturns. This pattern supports the concept of economic cycles, where heightened energy use correlates with economic growth and prosperity, while decreased energy consumption indicates recession, stagnation, or depression.

The analysis presented by Modis [45] contributes valuable insights into the relationship between energy consumption technology evolution and economic performance. By identifying and explaining these long-term cycles, and the new technologies that dominate each cycle, a framework is provided that helps to interpret past economic patterns and potentially forecast the future trends of the next megacycle from 2024 to 2080. Recognizing these cycles' existence and their relationship with energy consumption and new technologies equips policymakers, economists, experts in technological forecasting, futurologists, demographers, businesspeople, economic historians, political scientists and politicians, sociologists, anthropologists, and even philosophers with the knowledge to anticipate economic shifts and better prepare for periods of both growth and decline.

The chapter presents several complex issues that necessitate further research, primarily concerning the measurement of technological progress, the implications of global aging, changes in the labor market, and potential transformations in socioeconomic structures. These areas, individually and collectively, pose significant questions about the future of human society and demand closer examination. The current methods may offer valuable insights, but exploring alternative approaches could yield more accurate predictions and reveal new facets of technological change and economic cycles. A particularly pressing issue is the relationship between global aging and technological progress. Aging populations are an unprecedented phenomenon that could potentially slow down scientific and technological advances.

The chapter does not address the impact of technological progress, particularly in machine learning, AI, nanotechnology, biotechnology, robotics, information, and cognitive technologies, which may exponentially increase the changes in the economy and may influence the period of diffusion of the technologies in comparison with the past cycles.

This chapter is not taking into consideration the transformation of human civilization, with entirely new socioeconomic relationships likely to emerge. As technological advancements reshape industries, lifestyles, and consumption patterns, current models of production and consumption may become obsolete. The shift may be driven by various factors, including environmental constraints, resource scarcity, and changing values, leading to more sustainable and collaborative economic models.

The authors speculate that these transformations could result in a radical departure from today's consumption-driven economies, but they emphasize that more in-depth research is needed to understand the underlying causes and potential directions of this shift. Exploring topics like the circular economy, the sharing economy, and new forms of governance could provide insights into what such a future might look like. However, given the complexity of these issues, a comprehensive approach will be necessary to capture the breadth and depth of possible changes.

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Reasons for Change in Personal Income by Country in the Twenty-First Century and Evaluations of OECD Countries

Ahmet Yüzbaşıoğulları

Abstract

This chapter investigates the structural relationship between personal income and core macroeconomic indicators such as GDP and GNI, drawing on the theoretical contributions of Kuznets and institutional frameworks provided by leading economic bodies. It argues that sustainable growth in personal income, especially in high-income countries, is contingent upon the enhancement of national competitiveness through focused economic policy and institutional reforms. The ongoing transition from industrial production to service-based economies—amplified by globalization—has significantly reshaped income distribution and productivity dynamics. Utilizing the World Economic Forum's Competitiveness Framework, the study applies a Generalized Linear Model (GLM) to analyze the determinants of personal income across OECD countries. Empirical findings highlight Business Sophistication, Innovation Capacity, and the Efficiency of Goods and Labor Markets as the most influential drivers of income. Importantly, the analysis reveals that R&D investment exhibits a stronger and more consistent association with personal income growth than general education expenditures, underlining the importance of knowledge-based productivity strategies. The chapter concludes by outlining a set of integrated policy recommendations designed to foster inclusive economic well-being. These strategies emphasize the critical role of innovation systems, competitive market structures, and targeted human capital investment in enhancing national productivity and ensuring long-term income growth.

Keywords: personal income, business sophistication, innovation, global competitiveness, economic growth

1. Introduction

Personal income, as defined by the Bureau of Economic Analysis [1, 2], encompasses earnings from active labor participation, income from property or business ownership, financial assets, and transfers. It is a cornerstone of individual quality of life and a primary source of income tax revenue for states. The critical role of personal

income in both individual welfare and public finance necessitates close governmental monitoring and regulation. Changes in its level and composition serve as vital indicators of the societal impact of economic and social policies. Governments strive to boost overall personal income through economic policies and ensure its equitable distribution *via* social policies [3]. The simultaneous application of these policy sets is paramount; failure to do so can lead to social unrest and political instability, deterring investment and causing long-term declines in average personal income [4]. This chapter aims to delineate the specific policy levers and economic mechanisms necessary for sustainably increasing personal income in advanced economies, a matter of critical importance for both individuals and countries. The central argument is that enhancing national competitiveness, not just broadly but through targeted improvements in identified key economic mechanisms and pillars, provides a powerful pathway to sustainable personal income growth.

To properly structure this multifaceted investigation and build toward specific policy conclusions, the second section meticulously outlines the constituent components of personal income and elucidates its intricate relationship with key macroeconomic variables, thereby establishing the foundational economic linkages and transmission channels between national output and individual income. The third section highlights the pivotal role of education and R&D activities, conceptualized as crucial investments in human capital and innovation systems, which function as critical economic mechanisms for enhancing individual welfare and bolstering competitiveness, aligning with insights from endogenous growth theory [5]. The fourth section examines how significant twenty-first-century drivers—including rapid technological advancements and globalization—have impacted the distribution of income, exploring the underlying economic causes and consequences of trends such as job polarization and the changing composition of personal income, thereby identifying challenges that competitiveness policies must address. Subsequently, the fifth section presents a framework of policies for fostering personal income growth, emphasizing how leveraging global economic integration must be coupled with strengthening domestic capabilities. Given the robust statistical infrastructure of OECD countries, the study's empirical analysis and specific policy recommendations are tailored to this group. The Global Competitiveness Index (GCI) provided by the World Economic Forum (WEF) is utilized in the sixth section as an analytical framework. A Generalized Linear Model (GLM) analysis is applied to GCI data to empirically identify the most influential economic mechanisms, leading to concrete policy conclusions aimed at enhancing personal income through improved competitiveness. Section 6.13 discusses the robustness of the econometric models and addresses methodological limitations, framing the derived policy insights appropriately. This seventh and concluding section provides a clear synthesis of the findings, arguing that sustainable growth in individual prosperity is inextricably linked to enhancing national competitiveness through targeted, mechanism-based policies, particularly highlighting R&D investments and key competitiveness factors as critical policy levers for increasing personal income and fostering more equitable growth.

2. Components of personal income and their relationship with national accounts

Understanding the economic mechanisms that link national economic output to individual income is crucial for policy formulation. Simon Kuznets's seminal work in

the 1930s laid the groundwork for modern national accounts, providing a systematic approach to measuring national income and its distribution [1]. His categorization of personal income offered a detailed lens on economic dynamics. This foundational work was instrumental in developing comprehensive Systems of National Accounts (SNA), such as the framework standardized by the United Nations [6].

2.1 Formation of national accounts

Sustained growth in Gross Domestic Product (GDP) is fundamental for national welfare. While a key indicator of economic activity, GDP has limitations in capturing societal well-being, as it omits factors such as income distribution, unpaid work, and environmental externalities [7].

In an increasingly globalized economy, Gross National Income (GNI), which is GDP plus net factor income from abroad, often provides a more pertinent measure of income accruing to a nation's residents. The World Bank data (2000–2022) showing an average annual net transfer of approximately \$102 billion from low- and middle-income to high-income countries underscores the significance of these international flows in shaping national income and global disparities. Such transfers significantly influence development trajectories and represent a key external economic mechanism affecting national prosperity.

To address sustainability concerns, Adjusted Net National Income (ANNI) offers a more comprehensive measure by accounting for depreciation and the depletion of natural resources and environmental degradation, aligning with “green accounting” principles [8].

Critically, for OECD countries (2000–2021), strong panel correlations exist between per capita personal income and these national accounting aggregates (**Table 1**). The highest correlation (95%) is between per capita personal income and per capita GNI. This pivotal empirical finding suggests that policies successfully augmenting GNI per capita are highly effective economic mechanisms for enhancing average individual income levels. This implies that strategies optimizing a nation's net earnings from international engagements, not just domestic production, are crucial for improving residents' material well-being. Policy Insight: Strategies should focus on improving terms of trade, fostering outward Foreign Direct Investment (FDI), generating repatriated income, and attracting high-value inward FDI to directly leverage this mechanism.

2.2 Composition and development of GDP

The sectoral composition of GDP reveals underlying structural economic transformations. In most OECD countries, a pronounced shift from industry to services is

	PER.INC.	GDP	GNI	ANNI
PER.INC.	1.00	0.94	0.95	0.90
GDP	0.94	1.00	0.99	0.94
GNI	0.95	0.99	1.00	0.95
ANNI	0.90	0.94	0.95	1.00

Source: Personal income data is from the OECD; other data is from the World Bank.

Table 1.
Correlation between per capita personal income, GDP, GNI, and ANNI values.

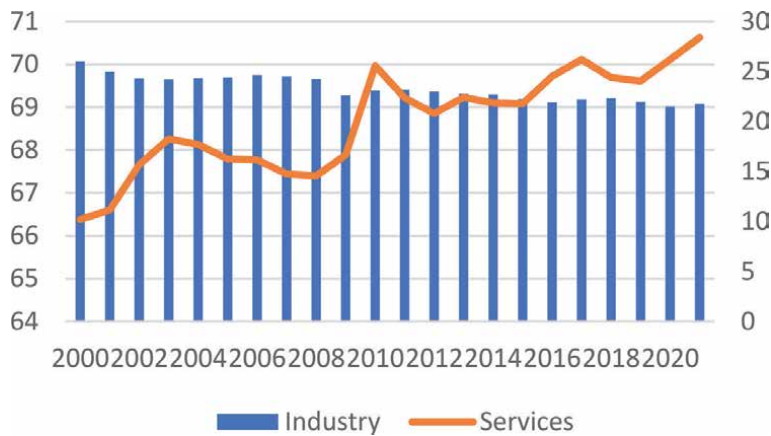


Figure 1.
Industry vs. services for OECD countries (value added (% of GDP)).

evident: the service sector’s GDP contribution rose from an average of 66% in 2000 to 70% in 2021, while the industrial sector’s share declined from 26–21% (conceptually illustrated in **Figure 1**). This “tertiarization” is driven by factors such as globalization, technological advancements (ICT, automation), and changing consumer demand patterns (Engel’s Law).

The service sector is highly heterogeneous, ranging from high-value, knowledge-intensive business services (KIBS) to traditional, often lower-wage personal services. This diversity has profound implications for overall productivity (“Baumol’s cost disease” [9]) and income distribution. These structural shifts impact employment, demanding new skills and potentially leading to labor market adjustments. The service sector is positioned as the primary engine for future personal income growth in OECD countries, presenting policy challenges in fostering productivity and ensuring inclusive benefits. Understanding this structural shift is vital for identifying the relevant economic mechanisms for income growth in advanced economies.

2.3 Composition and development of personal income

Empirical studies, such as analyses of Swedish household data, demonstrate that personal income comprises wages, social transfers, capital returns, and other sources [10]. The twenty-first century has witnessed a structural shift in advanced economies in the United States, for instance, the wage share of personal income declined from ~76% (1990) to ~68% (2019), while capital-related income (rents, royalties, capital gains) rose from ~6% to ~14% (U.S. Bureau of Economic Analysis, 2024; [11]; **Figure 2**).

This reallocation reflects broader economic mechanisms linked to rising inequality. The decline in labor’s share of income—documented globally [12, 13]—stems from deindustrialization, skill-biased technological change, and globalization [14]. In the U.S., the negative correlation (–0.71) between wage share and the GINI index challenges the Kuznets hypothesis, which posits that inequality eventually declines with development [15]. Piketty’s $r > g$ framework [16] further elucidates how excess returns on capital over growth rates perpetuate inequality, necessitating policy interventions to ensure equitable income distribution.



Figure 2.
Sources of personal income in the USA.

3. Contributions of education and R&D expenditures to changes in personal income

Investment in human capital—manifested through formal education and skill development [17, 18]—and strategic R&D expenditures [5, 19] are recognized as mutually reinforcing drivers of sustained personal income growth and aggregate economic prosperity. At the microeconomic level, the earnings function, often referred to as the Mincer equation ([20]; Eq. (1)), remains foundational for modeling individual earnings, with considerable subsequent research exploring its nuances, applications, and causal interpretations [21, 22]:

$$\ln(Y_i) = \beta_0 + \rho S_i + \beta_1 X_i + \beta_2 X_i^2 + \epsilon_i \quad (1)$$

Here, $\ln(Y_i)$ represents the natural logarithm of individual earnings, S_i denotes years of schooling, and $(X = \text{Age} - S - 6)$ approximates potential labor market experience, assuming school entry at age six. The parameter ρ estimates the private return to schooling, while coefficients β_1 and β_2 capture the concave lifecycle earnings trajectory. While Eq. (1) provides critical insights into individual-level wage determination, its direct extension to macroeconomic phenomena (e.g., national income) is conceptually limited, as it omits systemic factors such as R&D spillovers, institutional quality, and demographic dynamics [23].

In technologically dynamic economies, the education-income relationship grows more complex. Skill-biased technological change may exacerbate wage dispersion unless educational systems adapt to evolving skill demands [24]. Concurrently, R&D investment is essential for converting technological potential into productivity gains. Although middle-income countries have increased R&D intensity (from 0.6–2% of GDP), they remain behind high-income economies, where R&D averages 2.3–2.9% of GDP.

To assess macroeconomic linkages, we estimate a Generalized Linear Model (GLM) for OECD countries, regressing national personal income on government expenditures in education and R&D (as % of GDP). Results in **Table 2** indicate that R&D intensity exhibits a stronger association with income (coefficient = 5084.98, $p < 0.01$) than education spending (coefficient = 2005.77, $p < 0.01$). Three critical caveats apply:

Variable	Coefficient	Std. Er,	z-Sta,	Prob,
R&D Ex.	5,084.98	337.79	15.05	0.00
Gov.Ex.Ed.	2,005.77	107.09	18.73	0.00

Table 2.
Modeling of personal income with the ratio of education and R&D expenditures to GDP.

- Scale sensitivity: Coefficients reflect absolute income changes per 1 percentage point increase in GDP allocation. Presenting elasticities (e.g., percentage change in income per percentage change in R&D) would enhance interpretability.
- Causality limitations: The GLM identifies correlations, not causal effects, due to unobserved confounders (e.g., innovation ecosystems, institutional path dependency). Future work should employ instrumental variables (e.g., historical R&D policies) to isolate causal mechanisms.
- Experience measurement: The assumption of uniform school entry at age six is empirically invalid across OECD countries (e.g., school entry at age seven in Nordic systems), introducing measurement error in X_{it} .
- *Key implications:*
 - R&D investments yield higher marginal returns in advanced economies near the technological frontier, but their efficacy depends on a skilled workforce produced by robust education systems.
 - Education remains necessary but insufficient for income growth; complementary investments in innovation infrastructure (e.g., patent systems and technology transfer programs) are critical [5, 19].

A comprehensive framework for income growth must integrate human capital theory with broader macroeconomic determinants, including demographic dynamics, public health, and institutional quality [23]. Future research should employ dynamic models (e.g., panel vector autoregressions) to disentangle temporal lags and bidirectional relationships between R&D, education, and income.

4. Causes and consequences of changes in the distribution of personal income

Significant technological advancements in the twenty-first century have reshaped labor markets through job polarization, a key economic mechanism impacting income distribution [25, 26]. Technology complements high-skilled tasks while substituting for routine middle-skilled work, contributing to a reduction in the middle class and widening inequality. A Panel Generalized Linear Model (GLM) analysis of the GINI index in OECD countries (**Table 3**) empirically supports this, indicating a statistically significant upward trend in income inequality over the period 2001–2023. The significant positive coefficient for the lagged GINI variable (0.54, $p = 0.00$) suggests notable persistence in income inequality.

While OECD nations face technology-driven shifts, global income disparities persist, challenging assumptions such as “trickle-down economics,” as aggregate growth has not always translated into broadly shared prosperity [27, 28]. Economists advocate for proactive state roles, including strategic public investments and progressive reforms, to address inequality [29]. Sen’s capability approach [30, 31] emphasizes that true development requires expanding individuals’ capabilities and freedoms, considering how factors beyond income affect well-being. Understanding these dynamics of inequality and the changing nature of work is crucial for designing policies that promote not just income growth but also inclusive income growth.

From a macroeconomic demand perspective, household consumption is typically the largest component of GDP. Global trends show a divergence: while global GDP per capita rose from approximately \$7875 in 2000 to approximately \$11,112 in 2021, the share of household consumption in global GDP fell from 61–55%. This is illustrated in **Figure 3** (titled: GDP per capita vs. household consumption), which reportedly shows a strong negative correlation (–93%) between these trends. This suggests that national income increases are not proportionally translating into household consumption growth globally, potentially due to rising inequality (wherein higher-income individuals have a lower marginal propensity to consume) or shifts in income distribution toward profits or investment. While Gross Capital Formation (GCF) has increased, a declining household consumption share relative to GDP raises concerns about whether the benefits of growth are sufficiently enhancing current personal welfare.

Taxation policies are critical in shaping net personal income and its distribution. In high-income OECD countries, taxes on income and profits constitute about 25% of total tax revenue. While this share has been rising in middle-income countries (from

Variable	Coefficient	Std. Er,	z-Sta,	Prob,
C	10.94	0.88	12.45	0.00
GINI In.(–1)	0.54	0.03	18.43	0.00

Table 3.
Modeling of the GINI Index of OECD countries (2001–2023) using the GLM method.

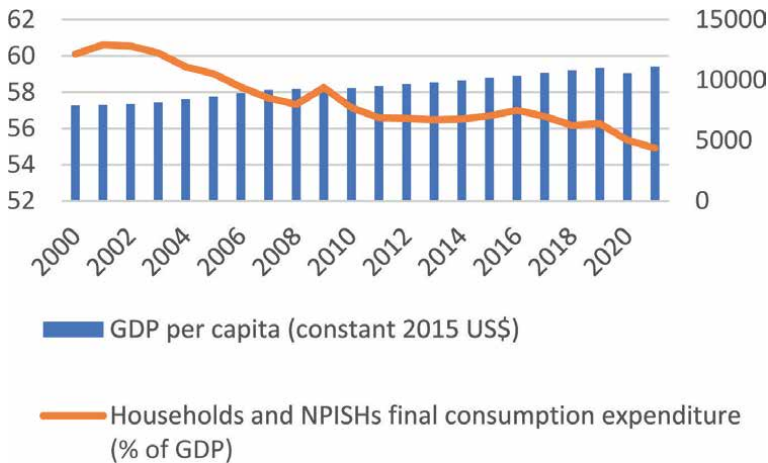


Figure 3.
GDP per capita vs. household consumption.

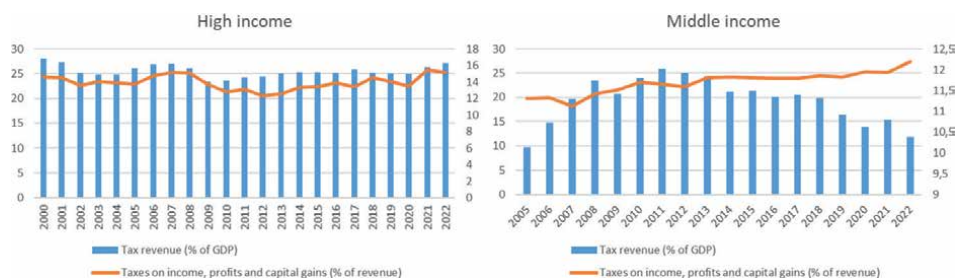


Figure 4.
The ratio of taxes in high- and middle-income countries to GNP and the share of taxes on income, profits, and capital gains in total taxes (2000–2022).

approximately 20–27%), the overall tax burden shows a declining trend in many nations. Reduced tax revenues can constrain public spending on essential services (such as education, healthcare, and infrastructure) that are crucial for personal income growth, exacerbate inequality if the tax system is not progressive, and potentially slow development.

Policy insight: Tax policies must balance public finance needs and redistribution goals with incentives for work and investment. Progressive tax systems and effective social safety nets are crucial policy levers to counteract rising inequality driven by the economic mechanisms discussed (Figure 4).

5. Policies to increase personal income

The contemporary global economic landscape, shaped by technology and globalization, necessitates policies that actively target the economic mechanisms driving value creation and income generation. While participation in Global Value Chains (GVCs) offers opportunities for national income growth, employment, and productivity gains [32, 33], harnessing these benefits requires a conducive policy environment focused on trade facilitation, infrastructure investment (especially in transport and ICT), and targeted skills development [34]. This represents a crucial mechanism for leveraging external economic engagement for domestic income growth.

National prosperity, as Porter [35] articulated, is created through national competitive power, built upon dynamic local companies, sophisticated domestic demand, and robust sectoral innovation capacity. Achieving such success requires continuous education, R&D investment, digitalization, and global thinking. Policies derived from Porter’s Diamond Model—enhancing “factor conditions,” stimulating “demand conditions,” fostering “related and supporting industries,” and promoting “firm strategy, structure, and rivalry”—are essential policy levers for building this competitive advantage. Such approaches can be complemented by strategic considerations from modern industrial policy aimed at nurturing specific national capabilities and addressing market failures in structural transformation [36].

Contemporary competitiveness increasingly hinges on non-price factors such as technological sophistication, product quality, and speed [37]. This shift mandates a focus on policies that prioritize the enhancement of technological competitiveness through R&D incentives, public funding, university-industry collaboration, and strong intellectual property rights. Improving logistics and supply chain efficiency,

promoting quality standards, and supporting innovative enterprises are also key mechanisms for competing on value rather than solely on price.

The effective diffusion of technological innovations is a critical determinant of productivity growth and, consequently, personal income enhancement [38]. Policies can foster such diffusion through technology extension services for small and medium-sized enterprises (SMEs), support for collaborative research, and incentives for technology adoption. Developing a well-functioning National System of Innovation [39, 40] is therefore a central policy objective. Ultimately, policies that strengthen these non-price determinants of competitiveness create an environment conducive to higher productivity, innovation, and value creation, which are the fundamental economic mechanisms through which sustainable increases in personal income can be achieved.

6. Policy recommendations based on the global competitiveness indexes of OECD countries

Internationally recognized competitiveness indices, such as the World Competitiveness Index (WCI) by International Institute for Management Development (IMD) and the Global Competitiveness Index (GCI) by the World Economic Forum (WEF), serve as critical analytical tools [41, 42] for identifying the multifaceted drivers of productivity and prosperity, with the very measurement and definition of competitiveness being an important subject of economic inquiry [43]. While these indices are widely utilized, their methodological construction and applicability to diverse national contexts, particularly developing economies, remain subjects of scholarly debate and ongoing economic evaluation [44]. Broadly, these frameworks emphasize factors such as innovation, technological investment, and human capital as key determinants of sustained economic growth and improved living standards, which are, in turn, strongly associated with higher personal income levels [45].

A robust empirical relationship between national competitiveness and personal income is evidenced by the strong positive correlation ($r = 0.70$) observed between OECD countries' IMD WCI scores and their per capita personal income over the 2001–2022 period (see **Table 4**). The covariance of 83,053.28 further underscores significant joint variability between these measures. This association reinforces the argument that enhancing national competitiveness can serve as an effective policy lever for fostering personal income growth.

To identify actionable policy priorities, this section subsequently analyzes the relative importance of the 12 pillars comprising the WEF GCI (2008–2017 data) using a GLM. The estimated coefficients from this model, indicating the impact of each pillar on overall competitiveness, are presented in **Table 5**. The analysis reveals that Business Sophistication (coefficient: 0.14), Innovation (0.13), and the efficiencies of the Goods Market (0.11) and Labor Market (0.11) are the most influential drivers. These findings provide an empirical basis for prioritizing policy interventions, which are detailed in the following subsections.

6.1 Institutions (coefficient: 0.05)

Institutions constitute the “rules of the game” that lower transaction costs and foster productive economic activity [46, 47]. Improvements in institutional quality necessitate the enactment of robust legal statutes, the impartial enforcement of

Covariance	IMD IND.	PER. IN.
Correlation		
IMD IND.	203.53	
	1.00	
PERS.IN.	83,053.28	69,732.184.00
	0.70	1.00

Table 4.
Correlation between personal income and the WCI.

Pillar	Variable	Coef,	Pillar	Variable	Coef,
1	Institutions	0.05	7	Labor Market Efficiency	0.11
2	Infrastructure	0.04	8	Financial Market Development	0.07
3	Macroeconomic environment	0.07	9	Technological readiness	0.05
4	Health and primary education	0.07	10	Market Size	0.09
5	Higher education and training	0.07	11	Business Sophistication	0.14
6	Goods Market Efficiency	0.11	12	Innovation	0.13

Table 5.
Ranking of GCI pillars by importance using the GLM method.

regulations, and the deployment of digital technologies to enhance transparency. Within the Global Competitiveness Index framework, the sub-pillars of Ethical Behavior of Firms (14% weight) and Property Rights (12%) are particularly salient.

Policy implication: Implementing stringent anti-corruption legislation, streamlining judicial procedures to reduce case backlogs, and codifying clear property rights regimes will strengthen investor confidence. Although institutions exert an indirect influence on personal income growth through market efficiency, their comparatively modest coefficient (0.05) indicates that complementary interventions—particularly in human capital and market liberalization—are required to generate more pronounced income effects.

6.2 Infrastructure (coefficient: 0.04)

Social overhead capital (SOC), exemplified by durable infrastructure, diminishes operating expenses and enhances overall welfare, though its realization is often contingent upon institutional capacity [48, 49]. The GCI’s principal sub-pillars in this dimension are the Quality of Electricity Supply (26%) and the Quality of Roads (21%).

Policy implication: Prioritizing sustainable financing mechanisms—such as public-private partnerships and user-fee models—for the expansion and maintenance of transport and utility networks can reduce logistical bottlenecks and raise productivity. Given the infrastructure pillar’s limited coefficient (0.04), synergies with institutional reforms and investments in human capital are essential to translate infrastructure improvements into substantial wage increases.

6.3 Macroeconomic environment (coefficient: 0.07)

A predictable macroeconomic environment, characterized by stable price levels, prudent public debt management, and exchange-rate stability, underpins long-term capital formation [50, 51]. Key GCI sub-pillars include Gross National Savings (21%) and Inflation Control (14%).

Policy implication: Coordinated fiscal restraint and credible monetary-policy frameworks—supported by independent central banks and transparent budgetary processes—can anchor inflation expectations and sustain domestic savings. The macroeconomic environment’s moderate coefficient (0.07) underscores its role in preserving economic value; yet, transformative gains in personal income also depend on structural reforms that enhance productivity and labor market flexibility.

6.4 Health and primary education (coefficient: 0.07)

Investment in health, conceptualized as a crucial component of human capital [52], alongside universal primary education, constitutes foundational elements of human capital accumulation. Although the statistical significance of individual sub-pillars may vary across contexts, the aggregate coefficient (0.07) highlights their collective importance.

Policy implication: Ensuring equitable access to frontline healthcare and primary school instruction—particularly in underserved regions—lays the groundwork for a more capable workforce. Targeted interventions, such as rural health clinics and community-based teacher training, are necessary to maximize the developmental returns on public spending in this domain.

6.5 Higher education and training (coefficient: 0.07)

Advanced education and ongoing vocational training equip individuals with specialized skills that align with evolving labor market demands [53]. The GCI designates Research and Training Services (25%) and Staff Training (19%) as its critical sub-pillars.

Policy implication: Fostering collaborations between universities and industry—through co-funded research centers and apprenticeship schemes—can enhance curriculum relevance and promote innovation. The moderate coefficient (0.07) suggests that improvements in the quality of tertiary and continuous learning, rather than mere expansion of enrollment, are pivotal for elevating personal incomes.

6.6 Goods market efficiency (coefficient: 0.11)

Efficient goods markets facilitate the optimal allocation of resources by ensuring competitive pricing and reducing barriers to entry [54], drawing on broader principles of market efficiency, aspects of which have also been extensively studied in contexts such as capital markets [55]. Within this pillar, Customer Orientation (28%) and Local Competition Intensity (15%) emerge as foremost sub-pillars.

Policy implication: Strengthening competition policy—*via* rigorous antitrust enforcement and the elimination of unwarranted trade and nontariff barriers—can stimulate entrepreneurship and drive down consumer prices. As an influential driver

(coefficient = 0.11), enhancing market contestability has a direct and observable effect on real incomes.

6.7 Labor market efficiency (coefficient: 0.11)

Efficient labor markets are crucial for matching workers with appropriate jobs, thereby ensuring the optimal utilization of human capital [46]. Significant Global Competitiveness Index (GCI) sub-pillars in this domain include the Ratio of Women in the Labor Force to Men (highlighted with a notable indicator value of 165%), Flexibility of Wage Determination (12% weight within the pillar), and the linkage of Pay and Productivity (12% weight). Achieving gender parity expands the available talent pool and can significantly boost household incomes, while flexible wage mechanisms and strong pay-productivity links ensure that labor markets can adjust to changing conditions and that workers share in productivity gains.

Policy implication: Also identified as a top critical area for overall competitiveness (jointly with Goods Market Efficiency, each pillar reflecting an 11% relative importance in the broader model), reforms enhancing Labor Market Efficiency are vital. Policy efforts should focus on implementing active labor market policies, promoting gender equality (e.g., through accessible childcare and equitable parental leave policies), and fostering flexible wage determination systems while ensuring fair labor standards. Furthermore, policies that strengthen the link between Pay and Productivity can concurrently boost employment levels and wage growth, directly impacting personal incomes.

6.8 Financial market development (coefficient: 0.07)

Developed financial markets play a key role in mobilizing savings, allocating capital to its most productive uses, and enabling effective risk management. Within the GCI framework, key sub-pillars include Ease of Access to Loans (32% weight) and Regulation of Securities Exchanges (29% weight). Access to credit is essential for business expansion, while robust regulation is critical for maintaining financial stability.

Policy implication: Policies should aim to foster both financial deepening and stability through prudent, well-enforced regulation. Promoting financial inclusion to broaden access to financial services and strengthening regulatory frameworks can provide the necessary capital for businesses to invest, innovate, and grow, thereby creating employment and income-generation opportunities.

6.9 Technological readiness (TR) (coefficient: 0.05)

A nation's capacity to adopt and effectively implement existing technologies, often termed "absorptive capacity," is crucial for enhancing productivity and national competitiveness. Key GCI sub-pillars in this area are the Availability of Latest Technologies (51% weight) and the extent of Foreign Direct Investment (FDI) and Technology Transfer (17% weight).

Policy implication: Fostering technology adoption requires concerted efforts, including investing in digital literacy programs, ensuring robust ICT infrastructure, maintaining open investment regimes that facilitate technological spillovers from FDI, and supporting firms in their technological upgrading efforts. Such initiatives

can enhance productivity across various sectors, a key driver of sustainable wage growth and improved personal incomes.

6.10 Market size (coefficient: 0.09)

The scale of a market influences levels of investment, the potential for economies of scale, and the intensity of competition. The GCI framework emphasizes the strength of the domestic market (carrying a 75% weight within this pillar) as a foundational element for competitiveness, a concept also highlighted in economic literature [35].

Policy implication: Policies aimed at expanding the effective Market Size can stimulate economic activity and business growth, ultimately leading to increased income-generation opportunities. This includes measures to strengthen domestic demand (e.g., through maintaining macroeconomic stability and robust consumer protection) and strategies to facilitate access to foreign markets (such as negotiating trade agreements and implementing effective export promotion programs).

6.11 Business sophistication (BS) (coefficient: 0.14)

Business Sophistication pertains to the quality and density of business networks as well as the operational and strategic capabilities of individual firms. Key GCI sub-pillars in this domain include the Quality of Local Suppliers (14% weight), Willingness to Delegate Authority within firms (13% weight), and the Extent of Marketing (13% weight). High-quality local suppliers, agile management structures, and effective marketing strategies are critical drivers of differentiation and value creation.

Policy implication: Identified by the GLM analysis as the single most impactful area for overall competitiveness (coefficient = 0.14), enhancing Business Sophistication is paramount. Policies should focus on supporting the development of dense, high-quality local supplier networks (e.g., through cluster development initiatives), encouraging the adoption of modern management practices and corporate governance standards, and fostering firm-level innovation and strategic marketing capabilities. Such efforts can drive firms toward higher value-added activities, thereby improving national competitiveness and creating better-paying jobs, which directly increases personal income.

6.12 Innovation (coefficient: 0.13)

Innovation is a fundamental driver of long-term productivity growth and competitiveness, enabling economies to create new value and maintain a dynamic edge. Key GCI sub-pillars reflecting a nation's innovation capacity include Company Spending on R&D (21% weight) and the Quality of Scientific Research Institutions (19% weight), both of which are central to national innovation systems thinking [39, 40].

Policy implication: As the second most critical pillar for overall competitiveness (coefficient = 0.13), fostering a robust innovation ecosystem is of utmost importance. This requires a multifaceted approach, including implementing R&D incentives, strengthening linkages between public research institutions and industry, actively promoting university-industry collaboration, ensuring effective intellectual property protection, and facilitating access to venture capital. A vibrant innovation ecosystem is vital for creating high-value jobs and increasing national income, which in turn directly boosts personal incomes.

6.13 Robustness checks of econometric models and methodological limitations

The robustness checks of the econometric models used to analyze the relationship between global competitiveness indices and personal income levels are critical for assessing the methodological validity of the study. The diagnostic test results presented in **Table 6** confirm that the statistical assumptions underlying the models are largely satisfied, supporting the reliability of the estimators.

Model fit and error term analysis: Low root mean squared error (MSE) values (e.g., 0.04 for GCI; 0.10 for Innovation) indicate minimized prediction errors and high explanatory power of the models. Negative and low Hannan-Quinn Criterion (HQC) values (e.g., –6.38 for Institutions; –67.51 for Market Size) suggest optimal model specification without overfitting. Proximity between the standard deviation of the dependent variable (S.D. Dep. Var.) and root MSE (e.g., 0.49 vs. 0.04 for GCI) further validates the models’ explanatory capacity.

Distributional assumptions: Skewness coefficients for most variables are close to zero (e.g., –0.31 for Institutions), reflecting near-symmetric residual distributions. However, some variables, such as Labor Market Efficiency (Skewness: 1.22), exhibit moderate skewness. Kurtosis values around 3 (e.g., 3.92 for macroeconomic environment; 2.42 for technological readiness) align with the properties of a normal

Variable	Root MSE	HQC	S.D. dep. Var.	Skew.	Kurt.	Jargue- Bera
GCI	0.04	–3.47	0.49	0.58	3.73	30.04
Institutions (1)	0.01	–6.38	0.84	–0.31	3.09	3.75
Infrastructure	0.19	–0.43	0.77	–0.37	4.19	24.39
Macroeconomic environment	0.90	2.66	0.76	–0.19	3.92	15.99
Health and primary education	Owing to the inconsistency of the p-values, the estimated coefficients were not considered reliable and were therefore disregarded.					
Higher education and training	0.11	–1.54	0.54	–0.48	3.28	15.11
Goods Market Efficiency (1)	0.07	–2.30	0.40	–0.07	3.26	0.58
Labor Market Efficiency	0.06	–2.67	0.55	1.22	5.10	65.87
Financial Market Development (1), (2)	0.18	–0.33	0.56	–0.02	3.03	0.00
Technological readiness (1)	0.21	–0.23	0.70	–0.37	2.42	7.01
Market Size (1), (2)	0.00	–67.51	0.97	–0.05	2.65	2.07
Business sophistication	0.03	–3.81	0.61	0.55	4.33	47.53
Innovation (1)	0.10	–1.67	0.85	0.45	3.56	9.18

(1) The error terms are normally distributed.
(2) There is no autocorrelation in the error terms.

Table 6.
Diagnostic tests of model robustness.

distribution for many variables. Jarque-Bera test results confirm normality for residuals in variables such as Institutions, Financial Market Development, and Market Size (denoted by (1) in **Table 6**), though normality is rejected for Labor Market Efficiency and Business Sophistication, suggesting that residuals in these specific models may deviate from a normal distribution.

Autocorrelation diagnostics: The absence of autocorrelation in Financial Market Development and Market Size models (marked by (2) in **Table 6**) supports estimator consistency for these specific models. However, the lack of comprehensive autocorrelation tests reported for all other pillar-specific models highlights a potential area for further investigation; future studies could benefit from employing dynamic panel models or time-series techniques (e.g., ARIMA) where appropriate to explicitly account for potential serial correlation.

Limitations and recommendations for future research: Inconsistent p-values for health and primary education excluded this variable from the detailed sub-pillar ranking in the GLM analysis of GCI components, necessitating advanced methodologies (e.g., structural equation modeling) or more disaggregated data to isolate its specific policy impacts more clearly. Timeframe and variable limitations, such as the GCI pillar analysis being restricted to 2008–2017 data (while some broader correlational analyses in the study may utilize data up to 2022) and the exclusion of emerging competitiveness factors such as the depth of digitalization across all sectors and green economy transition indicators, restrict the granularity of current policy recommendations. Extended models incorporating these next-generation variables are strongly recommended for future research. Causality gaps in the econometric framework are acknowledged. While the study identifies strong correlations and significant drivers, the methodologies employed (primarily GLM and correlation analysis) do not definitively establish causal relationships. Future research employing techniques such as Granger causality tests, Vector Autoregression (VAR), Vector Error Correction Models (VECM), or instrumental variable approaches would be valuable to explore the directionality of these relationships more rigorously.

Conclusion on robustness and limitations: While the models demonstrate robust explanatory power for macro-level analysis of the relationship between competitiveness and personal income in OECD countries, and the diagnostic tests for the GCI pillar models are largely satisfactory, the identified limitations should be considered. Micro-level policy design will always require further in-depth research using expanded and more current datasets, incorporating country-specific heterogeneity analyses, and employing dynamic modeling techniques. The methodological limitations identified do not invalidate the broad findings but provide a clear roadmap for future research aimed at refining competitiveness strategies in an evolving global economy.

7. Conclusion

This chapter has systematically interrogated the multifaceted determinants of personal income in OECD countries, arguing that sustainable growth in individual prosperity is inextricably linked to the enhancement of national competitiveness through targeted, mechanism-based policies. The empirical evidence presented moves beyond general correlations to illuminate specific leverage points for policy intervention. The strong (95%) correlation identified between per capita personal income and Gross National Income (GNI) is not merely an observation but a clear

policy directive: to significantly elevate personal incomes, OECD nations must strategically optimize their international economic engagement to bolster net factor income from abroad, alongside fostering robust domestic production. This involves a sophisticated approach to trade, Foreign Direct Investment that encourages high local value addition and knowledge spillovers, and the cultivation of globally competitive domestic enterprises capable of generating substantial international earnings.

A pivotal finding with direct policy consequences is the demonstrably greater impact of R&D investment (coefficient: 5084.98) compared to general education expenditure (coefficient: 2005.77) on personal income within the OECD context. This does not diminish the foundational role of education; rather, it signals an urgent need for strategic prioritization.

7.1 Policy imperative 1

OECD governments must amplify and strategically channel R&D investments toward areas that drive commercially viable innovation and tangible productivity enhancements across the economy. The economic mechanism here is clear: targeted R&D fuels the development of new technologies, products, and services, leading to the creation of high-value industries and specialized, well-compensated employment, directly boosting personal incomes. This must be complemented by an agile education and skills system that equips the workforce to participate in and drive this innovation-led growth.

Furthermore, the robust 0.70 correlation between the IMD World Competitiveness Index and personal income provides compelling validation that a holistic and sustained effort to improve overall national competitiveness is a direct and effective strategy for enhancing citizens' income levels. The GLM analysis of the WEF Global Competitiveness Index pillars pinpoints where such efforts can be most impactful, identifying Business Sophistication (14% relative importance), Innovation (13%), and the combined efficiencies of Goods and Labor Markets (11%) as the most potent drivers. This leads to further specific policy imperatives:

7.2 Policy imperative 2

Elevate Business Sophistication. Enhancing this crucial pillar requires moving beyond generic support for businesses. Policies must actively cultivate sophisticated business ecosystems by incentivizing the adoption of advanced managerial practices and data-driven decision-making, promoting the integration of cutting-edge production and digital technologies within firms of all sizes, and fostering the development of high-quality, specialized local supplier networks capable of meeting global standards. The economic mechanism involves significant improvements in firm-level productivity, enhanced value capture within global value chains, and the creation of more skilled, higher-wage employment and dynamic entrepreneurial opportunities.

7.3 Policy imperative 3

Catalyze the Entire Innovation Pipeline. To leverage the identified importance of innovation, policy must address the entire innovation lifecycle. This means not only increasing public and private R&D expenditure but also critically strengthening the pathways from knowledge creation to market impact. This includes fortifying basic research in scientific institutions, fostering dynamic and outcome-oriented

university-industry R&D collaborations, ensuring access to early-stage venture capital for innovative start-ups, and creating regulatory environments that are conducive to experimentation and the rapid adoption of new technologies. The economic mechanism is the generation of new economic frontiers, the launch of high-value products and services, and the specialized, well-remunerated jobs that these innovations necessitate.

7.4 Policy imperative 4

Optimize Market Efficiency for Inclusive Gains. Efficient goods markets, cultivated through robust pro-competitive regulatory frameworks, the reduction of unnecessary barriers to entry and trade, and consumer protection, translate into lower prices (thereby increasing real personal income) and greater opportunities for business growth and employment. Concurrently, labor market policies must be calibrated to foster adaptability and productivity while ensuring fairness. This involves not just flexibility but also significant investment in lifelong learning and reskilling initiatives, particularly for workers affected by structural and technological changes, alongside measures that promote gender equality in labor force participation and remuneration, and mechanisms that ensure productivity gains are more broadly shared with the workforce through wage growth. The economic mechanism here is the efficient allocation of resources across the economy, coupled with pathways for translating macroeconomic gains into tangible benefits for individuals.

While a highly skilled and educated workforce remains foundational, its impact on personal income is significantly amplified when embedded within a dynamic, competitive, and innovative business environment. Addressing the persistent challenge of income inequality, exacerbated by the structural shifts discussed, requires that these growth-oriented, competitiveness-enhancing policies be designed and implemented in concert with effective social policies and progressive fiscal measures that ensure the widespread and equitable distribution of the ensuing economic gains.

The findings from this study offer a clear directive: for OECD countries to achieve sustainable and meaningful increases in personal income, a departure from piecemeal interventions is required. Instead, an integrated, evidence-based, and strategically focused policy approach that targets these identified key economic mechanisms is paramount. Such an approach, by strengthening the underlying drivers of competitiveness and productivity, can create a virtuous cycle of innovation, growth, and rising prosperity for all.

8. Limitations

This study's focus on OECD countries, while ensuring data quality, restricts the global generalizability of its findings. The use of WEF index data covering 2008–2017 for the GCI pillar analysis limits the assessment of more recent long-term effects using this specific model (although some broader correlational analyses in the study may utilize more current data). Sectoral structure and population dynamics were excluded to maintain focus, but are relevant factors for broader analyses.

Regarding the econometric analysis, while the GLM results generally yielded favorable p-values for key drivers and relatively low Root MSE values (suggesting reasonable model fit within the analyzed data), significant methodological limitations

remain. Diagnostic tests (indicated in **Table 6**) revealed that assumptions regarding the absence of autocorrelation and the normality of residuals were not met for many of the individual pillar models. For instance, while models for Financial Market Development and Market Size passed autocorrelation tests, and several models showed normally distributed residuals according to the Jarque-Bera test, others (like Labor Market Efficiency and Business Sophistication) exhibited deviations from normality, and autocorrelation issues might be present in models where comprehensive tests were not reported or passed.

Furthermore, the employed frameworks (primarily GLM and correlation analysis) cannot definitively establish causal relationships; they identify strong associations and significant drivers but cannot ascertain the directionality of these relationships with certainty. Consequently, while the overall GLM analysis strongly points toward the importance of areas like Business Sophistication, Innovation, and Market Efficiency, the policy implications derived from the specific coefficients of individual pillar models should be interpreted with caution due to the unmet statistical assumptions. The broad strategic direction suggested by the findings holds value, but the precise quantitative impact estimated for specific interventions warrants further validation. Therefore, generating highly specific, actionable policy recommendations tailored to individual national contexts requires more granular analysis.

8.1 Extension (future research)

Future research would benefit from utilizing long-term, up-to-date data across all 12 GCI indicators and incorporating new metrics reflecting digitalization and green transitions. Analyzing highly developed Asian economies and investigating growth disparities between similar countries during different time periods could yield valuable strategic insights. Modeling the interplay between production sectors, demographic shifts, and personal income will deepen understanding.

Crucially, to address the limitations identified in this study, particularly concerning causality and the unmet assumptions of autocorrelation and normality in several GLM specifications, the application of more advanced econometric techniques is highly recommended. This could include dynamic panel data models, robust standard errors, panel VECM/VAR models, or instrumental variable approaches. Furthermore, to move beyond broad strategic guidance toward formulating more specific and accurate policy interventions, future research should prioritize country-specific studies. Utilizing longer time-series data within these national contexts would allow for a more nuanced understanding of the dynamic relationships between competitiveness factors and personal income, thereby yielding more reliable and directly applicable policy conclusions tailored to individual countries' unique circumstances and developmental trajectories. Such methodologically enhanced and contextually specific research is essential for refining competitiveness strategies effectively in an evolving global economy.

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Section 2

Inclusion, Inequality,
and Human Development

Chapter 4

Information Literacy Model for Economic Development

Mijo Knezović and Tihana Babić

Abstract

In the information society, information becomes a key resource for economic development. Such an environment requires a high level of information literacy. The chapter of the book provides an overview of current theory and recent research in the field of information literacy. The aim of the research was not only to identify a relevant model of information literacy (IL) that supports economic growth but also to present the evolution of information literacy, its importance, and relevant models. The results of the research identified A New Curriculum for Information Literacy (ANCIL) as a model of IL that strengthens the development of education and workforce skills for the information society, technological development, and socially responsible practices for a better future. In conclusion, the research results affirmed the importance of IL and ANCIL as a development force for humans and thus society in general, which means humans are a factor in successful economic development (a high level of IL strengthens innovation, productivity, information inclusiveness, and economic development).

Keywords: information literacy, information literacy model, economic development, sustainable development, innovation, information inclusion, education

1. Introduction

Today, the individual has increased access to information due to the development of information and communication technology (ICT) and lives in an information society. This new information environment has its drawbacks, but it also offers opportunities for knowledge sharing, innovation, and the creation of new knowledge. The economy is crucial for social sustainability; therefore, the potential of the information society should be taken as the key to economic development. In this context, the goal is to create an organisation that is agile, that constantly learns, maintains, and develops its capabilities, and in this way adapts adequately to the dynamics of changes in the environment.

The question that logically arises is what transformative force can offer society, organisations, and individuals a relevant direction in such an information landscape towards a better future. The phenomenon of IL as a transformative force emerged

to respond to this demand. Since people are the foundation of everything, including economic growth, they have been a key force throughout history, as has literacy in general.

Following the above, this part of the book will present research aimed at identifying a relevant model for the development of IL that supports economic development.

To achieve the research goal, the concepts of IL and literacy, in general, will be determined at the beginning. Subsequently, the evolution of IL, its importance, and the evolution of the IL model will be presented.

As a result of this research, a relevant model of IL will be presented that strengthens the development of education and workforce skills for the information society and technological development, as well as the practice of socially responsible action for a better future.

In conclusion, it will be shown that a high level of IL strengthens innovation, productivity, information inclusivity, and economic development.

2. Definition of literacy

The concept of “literacy,” coined towards the end of the nineteenth century, was initially focused on the human ability to decode and encode text. However, in the middle of the twentieth century, it implied a higher level of cognitive ability, and in the 70s, the term became visible in the educational discourse and moved away from the simple “coding and decoding of the text towards the consideration of meaning-making activities; different texts require different background and comprehension skills to get them right” [1].

The credit for raising literacy to the world level goes to UNESCO. UNESCO, which has been taking care of literacy since 1946 and directing literacy on a global level, recognised literacy as a key factor and linked it to human rights, accepting it in a broader concept as “an integral part of the right to education and the basis of lifelong learning and the driver of sustainable development” [2].

Reading and writing are fundamental skills that enable a person to understand and participate in the environment. They are skills that encourage the development of competent inclusion of an individual in society, eliminating the consequences of changes that affect the exclusion of an individual from society. However, considering the changes and interweaving of the environment, the aspiration and branching of literacy according to a certain social and cultural context, and its transition from basic skills to social practice, is understandable. This trend is especially pronounced in today’s age compared to past times [3]. The contextualisation of literacy has resulted in a broadening of views and diversification of the definition of literacy. Literacy begins to be linked to functional areas; that is, literacy acquires its meaning in the context of competitive involvement in a certain area. The consequence of these processes is the emergence of literacy, except in its basic form, also through special functional, scientific, and professional areas, so that we have the emergence of a series of literacies: IT, financial, media, academic, health, legal, library, etc. Recognising this process can be understood from the UNESCO definition of literacy:

“Literacy is the ability to identify, understand, interpret, create, communicate, and compute using printed and written materials associated with varying contexts. Literacy involves a continuum of learning in enabling individuals to achieve their goals, to develop their knowledge and potential, and to participate fully in their community and wider

society. Generally, literacy also encompasses numeracy, the ability to make simple arithmetic calculations. The concept of literacy can be distinguished from measures to quantify it, such as the literacy rate and functional literacy” [4].

UNESCO sees literacy not only as the ability to read and write but also as an individual's ability to determine himself in different situations when faced with a flood of confusing messages through various media and from various sources that will affect his perception of reality. The definition emphasises the essence of literacy: “literacy not only transforms the individual, it is also a condition for the individual's power to transform society. Therefore, literacy expands from mechanical skills to the ability to think critically and question dominant ideologies” [3].

However, the following question arises: why do these processes occur? According to Šipranec and Banek Zorica, the reason for this lies in the transition from an analogue environment, in which accumulated human knowledge came from printed sources and books, and information was created, written down, published, disseminated, and presented through analogue media, until today, where information mostly comes from digital media. Therefore, this fact triggered the need to branch out and expand the concept of literacy [5]. O’Farrill sees the reason for this phenomenon as “the result of disciplinary reactions to events in the information society” [6]. Stordy, citing Bawden and Tyner, will say that identical concepts are understood differently in terms of emphasis and scope by different individuals and organisations. Stordy adds “that scientists and organisations have developed their concept of literacy without reference to others or have chosen an idea to form their own concept” [6].

3. Emergence and evolution of information literacy

One of the concepts with heterogeneous definitions of literacy is information literacy (IL). Even though it was coined in 1974, it is still the subject of information science research, and there is no consensus on it. This can not only be connected to the uncertainty of the scientific public but also to the general public regarding the concept of information. In this study, the term information will not be defined.

Theoretical considerations, Šipranec and Banek Zorica put IL in a different relationship with the other mentioned concepts of literacy. According to their research, IL is an umbrella literacy under the umbrella of which digital, media, library, and IL are located (**Figure 1**). IL not only focuses on literacy in the information context and on the challenges of the information context, but it is also a transformational force towards the knowledge society [5 and 2]. In this context, the following picture shows IL as protection that ensures success during the lifelong education of an individual in a modern environment.

The definition of IL changed and evolved as the view on it changed and as the ideology gained importance in scientific communication, but it is important to point out that all the models of IL or definitions come from higher education. The following table (**Table 1**) shows part of the definitions of IL from relevant institutions and authors.

From the beginning until today, the perspectives of IL have changed under the influence of social, cultural, and technological changes. The initial classic view was structured, goal-oriented, and individual-oriented and was primarily focused on information as a resource, but later it took on a holistic view (more details in Ref. [13]). This is what the research on the evolution of IL from 1975 to 2018 tells us, revealing how



Figure 1.
Presentation of the elements of information literacy by Špiranec and Banek (Source: Author's preparation according to Špiranec and Banek Zorica [5]).

#	Organisation	Definition
1.	UNESCO	Knowledge of one's information concerns and needs and the ability to identify, locate, evaluate, organise and effectively create, use and communicate information to address issues or problems at hand; it is a prerequisite for participating effectively in the Information Society and is part of the basic human right of lifelong learning.
2.	UNESCO Alexandria Proclamation	Information Literacy lies at the core of lifelong learning. It empowers people in all walks of life to seek, evaluate, use and create information effectively to achieve their personal, social, occupational and educational goals. It is a basic human right in a digital world and promotes the social inclusion of all nations.
3.	METALITERACY	Metaliteracy promotes critical thinking and collaboration in a digital age, providing a comprehensive framework to effectively participate in social media and online communities. It is a unified construct that supports the acquisition, production, and sharing of knowledge in collaborative online communities. Metaliteracy challenges traditional skills-based approaches to information literacy by recognizing related literacy types and incorporating emerging technologies. Standard definitions of information literacy are insufficient for the revolutionary social technologies currently prevalent online.
4.	CILIP	Information literacy is the ability to think critically and make balanced judgements about any information we find and use. It empowers us as citizens to develop informed views and to engage fully with society.
5.	ACRL	Information literacy is the set of integrated abilities encompassing the reflective discovery of information, the understanding of how information is produced and valued, and the use of information in creating new knowledge and participating ethically in communities of learning.
6.	ANCIL	Information literacy is a continuum of skills, behaviours, approaches and values that are so deeply connected to the use of information that they are a fundamental element of learning, teaching and research.

Table 1.
Presentation of definitions of information literacy (Source: Author's preparation according to NCLIS, NFIL, UNESCO [7], UNESCO, NFIL, IFLA [8], Mackey and Jacobson [9], CLIP [10], ACRL [11] and Secker and Coonan [12]).

IL evolved over 43 years from a concept focused on librarianship to a multidisciplinary field, spilling over beyond the social sciences and into other sciences. IL is no longer a part of information sciences and librarianship but also of other disciplines [14]. In their research, Addison and Meyers [15] tried to make a synthesis of different points of view of presenting IL by identifying three different perspectives from the researched literature. According to them, the three perspectives are (1) IL as the acquisition of information-age skills, (2) IL as the cultivation of a habit of mind, and (3) IL as engagement in information-rich social practices. Hepworth and Walton [16], investigating the discourse of various research results, observed that IL moves in three broad areas:

- a strategic view
- provision of IL education
- links between university and work.

In this evolution of information science, it is crucial to point out its beginning and the turning point in the context of the change of view on it.

The beginnings of IL are placed in the context of librarianship, and all models were developed in the context of higher education and the development of students' abilities, but IL did not actually originate from that environment. Its originator, Paul Zurkowski, placed it in a business and industrial context in 1974. Zurkowski [17] recognised that the trend of exponential growth of information, driven by the development of technology, will enable users to search for new ways and sources to satisfy their information needs. Although individuals could read and write, few of them could be said to be information literate.

However, he also pointed out what is a crucial problem for humans, which is the influence of this trend around information on humans' perception. Today, we are witnessing how humanity faces this problem through all his activities, and this trend affects him like never before in history, blurring reality, erasing objectivity, and affecting individual subjectivity, because, as Zurkowski says:

"Information is not knowledge; these are concepts or ideas that enter a person's fields of perception, are evaluated and integrated, reinforcing or changing the individual concept of reality and/or the ability to act. As beauty is in the eye of the beholder, so information is in the mind of the user" [17].

In this way, Zurkowski, penetrating to the essence of the matter, points to the need to broaden the view of IL, moving away from the classical, librarian one. This later came true because the scientific community branched out from the perspective of developing IL. He also pointed out the need to enthrone IL as a vital instrument for navigating through the abundance of information in the digital age because today, when we are witnessing the blurring of reality as never before in history, we are looking for an instrument that will draw clearer forms of emerging phenomena. IL emerges as a key solution.

Although science communication takes Zurkowski as the originator of the introduction of IL, Whitworth will point out that he did not present a concept. In that early initial period of development of IL, apart from Zurkowski, two others are important: Burchinal and Hamelink. Those three founders of the IL tradition had

different approaches. Zurkowski's approach was knowledge management, Burchinal's was towards the education system, and the Dutchman Hamelink had a transformative approach. The key difference is that Zurkowski and Burchinal saw IL as "something that needs to be developed in the population in order to assimilate into the emerging society rich in ICT and information," and unlike them, Hamelink sees IL "as something that the population must develop in order to be able to defend against the cognitive costs of society." He emphasises the individual evolution of the student, who must develop the skills of critical evaluation and effective use of information for problem solving and decision making in order to reduce his mental effort caused by information overload. The three branches developed intertwined, and during the 80s and 90s IL became institutionalised in information science as a reference, and those years were dominated by the work of Carol Kuhlthau, who brings a psychological dimension to IL, and Christine Bruce, together with Lupton, Edwards, and Partidge, who see IL as a continuous activity rather than a series of individual ones. From these beginnings of IL, a focus on people rather than machine components is already visible [18].

The year 1989, when the report: Final Report from the Presidential Committee on IL of the American Library Association was published, is taken as one of the turning points in the view of IL. The report pointed out the consequences of the information age in different contexts. For example, insufficient IL can lead to the exclusion of individuals from social life due to the limited availability of information to a narrow population—the information elite. It can lead to an individual's dependence on others; it can lead to a situation where he accepts the opinions of others and becomes helpless in situations of facing problems. Therefore, the significance of IL as a means of personal empowerment through lifelong learning is understandable. Also, IL has become vital not only in the business environment but also for the sustainability of the democratic system. In addition to this, the report also calls for the adaptation of the education system related to IL and its recognition as a vital instrument in the new information society. Education must be more active and integrative and influence the development of active learning abilities after leaving the school and academic environment. Poor IL can also affect the democratic way of life and reduce the ability of the American nation to compete effectively internationally. Therefore, the report rightly concludes that IL is a survival skill in the information age, and "people who are information literate—who know how to acquire knowledge and use it—are America's most valuable resources" [19].

This report comprehensively illuminates the challenges of the information age and elaborates on what Zurkowski previously said, showing why IL is vital to the modern information society. It becomes an unquestionable fact that should continue to be developed in school and academic environments with a different approach but also developed in the context of business and everyday life environments, so the connection with the process of lifelong learning is understandable. It is also looking for a new perspective on librarianship. However, the report also highlighted the importance of accessing IL not only through the prism of information search but also through individual behaviour and critical thinking due to all the bad challenges brought by the digital age. The report highlights the great importance of recognising IL in the context of the maintenance and development of democracy, which is additionally contributed to by the possibilities of the Internet. The report shows the pervasiveness and thus the importance of IL for the political, economic, social, and cultural development of a country and the world.

4. The evolution of literacy models

In illuminating the optimal path of an individual in a dynamic and changing information ecosystem towards his final state of being literate, a series of models, guidelines, standards, and frameworks appeared with which the authors wanted to show what is the optimal path of an individual in meeting his needs for information, depending on his subjectivity and the external environment in which he operates. Although some authors see models as abstract ideas, as prescriptive tools or manifestos, for them, they are not explanations of how IL or information behaviours take place. According to Hepworth and Walton, they make assumptions about IL:

- notions regarding the nature of information
- the context in which individuals are seeking information
- the existing knowledge that individuals bring to the information seeking process
- individuals' approaches to finding information
- how individuals go about the process of engaging with information
- how individuals' think about, analyse, evaluate and communicate information [16].

List of the developed models, frameworks, and standards IL is shown in **Table 2**. The aforementioned models were developed following the development of the social and cultural environment, and Hicks and Loyd note in their research

Berrypicking model (Marcia Bates)	EMPOWERING-8 IL model	National information literacy framework (Scotland)
Kuhlthau Information Searching Process Model	The Big6 Information Process Model (Mike Eisenberg and Bob Berkowitz, 1990)	Seven Faces of Information Literacy and Six Frames for Information Literacy Education (Christine Bruce)
TFPL model	CLIP Information Literacy Model	Metaliteracy
Plus Model (James Herring)	Research Cycle	New Curriculum for Information Literacy (ANCIL)
8Ws IL Model	The Alberta Model	New Curriculum for Information Literacy (ANCIL)
DIALOGUE Model	Action Learning Model	The ACRL Framework itd.
The Society of College	Super 3 Model	
National and University Libraries (SCONUL) Seven Pillars Information Literacy Model	Follett's Information Skills Model	

Table 2.
Presentation of developed models, frameworks, and standards.

that their development moved from linear to constructivist. The turning point of the trend can be taken as 2010, when the second wave started, the constructivist waves of the IL model [20]. The table below (**Table 3**) by Talja and colleagues on the currently dominant metatheories and perspectives can be used to illustrate this trend [21].

The above-mentioned trends in the development of the IL model led to a change in the scientific paradigm, from one that maintains the existence of objective reality and understanding as a search for certain truth, measurable facts, which is a feature of positivism, to constructivism, where knowledge is formed through social interaction and social constructs and where subjectivity is more pronounced in the process of creating their perception. On this path towards the social dimension, we

#	Metatheory	Constructivism (Cognitive constructivism)		Collectivism (Social constructivism)	Constructionism
1.	Origin of knowledge	Individual creation of knowledge structures and mental models through experience and observation	Individual creation of knowledge structures and mental models influenced by history and social relationships	Knowledge is social in origin; the individual lives in a world that is physically, socially and subjectively constructed; mutual constitution of the individual's knowledge structures and the sociocultural environment	Production of knowledge in ongoing conversations; knowledge and identities are constructed in discourses that categorise the world and bring phenomena into sight
2.	Philosophical influences	Kelly; Piaget	Bruner (rani rad)	Bruner (later work); Vygotsky	Bakhtin; Foucault; Garfinkel; Gergen; Wittgenstein (later work); Volosinov
3.	Representatives	Brookes; Todd	Belkin; Ingwersen; Kuhlthau	Hjørland and Albrechtsen; Rosenbaum; Taylor	Blair; Frohmann; Given; McKenzie; Savolainen; Talja; Tuominen
Major fields of application of cognitive constructivism, collectivism and constructionism in IS					
1.	Thematic focus of the metatheory	Individual searchers' interaction with information retrieval systems; situational relevance		Information practices and relevance assessments in organisational, professional and disciplinary communities	Formation of knowledge and classifications in discourses; knowledge production practices and epistemic disputes in knowledge domains
2.	View of Language	Representational-referential Language is a neutral vehicle for reporting observations and a (more or less clear) window to the speaker's mind		Pragmatic-instrumental Language is an instrument serving in the creation, organisation and sharing of knowledge in thought-collectives	Rhetorical-responsive Language is constitutive for the construction of selves and the formation of meanings

#	Metatheory	Constructivism (Cognitive constructivism)	Collectivism (Social constructivism)	Constructionism
3.	Major fields of application in IS	Information retrieval interaction; information search behaviour; task-related searching. User requirements elicitation aiming at improved user interfaces and better user-system interaction. Design of personalised libraries, filtering mechanisms and information management systems	Integrated study of information practices and knowledge organisation in specific domains. Studies on terminology, document structures and genres in knowledge domains. Development of domain-specific classification and indexing systems and thesauri	Information seeking research focusing on accounts of information practices. Analysis of professional and scientific discourses of IS and information technology. Design of digital libraries and argumentation visualisation systems for mapping literatures, perspectives and debates. Design of collaborative knowledge filtering and synthesis systems

Table 3.
The main features, influences, representatives of cognitive constructivism, collectivism and social constructivism, and the main areas of their application in information science (Source: Ref. [21]).

see a different understanding of the social, i.e., its influence, and the emergence of constructivism, which is connected with the linguistic turn in the humanities and social sciences, in which language is not only considered a carrier of meaning “but a social tool and action that in itself produces and organises reality,” which implies “the dependence on context and perspective and the argumentative nature of language ... reality is constructed through conversation as we speak (how, where, and when), and meaning is socially negotiated in the situation” [6]. “The student does not focus on acquiring abstract knowledge but rather on learning the skills of inclusion in the process of belonging to the community and participating in its practices. Learning is a way of being in the world, not just of arriving in it” [6]. It can be said that the essence of learning shifts to being a student/learner and to the development of an active individual who constantly creates his own realities.

Representatives of models influenced by the constructivist wave are the modified ACRL [14], SCONUL [22], ANCIL [23], and Metaliteracy by Tom Mackey and Trudi Jacobson, 2011–2022 [20, 24].

In the context of these changes, Hicks and Lloyd point out that it is important to consider the discourse around IL because it creates epistemological assumptions for shaping practice, so it is necessary to critically question those documents that promote messages but also their effect on practice and related practitioners. For example, institutional guidelines, support, and influence of these documents are emphasised by the support of professional associations, which represent a mature professional culture and practical knowledge for the profession. This culture is shaped by professional texts with educational materials (textbooks, instructional and reference books), and then these texts direct the creation of teaching activities, shaping the discourse of IL by strengthening the basic principles of professional knowledge and directing constant professional development [20].

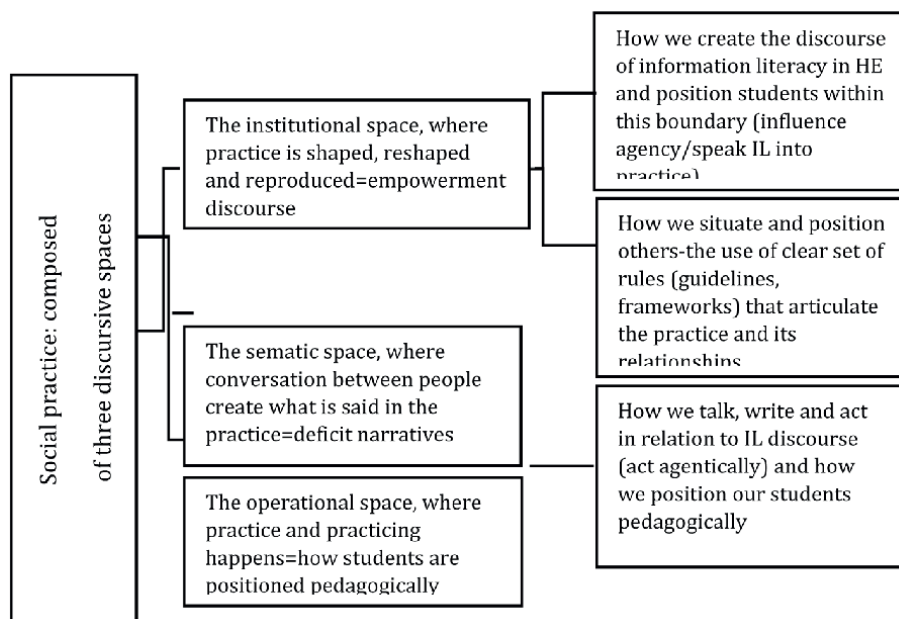


Figure 2.
Presentation of discursive spaces of IL (Source: Ref. [20]).

Today's models and guidelines, for example, in the practice of IL in higher education (ILiHE), are considered a significant departure from their previous understanding. Ideological changes impose the need to consider the creation of new models. Through their research, Hicks and Lloyd have identified the following discursive spaces within the higher education sector that can lead to further research (**Figure 2**).

According to Hicks and Lloyd, there are four key models of IL in higher education: ACRL (2016), Metaliteracy (2011), SCONUL's seven pillars of information literacy (2011), and ANCIL (2011) because they have a prominent role in shaping the narrative in professional practices of the USA and the UK [20], which points to the current dominance of the constructivist wave. Of the relevant four models, in the following text, we will get to know in detail the model ANCIL.

5. Presentation of the new curriculum for information literacy (ANCIL)

As part of the Arcadia project, the University of Cambridge developed ANCIL, or the New curriculum for information literacy, in 2011. Its authors are Jane Secker and Emma Coonan. Detailed materials about ANCIL are available in print and on the website. On the website www.newcurriculum.wordpress.com, authors Jane Secker and Emma Coonan, and in print, J. Secker and E. Coonan: *Rethinking Information Literacy: A practical framework for supporting learning*. "ANCIL was developed using a modified Delphi approach with experts from the fields of education as well as information studies" [25]. This framework was actually developed for undergraduate students in higher education and meant to be something that would work out how to teach IL for the next 5 years (so from 2011 to 2016).

Heterogeneity trends in the context of defining the concept of IL, which was discussed in the previous chapters, were also recognised in the development of the ANCIL model. The authors also pointed out that IL overlaps with other literacies (academic, media, digital, and new literacy), but they emphasise that the desire is the same: “the development of critical thinking, evaluation, and a high level of students’ cognitive skills” [26]. Below is an illustration describing ANCIL’s IL landscape (**Figure 3**).

The goal of ANCIL is “to help students to develop a reflective understanding of the information context and problems at a high level, which will empower them with a solid framework for mastering the new information situation and generating strategies for evaluating, analysing, and assimilating that information when it is needed and at the moment it is needed” [27].

The key ideas that are emphasised in relation to student development are the discerning/prudent student, the informed citizen, and the autonomous lifelong student.

Thus, the set ANCIL led to the definition of the term IL. According to the authors, it is: “IL is a continuum of skills, behaviours, attitudes, and values that are so deeply

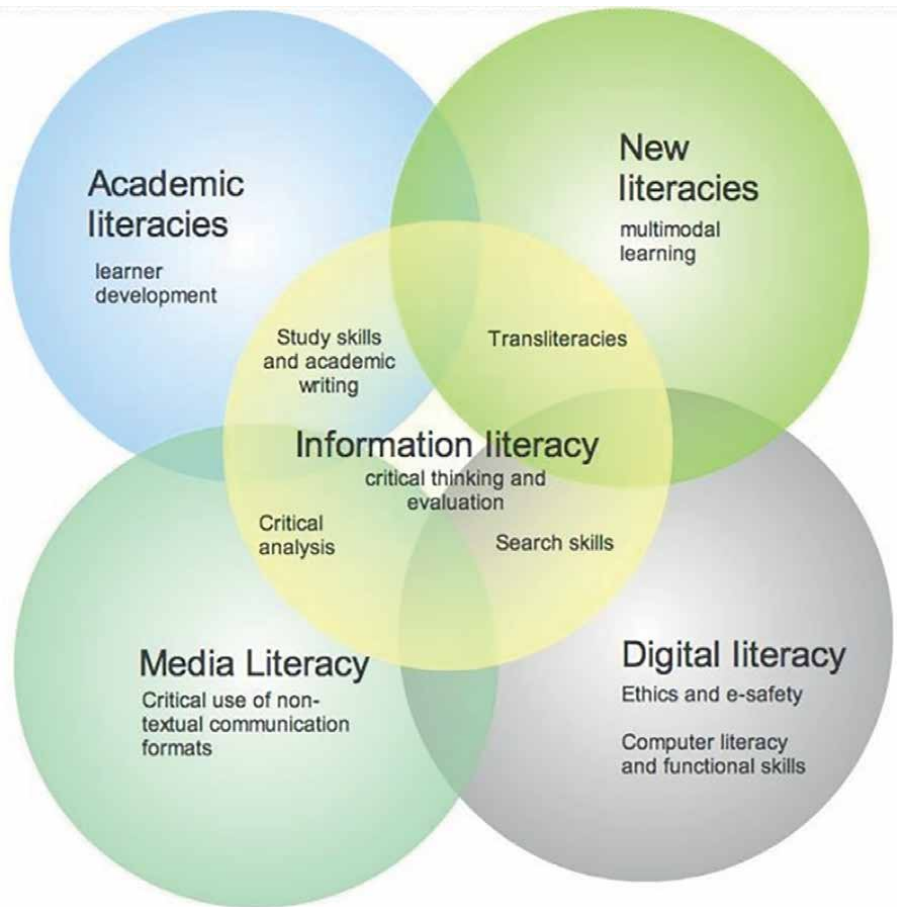


Figure 3.
Presentation of ANCIL’s information literacy landscape (Source: www.newcurriculum.wordpress.com, The authors: Jane Secker and Emma Coonan).

connected to the use of information that they are a fundamental element of learning, teaching, and research.” [12].

From these statements, it can be seen that they are based on learning about IL, which “emphasises the situated, contextual nature of IL as the key to attention” and which leads to the conclusion that the presentation of IL requires the identification of broader directions. Achieving a defined goal is not possible through a one-time place or a connected number of courses during a course designed to achieve disciplinary goals [28]. In addition, it is important to point out how it emphasises the student’s transition, as well as higher-order activities and the affective (feeling) component of learning [25]. The definition of IL, according to ANCIL, shows a closeness to the more comprehensive UNESCO Alexandria Proclamation definition of IL (**Table 1**).

The authors emphasise that during the development of the project, they recognised three key attributes of IL and embodied them in their curriculum, so the curriculum:

- Transition—which happens to a student when he enters the academic context from different backgrounds, but also the need to transition from a dependent to an independent student.
- Transferable—IL curriculum forms part of education. “IL encourages and develops appropriate behaviours, approaches, cognitive functions and skills related to the use of information. In essence, IL equips students to create their own strategies for dealing with new information contexts, for example, when they leave a higher education programme and enter the workplace.”
- Transformational—“IL should be transformational for the student, changing their attitude, behaviours, point of view, and even their view of the world. Therefore, this curriculum has the potential to change lives and make a real difference in society” [29].

And the key discoveries of the project were that the way in which IL is taught, its structures and implementations, as well as the topics covered by any new curriculum, are equally important; IL should be incorporated into the academic curriculum as much as possible; IL should take place during the student’s academic career and should be adapted to the specific requirements of the discipline; and the curriculum should include opportunities for students to collaborate and reflect on their learning and should be based on real needs, ideally after an audit. Meaningful assessment is an important part of this curriculum, but the difficulty of overall assessment of IL is recognised, so peer assessment is a key approach [26].

Secker explained the functioning of ANCIL in this way (**Figure 4**): “Four learning lanes radiate outward from the student in the centre. Beginning with the development of practical skills, they expand toward increasingly complex processes—establishing an evolving subject context within which skills are to be applied, high-level cognitive operations, including critical evaluation, synthesis, and the creation of new knowledge—and culminate in a conscious, reflective framework, which is key to managing personal learning” [12].

During the implementation of the research, experts emphasised the importance of the format and structure of each IL curriculum. As for the structure of the curriculum, it must be embedded in academic disciplines, flexible, holistic, student-centred, and unified for the entire institution. By built-in, we mean that students do not need

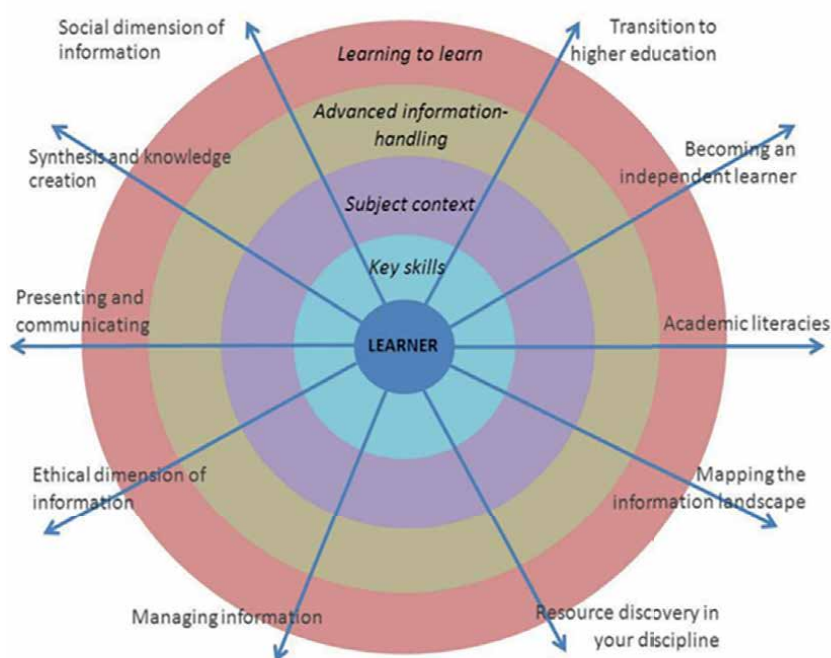


Figure 4.
 Functioning of ANCIL (Source: www.newcurriculum.wordpress.com, The authors: Jane Secker and Emma Coonan).

anything specifically labelled but only academic learning. It means that the elements of IL should be part of the curriculum of the basic subjects of the discipline, but that the information can be visible when necessary, but not separately. Of course, this approach requires cooperation of librarians with professors/teachers but also an understanding of what students need in order for the curriculum to meet their needs. This approach will require the training of teachers/professors without expanding the scope of IL experts [29].

Accordingly, ANCIL has six aspects: Holistic: supporting the whole process of study and research rather than just teaching traditional library skills; Modular: consisting of ongoing classes to meet the developing needs of students during their whole undergraduate career, not just one-shot sessions; Embedded: forming a salient part of academic teaching or running closely alongside it over the course of the academic year, with activities and problems directly related to students' subject context; Active and evaluable: containing a significant element of active and reflective learning, including peer assessment elements; Flexible: for use and adaptation in all UK higher education institutes, and designed specifically for flexible implementation; Transformative: grounded in a broad reading of "IL" which sees IL not as a set of competencies but as a fundamental attribute of the discerning scholar and as a crucial social and personal element in the digital age.

During the research, the experts identified a wide range of topics that should form the basis of the curriculum. Subsequent analysis, refinement, and grouping resulted in ANCIL forming ten thematic threads covering a range of aspects of IL in the educational environment, "starting with the student's transition into higher education

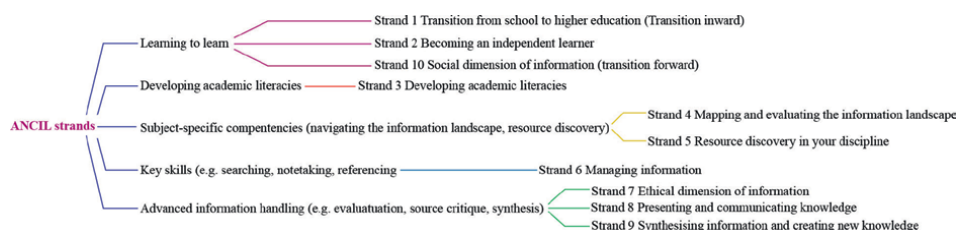


Figure 5.
Overview grouping of ANCIL threads into broader topics (Source: Creation of the author according to Secker [29]).

and culminating in the post-higher education transition into the workplace (including the use of skills in everyday life)” [30], which are “supported by learning outcomes, as well as appropriate activities and assessment” [25].

Those 10 strands are: Transition from School to Higher Education, Becoming an independent learner, Developing academic literacies, Mapping and evaluating the information landscape, Resource discovery in your discipline, Managing information, Ethical dimension of information, Presenting and communicating knowledge, Synthesising information and creating new knowledge, Social dimension of information [29].

According to the authors Secker and Coonan, it should be pointed out that these “are not direct models, but they should be included in the academic curriculum appropriate to the needs of the discipline” [26].

Strands are mapped to four levels (**Figure 5**), and each provision, in any form, should contain elements of each level, whether it is a one-on-one conversation with a student or a formal workshop. Provisions should include: What did I learn to do? – basic key skill (5, 6), How does it apply in my context? – subject-specific context in which the skill should be understood and used (3, 4), How does that change my understanding? – advanced handling of information, e.g., evaluation, assimilation, synthesis of information (7, 8, 9), How does it reveal or change my learning? – learning how to learn, thinking (1, 2, 10)” [27].

The strands are grouped into five broad learning categories (**Figure 5**): 1. Key skills, e.g., searching, recording, referring (Strand: 6), 2. Academic literacy (Strand: 3), 3. Subject-specific competencies (navigating the information landscape, discovery resources) (Strands: 4 and 5), 4. Advanced information handling, e.g., evaluation, criticism of sources, synthesis (Strands: 7, 8, 9); 5. Learning to learn (Strands: 1, 2, 10).

6. General implications of the use of ANCIL

In the book *From Information literacy to Social Epistemology, Insights from Psychology*, authors Anderson and Johnston [28] explored the possibilities of ANCIL around the effectiveness of IL education in higher education. Their goal was to contribute to the illumination of the problem of where IL should be introduced, in what way and to what extent. They read very positively about ANCIL, pointing out that it is a “significant and useful contribution to the development of IL education,” adding that the author’s approach is “generative/expansive and goes beyond previous narrow frameworks for teaching IL in higher education.” In addition to positive reviews, Anderson and Johnston pointed out that IL educators need to “develop their understanding of pedagogical thinking and practice.”

As pointed out in the previous section, ANCIL, along with modified ACRL and SCONUL, and Metaliteracy, belong to the group of IL models influenced by constructivism [20, 25].

The authors of ANCIL were influenced by Biggs and Tang - Constructive Alignment, which seeks to align learning objectives, teaching activities, and assessment towards the same goal [31]. But in creating the optimal path from novice to expert in a discipline, to the degree of being literate, ANCIL also recognised the thinking of Perkins and can be connected to the concept. Threshold concept was developed by Jan Meyer and Ray Land [32, 33]. According to him, troublesome knowledge appears on the development path as something counterintuitive. According to Perkins, there are five problematic knowledges: Ritual Knowledge, Inert Knowledge, Conceptually Difficult Knowledge, and Alien Knowledge, and Meyer and Land added Tacit Knowledge. As problematic, the authors pointed out Troublesome Language and Ways of Thinking and Practicing WTP) [32, 34]. Also, ANCIL recognises three different roles in Constructivism, highlighted by D.C. Phillips, which Perkins named: Creative learner, Social learner, and Active learner [34, 35]. However, in addition to IL, ANCIL also proclaims the concept of Lifelong learning, which can be said to be in line with the discourse under the influence of constructivism. Thus, it materialises the idea of Bibliotheca Alexandria that “IL and lifelong learning are the beacons of the information society, which illuminate the directions of development, prosperity and freedom”.

ANCIL recognised the need for the higher education programme to respond to the challenges of dealing with uncertainty and complexity. They are a consequence of the pronounced continuous changes in the information landscape of today's society, which are driven by the development of technology. Also, ANCIL highlights the fact that today the higher education programme does not have the ability to provide students with all the information and knowledge that is necessary for their whole lives, but through the learning outcomes, the competencies necessary for the student to continue and persist in further learning after the completion of the higher education programme should be developed through the concept of lifelong learning. An example of this is the competency Learn to learning, as one of the key competencies in the concepts of a knowledge society, but a learning organisation (strands 1, 2, 10). It contextualises IL and proclaims the position of Limberg and colleagues that IL should be linked to the context where these abilities will be applicable [3].

In that context, IL finds its place also in the practice context, not just in its natural environment of the higher education system. IL in the workplace is becoming one of the main narratives of IL, as scientific research recognises IL as a crucial competency for workers and a critical element for building organisational capacities and economic development. It becomes a factor of strategic value in the decision-making process in a highly competitive environment [36]. Today's workplace is “driven by knowledge and the influence of technology, where learning is lifelong and change is the only constant.” For the sake of today's organisations, in order to perform tasks efficiently, three concepts are taken into account: intellectual capital, knowledge work, and the learning organisation [37]. This trend is understandable, as IL aids in the processes of transforming information into essential knowledge. It is not just important to possess information but also to know what you know and have the wisdom to achieve what is vital for an organisation (vision, mission, aims...).

According to Loyd, employees who are capable of “developing information pathways and creating new corporate knowledge represent a strategic difference between

very successful businesses and those that remain mediocre.” No, Loyd realised through the process of writing her doctoral dissertation that IL in the workplace is not synonymous with what is generally understood as “define, locate, and access,” but rather it is a much more complex phenomenon. Lloyd emphasises that “as the amount of information available to workers and the nature of access to information become more complex, it becomes important to explore a new concept of IL in the workplace to facilitate meaningful learning about work and collective practice” [38]. The escalating pace of change in professional environments is driving an increased necessity for IL competencies.

ANCIL recognises that the educational system is the source and confluence of sociocultural changes and the prevention of social exclusion through the development of competence that will enable the individual to continue learning in the information landscape and outside the academic context in the context of the workplace and everyday life. It develops the individual not only through an epistemological prism but also through an ontological concept. This supports what Toffler points out in his book: “The illiterate of the twenty-first century will not be those who cannot read and write, but those who cannot learn, unlearn, and relearn” [39].

As a result of the above, it can be seen that IL developed by the ANCIL strengthens critical and creative thinking, ethical and socially responsible action, and improves the process of quick and effective problem solving. IL reduces human exclusion and therefore strengthens the cohesion of stakeholders in all economic development processes. ANCIL accelerates and strengthens the development of key theoretical economic knowledge and skills among students that will enable them to more easily overcome challenges after leaving higher education and further develop their knowledge in the workplace and society in general. But also to be an active agent in spreading the corpus of new knowledge in the business environment. In conclusion, the ANCIL develops competencies of critical value for expert practitioners in the economic information landscape.

While IL is vital in advanced higher education systems, it is equally important in developing countries with limited access to formal education. In these contexts, IL serves as a catalyst for economic growth by fostering individual development outside formal educational settings. This enables both individuals and their communities to make significant contributions to economic progress despite existing constraints. In such circumstances, IL can act as a link between community development and economic development.

*“Dear Adsone, you should learn to think for yourself.”
Eco, *The Name of the Rose*, 1987.*

7. The ANCIL thread is discussed within the context of economic development

The text that follows will present the development of information competencies of students, future experts for economic development, through the presented strands of the ANCIL model (more details in Ref. [29]).

The first strand, Transition from School to Higher Education, is primarily concerned with developing an understanding of the importance of higher education in comparison to the student’s past experiences and changing perceptions of the

importance of information. This is crucial for the professional development of economists, as critical evaluation of information is essential for finding relevant information in the unexpected and complex landscape of economic information. Students need to understand the consequences of misinformation from the outset and start reading key sources in their discipline. This initial step strengthens their information awareness, enabling them to develop information competencies for higher education and the workplace, i.e., lifelong learning and learning.

The second part, *Becoming an Independent Learner*, helps students become independent learners and be able to continuously acquire new knowledge in the economic information environment. Through this thread, competencies are developed that ensure the student's perseverance in a business career despite the challenges and expected mental effort. Students must become active, responsible carriers of knowledge development, with the ability to collaborate with organisations and society, overcoming mental efforts and reducing the negative impact on health. This is crucial in the context of a successful transition in the economic information landscape.

By developing competences through the third strand *Developing academic literacies*, which will enable, for example, academic writing using appropriate terminologies, speed reading techniques, etc., from a field/discipline, will influence the empowerment and speed of knowledge development both in the process of obtaining information and knowledge, as well as in their assimilation.

Future leaders of economic development must be aware of relevant sources and authorities in their field, especially as the field of economic information is expanding exponentially. In order to accelerate and strengthen the processes of economic development, leaders of economic development must possess both a thorough knowledge of individual scientific disciplines as well as information and knowledge about the wider relevant scientific community. To do this, they will need information competencies that are developed through strands 4. Mapping and evaluating the information landscape and 5. Resources for discovery in your discipline of the ANCIL, in which "Unit 5 is intended to accustom students to specialist resources of various types and content in their discipline, while Unit 4 is focused on developing awareness and understanding of the spectrum of types of sources available and how to evaluate them in the areas of reliability, authority, and compliance with the specific purpose of the student" [26].

The development of information competences through this strand will enable future economic development leaders to become familiar with the specific economic information landscape, promoting less is more and reducing the demands for information management. These competencies are also essential for identifying drivers of change, which is vital for economic development. The development of these competencies will help resist the black hole model, where existing knowledge is at the centre and revolutionary ideas, such as sustainability, are hard to find. Revolutionary ideas, such as the sustainability of transformative technology, should be sought at the periphery, ensuring that future economic development leaders can effectively navigate and shape the changing information landscape [40, 41].

The ANCIL 6 strand focuses on developing vital business skills, including note-taking, time management, and planning competencies, for example, effective time management. This strand is crucial for familiarising future economic leaders with the importance of information management and information storage because it strengthens the understanding of information storage, organisation of information, and the advantages/disadvantages of different methods. The production and re-application of

information and knowledge are inseparable from educational and economic development. However, this information must be adequately stored to serve as a resource for further development. By strengthening information competence through this ANCIL strand, the efficiency of business processes and effective use of limited storage resources are ensured, as well as the reduction of necessary energy.

Maintaining a consistently high level of awareness of future drivers of economic development is ensured by developing information competences for push services and keeping up to date with current events. However, when developing information competence, one should not ignore the challenges of using artificial intelligence (AI) technology, because AI tends to displace information from people, according to the Philosophy of Information (PI) [42, 43]. In this context, artificial intelligence can be seen as a Trojan horse, as it introduces a computational/information paradigm into the philosophical fortress, changing the traditional understanding of philosophical concepts such as mind, consciousness, experience, reasoning, knowledge, truth, ethics and creativity [42, 43].

Future leaders and other participants in economic development have a key responsibility. Through their actions, they strongly influence the future. They must be aware that their decisions shape a possible future and that every mistake they make can have significant consequences for the individual, the institution, and society as a whole; therefore, they have a moral obligation. This connection illuminates the link between economic development and ethics. Economic development, especially sustainable development initiatives, cannot develop without an ethical framework because there is a risk that development will go the wrong way and environmental challenges will worsen.

The ANCIL model recognises the challenge of ethics in the development of IL precisely through strand 7. Through the content of this unit, from quoting and avoiding plagiarism to correct sharing of information to awareness of the protection of originality and intellectual property rights, an information-literate person will be able to face and successfully deal with the ethical challenges of economic development.

Developing the ability to effectively present and transfer knowledge is a key competence that underpins all business processes. Strand 8 responds to this challenge. Developing information competencies through this ANCIL's strand enables future leaders of economic development to construct a positive, distinctive identity as senders of information. In addition, it can help them create effective strategies for transmitting information, especially in digital environments. This is crucially essential for bridging the gap between the message the sender wants to send and the perception of the recipient, which is crucial, for example, in brand development and the implementation of organisational vision and strategy.

Economic development involves the constant synthesis of information and the creation of new knowledge, moving away from existing trends. This requires future leaders of economic development to have a fresh perspective and creativity in identifying emerging problems and formulating research questions. In these circumstances, the goal is to discover revolutionary knowledge that has the power to trigger a change in existing paradigms and transform economic development. Developing information competences through ANCIL's Strand 9 will make this possible. The aim is to improve understanding of the causes and key concepts that influence paradigm shifts. This understanding can lead to insightful research questions and problem definitions, thus enabling the emergence of new paradigms. Also, the competencies developed through Strand 9 facilitate the integration of different ideas, which are crucial for economic development.

In line with the idea of lifelong learning, ANCIL Part 10 focuses on the application of information literacy skills, attitudes, and behaviours in everyday life [26].

Through this strand, the awareness of future economic development actors is developed that learning is a continuous, ongoing process that goes beyond educational institutions. If they develop the skills to find, critically evaluate, and apply information in the workplace and in everyday life, they become lifelong learners who are able to deal effectively with information, solve problems, and make decisions in professional and personal contexts. By developing information competencies through this strand, future economic development actors will be capable of lifelong learning in all contexts and will be able to respond to the challenges of the dynamic nature of economic development. If they want to stay awake, they must commit to lifelong learning.

8. Conclusion

The aim of this paper was to identify a relevant model of IL that supports economic growth.

In the initial part of the research, literacy was conceptually defined, and its connection with human rights in the context of education and lifelong learning and sustainable development was established, especially in the context of the necessity of developing critical thinking skills.

In further research on a relevant theoretical basis, it was determined that, due to the change in the environment and the transition from an analogue to a digital environment, i.e., the information society, disciplinary reactions and the development of various literacy concepts have occurred. Literacy no longer refers only to the individual's ability to read and write, but literacy is moving towards social practice. It also gains its meaning in the context of competitive inclusion in a certain area, which is why literacies appear through specific functional, scientific, and professional areas. This trend of contextualisation of literacy has also resulted in the emergence of the concept of IL as an umbrella under which other literacies (informatics, media, and digital library competences) are placed. Research shows that IL, due to the nature of the current and future sociocultural environment, has imposed itself as a phenomenon of vital importance for the political, economic, social, and cultural development of a country and the world, retaining information as a fundamental part of human existence and the meaning of life. It has spilt over from its natural academic context into the context of the workplace, becoming a key competence of workers and a critical factor in building an organisation and society.

This in turn has led to the need for a sociocultural view of IL and the importance of contextualising IL in a higher education programme with the workplace and the general social context and encouraging the development of an individual who will be a lifelong learner, thus eliminating the causes that lead to the exclusion of the individual from the transformation processes of the sociocultural context. From the evolution of IL trends, a tendency towards ontological understanding has been observed, because the result of the information revolution is the inclusion of intangible entities and the additional blurring of the boundaries between the physical and cyber spheres, which again represents a challenge for the perception of reality, which is now more fused with interaction than with physical reality and tangibility.

By looking at the evolution of trends in the understanding of IL, knowledge was gained about the key models of IL development. Through that research, ANCIL was identified and selected as relevant for IL.

The proposed model of IL ensures the education of a person on relevant facts from the past, which, with imagination and creativity, can turn the organisation

and society towards a better future. The development of IL according to this model enables the development of a human towards an active, creative, and social lifelong learner, but also the model develops a human who will empower ethical and socially responsible behaviour. Furthermore, the ANCIL defines the role of a human who does not move away from technologies but, on the contrary, recognises the benefits of technological development, placing it within the framework of strategy, and does not allow technology to dominate strategy.

The ANCIL model paves the way for experts and the development of abilities to more easily overcome the challenges of an environment characterised by unpredictability and complex systems such as economics. Through the education system, it develops human abilities with which they will be able to respond to the challenges of the profession, the workplace, and also everyday life in general. In this way, the workforce, especially the management part, can be a stronger support/lighthouse in the context of navigating the modern economic information landscape and developing knowledge, both for the organisation and the learning society in general.

The increasing significance of information literacy in the future requires a focus on studying and creating new forms of information literacy in the workplace. Additionally, in situations where access to higher education is limited, IL can be a link between community development and economic development.

In conclusion, the results of the research showed that the education system is a source of sociocultural changes and prevention of social exclusion and affirmed the importance of IL and ANCIL models as a developmental force of humans and society and thus a factor in successful economic development.

Remark

This chapter includes sections from a doctorate dissertation in progress by Mijo Knezovic, titled “Information Literacy as a Precursor of Strategic Foresight,” supervised by Assistant Professor Tihana Babic at the Faculty of Humanities and Social Sciences, University of Zagreb.

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Assessing Financial Inclusion Progress in Nigeria: Exclusion Gaps, Policy Strategies, and Implications

Olayinka Adegbite

Abstract

Financial inclusion is a key driver of economic growth. While Nigeria has made notable strides since the introduction of the National Financial Inclusion Strategy (NFIS), the country fell short of meeting its ambitious targets. This study, utilizing Global Findex Data from 2011, 2014, 2017, and 2021, employed a mixed-method approach to evaluate Nigeria's progress, exclusion gaps, policy strategies, and their broader implications. Findings highlight significant advancements in formal account ownership, inclusive of mobile accounts, and increased use of finance and digital services, largely fueled by targeted policies and technological innovation. Despite this progress, exclusion gaps, particularly in gender, rural-urban and digital disparities remain prominent, pointing to the need for more inclusive approaches. While formal accounts are increasingly utilized for savings, barriers persist in using these accounts for borrowing and remittances. The shift toward digital transactions for wages and government payments underscores progress toward a cashless economy, though the digital divide continues to limit widespread adoption. Effective policy strategies, continuous evaluation, and adaptive measures are essential for fostering an inclusive financial ecosystem. Priorities should include bridging the digital divide and addressing structural inequalities. These efforts will be pivotal in sustaining progress and scaling advancements in financial inclusion.

Keywords: financial inclusion, gender gap, rural-urban gap, digital divide, policy strategies, Global Findex, Nigeria

1. Introduction

Financial inclusion has emerged as a critical component of global development initiatives aimed at enhancing economic growth, poverty reduction and socio-economic inclusion [1–3]. Owning a formal account at a regulated financial institution or mobile money provider is basic to financial inclusion, as it provides initial access to finance, enabling economic participation, financial independence and empowerment [4]. Over the decade, global account ownership among adults has surged by 50%

from 2011 to 2021, rising from 51% in 2011 to 62% in 2014, 69% in 2017, and 76% in 2021 [4–7]. However, having only formal accounts is inadequate to achieve significant development outcomes without their usage to manage emergencies, borrow, save, and make or receive payments and remittances [8].

Studies have shown that using formal accounts offers significant gains that drive financial well-being for individuals and broader economic advancement. Formal savings enable individuals to securely store money, decreasing fraud [3]; increase production among agricultural households [9]; achieve food security and money transfer to other households during periods of food scarcity [10]; build financial resilience, and reduce vulnerability to economic shocks [11]. Formal borrowing provides access to regulated credit, compared to informal lenders, fostering entrepreneurship and investment opportunities [4]. Moreover, using accounts for digital payments not only expedites money transfers efficiently but also encourages recipients to use other financial services [12]. Notably, 83 percent of adults in developing countries who received a digital payment also initiated one; approximately 66% utilized their accounts to manage funds, 40% were involved in formal saving, and another 40% engaged in formal borrowing [13].

Conversely, the inability to access and use affordable formal financial services limits individuals and businesses' ability to participate fully in the economy and the gains arising from economic participation [4–6]. Several studies have attributed financial exclusion to reasons such as lack of trust, technology barriers, cultural and social factors, geographic barriers, lack of financial and digital literacy, economic and resource constraints, lack of identification documents and high cost of financial services [13–16]. As a result, inequalities persist, especially among women, rural residents, and low-income households [4].

Since the introduction of Nigeria's National Financial Inclusion Strategy (NFIS) in 2012 and its revision in 2018, substantial efforts have been made to cut down the proportion of adults (from 15 years and above) who are financially excluded from 46–20% between 2010 and 2020 [15, 17]. Despite notable successes achieved in financial and digital inclusion, overall exclusion levels remain higher than the NFIS set targets [14]. The challenge of financial exclusion remains substantial despite concerted efforts by policymakers, financial institutions and development partners to advance financial inclusion [16].

Previous studies found that financial inclusion significantly determines the economic inclusion and output of a country, alleviates poverty and facilitates income equality thereby promoting savings, access to credit, entrepreneurship and job creation [2, 3, 18, 19]. Other authors emphasize the role of mobile banking and digital payments in addressing financial inclusion disparities, especially in underserved rural areas and among women [20–22]. However, Nigerian women are disproportionately excluded from formal financial services even though enhancing their inclusion has a multiplier effect on household welfare, food security, and healthcare outcomes [20]. Moreover, digitally including women in finance has a significant positive relationship with economic growth [21].

By leveraging the Global Findex Database for the years 2011, 2014, 2017, and 2021 [23–26], this chapter explores the progress of financial inclusion in Nigeria, shedding light on persistent exclusion gaps, assessing the policy strategies for advancing financial inclusion, and examining the broader policy and economic implications. The insights from this chapter will not only contribute to the discourse on economic development but also underscore the urgency of addressing exclusion gaps with targeted policies to harness the full potential of Nigeria's diverse and dynamic population.

2. Methodology

This chapter employed a mixed-method approach to evaluate its objectives, using both quantitative data from the Global Findex Database and qualitative insights from policy documents issued by the Central Bank of Nigeria. Quantitative data was sourced from the Global Findex Database (2011, 2014, 2017, and 2021, Nigeria), providing metrics on financial inclusion such as account ownership, formal savings, formal borrowings, payments and remittances, including access to and usage of digital financial services [23–26]. The Global Findex is the most extensive demand-side data resource on financial inclusion worldwide [4]. Since 2011, the database has gathered financial inclusion indicators every three years, enabling analysis on a global, regional and national scale. The Global Findex Nigeria data comprise a nationally representative sample of 1000 Nigerians aged 15 years +.

Descriptive statistical methods were used to examine trends in financial inclusion over the years. Key indicators analyzed include formal account ownership, mobile money account ownership and usage, savings, borrowings, payments and remittances. The data was also used to evaluate exclusion gaps relating to gender, rural-urban and digital divides. A review of policy documents, including the initial and revised NFIS and other Central Bank of Nigeria initiatives, was conducted to evaluate the alignment of implemented strategies with observed trends. Policy recommendations were formulated based on gaps identified in data and the evaluation of existing strategies. Qualitative insights are constrained by the availability of detailed policy documentation and case-specific evaluations. The author acknowledges the use of ChatGPT for the language polishing of the manuscript.

3. Financial inclusion progress in Nigeria (2011-2021)

3.1 Formal account and mobile money account ownership

The trend in owning formal accounts in Nigeria (**Figure 1**) showed significant progress over the past decade. In 2011, only 30% of Nigerian adults had formal



Figure 1.
Formal account and mobile account ownership.

accounts, indicating limited access to financial services. By 2014, this figure had increased to 44%, reflecting efforts to enhance financial accessibility. However, there was a slight drop to 40% in 2017. Despite this setback, the trend resumed its upward trajectory, reaching 45% in 2021. On the other hand, the trend in mobile money account ownership in Nigeria has shown a notable upward trajectory over the past decade. In 2011, data on mobile money account ownership was not prominently recorded. By 2014, approximately 2% of Nigerian adults had mobile money accounts, marking the beginning of a gradual increase in adoption. This figure rose to 6% in 2017, indicating growing acceptance and use of mobile money services. The most significant growth occurred by 2021, with mobile money account ownership reaching 9%. While mobile money account ownership has the potential to drive growth in and formal account ownership, technological barriers such as not having a mobile phone and digital financial illiteracy could deter progress [13]. Nevertheless, the overall increase in formal account ownership, highlights the ongoing initiatives and improvements aiming to provide more Nigerians with access to formal financial services.

3.2 Debit and credit card ownership

Debit and credit card ownership fosters digital financial inclusion, enhances convenience, and reduces reliance on cash, thereby promoting access to finance [27]. According to the Global Findex Database, debit card ownership in Nigeria (**Figure 2**) rose significantly from 19% in 2011 to 36% in 2014, a period marked by the Central Bank of Nigeria’s (CBN) “Cashless Policy” initiated in 2012 [28]. This policy likely spurred the adoption of electronic payment methods. However, ownership declined to 32% in 2017 due to economic challenges such as the 2016 recession, which impacted consumer behavior [29]. By 2021, debit card ownership recovered slightly to 35%, reflecting the influence of the COVID-19 pandemic in accelerating digital payment adoption [30].

In contrast, credit card ownership remained continually low, increasing marginally from 1% in 2011 to 4% in 2021 (**Figure 2**). This limited uptake can be attributed to socio-cultural preferences for cash-based transactions, inadequate financial

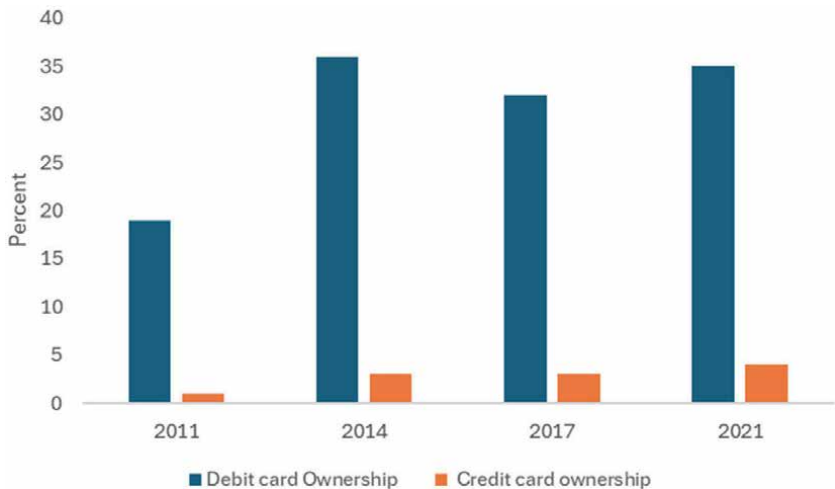


Figure 2.
Debit and credit card ownership.

literacy, and a lack of robust digital and credit infrastructure [14]. Structural issues such as inflation or high interest rates, low trust in financial institutions, and restricted credit access for individuals and small and medium enterprises (SMEs) could further constrain credit card adoption [31, 32].

3.3 Use of formal account for savings, borrowings, remittances and payments

The use of formal accounts for savings, borrowings, remittances, and payments between 2011 and 2021 highlights notable trends that reflect economic conditions and systemic challenges (**Table 1**). The use of formal accounts to save increased from 24% in 2011 to 27% in 2014, reflecting improved use of financial services facilitated by government programs and private sector interventions aimed at underserved populations. However, this progress was short-lived, as formal savings declined to 21% in 2017, coinciding with the 2016 economic recession in Nigeria, triggering a 1.5% decline in GDP [29]. Further economic recession in 2020 due to the pandemic, causing a 1.8% fall in GDP, rising core inflation from nearly 20% in the first quarter of 2023 to approximately 26% in the first quarter of 2024 and reduced disposable incomes [31–33] suggests the reduced ability of households to save. By 2021, the proportion of formal savers dropped further to 18%, emphasizing persistent economic instability and the need for policies that improve formal savings for low-income earners.

Formal borrowing saw slower but steady growth, suggesting a gradual shift from reliance on informal credit mechanisms to more structured formal credit systems. Results from **Table 1** showed that only 2% of Nigerians borrowed through formal accounts in 2011. By 2014, formal borrowing increased to 5%, driven by financial literacy campaigns and the expansion of microfinance institutions. Despite these gains, borrowing dipped slightly to 4% in 2017, likely due to the economic challenges following the 2016 recession in Nigeria. By 2021, formal borrowing had recovered to 5%, aided by the rise of digital lending platforms and the expanding role of microfinance in providing credit to underserved groups.

The use of formal accounts for remittances, both sending and receiving, experienced consistent growth, reflecting the increasing adoption of digital financial systems. In 2011, 37% of Nigerians used formal accounts to send money to friends or relatives, while 53% relied on such accounts to receive funds from family. As of 2014, these figures increased to 53% and 52%, respectively, signaling the early success of mobile money platforms and digital banking initiatives. By 2017, 60% of Nigerians used formal accounts for sending remittances and 55% for receiving them. These numbers

Use of formal account	2011	2014	2017	2021
Savings	24	27	21	18
Borrowings	2	5	4	5
Sent remittances	37	53	60	63
Received remittances	53	52	55	59
Received work/wage payments	40	55	47	44
Received government payments/transfers	21	39	51	57

Table 1.
Use of formal account for savings, borrowings, remittances and payments.

rose further in 2021, reaching 63% for sending and 59% for receiving remittances. The steady growth in the use of formal channels for remittances reflects the growing convenience and efficiency of digital platforms.

Using formal accounts for payments, such as receiving wages and government transfers, also exhibited growth but with fluctuations. In 2011, 40% of Nigerians used formal accounts to receive wages, a figure that rose sharply to 55% in 2014, influenced by the expansion of digital payroll systems. However, this declined to 47% in 2017 and further to 44% in 2021, reflecting challenges in extending financial inclusion to the informal sector and the economic impacts of the COVID-19 pandemic. Meanwhile, government transfers saw dramatic growth, with formal account usage rising from 21% in 2011 to 39% in 2014 and to 51% in 2017. By 2021, this reached 57%, driven by government efforts to digitize welfare and subsidy payments, such as the Federal Government’s Conditional Cash Transfer Programme. These trends underscore both progress and the need for targeted policies to ensure equitable access to formal financial services across all sectors.

3.4 Trend in digital financial transactions (2011–2021)

Digital financial inclusion enables broader, faster, and more convenient access to formal financial services, especially for underserved populations in remote areas without physical banking infrastructure [2, 3]. The use of mobile phones for financial transactions in Nigeria has grown steadily over the decade, reflecting the increasing adoption of digital financial platforms (Table 2). In 2011 and 2014, only 1% of Nigerians used mobile phones to pay utility bills. As of 2017, this figure increased to 4%, and it reached 11% by 2021 (Table 2). This growth was driven by utility companies embracing digital payment systems, increased smartphone penetration, and heightened consumer awareness of the convenience and efficiency of mobile platforms for bill payments.

Mobile phone usage for remittances, both sending and receiving, exhibited a mixed trajectory. In 2011, 10% of Nigerians used mobile phones to send money domestically, but this figure dropped to 5% in 2014 before rebounding significantly to 16% in 2017. Similarly, 11% used mobile phones to receive money in 2011, which declined to 6% in 2014 but returned to 11% by 2017. Although data for 2021 is unavailable, the upward trend through 2017 highlights the growing appeal of mobile money services due to their convenience and affordability. These fluctuations may reflect competition among digital platforms and systemic challenges in scaling mobile money services in Nigeria.

The use of mobile phones to receive work or wage payments has consistently grown. Although no data is available for 2011, 7% of Nigerians relied on mobile

Digital finance transactions	2011	2014	2017	2021
Used mobile phone to pay utility bill	1	1	4	11
Used a mobile phone to receive wage payment	—	7	12	21
Used the mobile phone to receive the government payment/ transfer	—	9	18	11
Used Debit card	—	40	31	35
Used Credit Card	—	68	77	84

Table 2.
Trend in digital finance transactions.

phones for wage payments in 2014, rising to 12% in 2017 and 21% in 2021. This demonstrates increasing adoption of mobile payment systems by employers to reach unbanked workers and remote workers. However, receiving government transfers through mobile phones showed fluctuations. While no data exists for 2011, 9% of Nigerians used mobile phones to receive government payments in 2014, which doubled to 18% in 2017. By 2021, however, the figure dropped to 11%, potentially indicating a shift to other digital payment methods or challenges in mobile payment implementation. Receiving wages and government benefits digitally promotes higher savings, reduces illicit fees and administrative costs, and minimizes payment leakage, while fostering financial self-reliance [4, 13].

Debit and credit card usage (**Table 2**) presented contrasting trends. Debit card adoption fluctuated, with 40% of Nigerians using debit cards in 2014. This declined to 31% in 2017, likely due to economic challenges like the 2016 recession, which reduced disposable income and electronic payment attractiveness. By 2021, debit card usage rebounded slightly to 35%, reflecting renewed cashless transaction promotion and improved banking infrastructure. In contrast, credit card usage showed consistent growth, rising from 68% in 2014 to 77% in 2017 and reaching 84% in 2021.

3.5 Exclusion gaps in Nigeria (2011 to 2021)

3.5.1 Gender and digital exclusion gaps

Findings from **Figure 3** showed that gender gap in formal account ownership grew from 7% in 2011 to a peak of 27% in 2017 but dropped to 21% in 2021. This decline reflects challenges in sustaining financial inclusion gains, particularly for women, who face structural and cultural barriers to accessing financial services [20]. The gender gap in mobile account ownership, a key driver of digital financial inclusion, increased modestly from 0% in 2011 to 7% in 2021. While mobile technology has the potential to bridge access gaps, adoption among women remains low due to limited access to mobile phones, poor digital infrastructure, lack of digital and financial

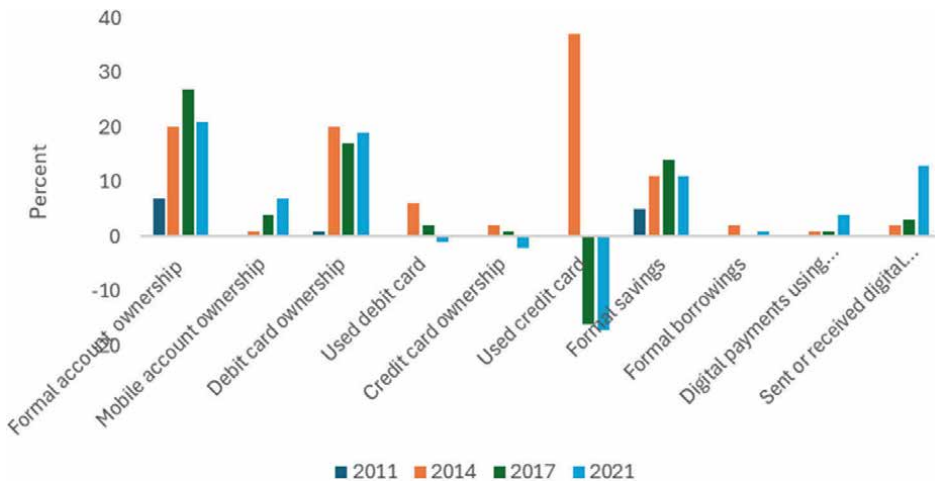


Figure 3.
Gender and digital gaps in financial inclusion.

literacy and inadequate trust in digital platforms [13, 14]. Expanding mobile account usage is essential for reaching women in underserved and rural areas, where physical banking infrastructure is scarce [21].

The trend in debit and credit card gender gap ownership and usage (**Figure 3**) highlights further disparities. Gaps between men and women owning debit cards rose from 1% in 2011 to 20% in 2014, dipped to 17% in 2017, and slightly rebounded to 19% in 2021. However, in terms of debit card usage, gender gaps continue to decline from 6% in 2014 to 2% in 2017 and in 2021, men's ownership of debit cards reduced by 1% beyond women's (–1%). Also, as of 2021, a negative gender gap of (–2% and – 17%) in credit ownership and usage suggests that women's ownership of credit cards and usage increased beyond men's.

Savings and borrowing trends also reveal significant gender gaps, increasing from 5% in 2011 to 14% in 2017 but declining to 11% in 2021. This volatility reflects broader economic instability and a lack of targeted financial products for women. Formal borrowing remains exceedingly low, with only 1% of women borrowing through formal channels by 2021, hindered by stringent requirements and limited access to credit facilities tailored to women's needs.

Digital payments and remittances have shown consistent growth but still highlight the digital divide. The gender gaps in digital payments rose from 0% in 2011 to 4% in 2021, and digital remittance transactions increased from 0 to 13% over the same period. Despite these gains, women continue to lag due to unequal access to mobile devices and digital payment platforms, compounded by lower levels of digital literacy and trust in technology.

3.6 Rural-urban and digital financial exclusion gaps (2021)

Findings from **Figure 4** revealed that rural areas in Nigeria have exclusion and digital gaps compared to the urban areas across all the financial access and usage indicators investigated except in credit card ownership. As of 2021, 54% of urban dwellers in Nigeria own formal accounts, 79% own mobile phones, 34% have internet access, and 12% have a mobile account. When compared with the rural populace, 35% own formal accounts, 65% own mobile phones, 13% have internet access, and only one in

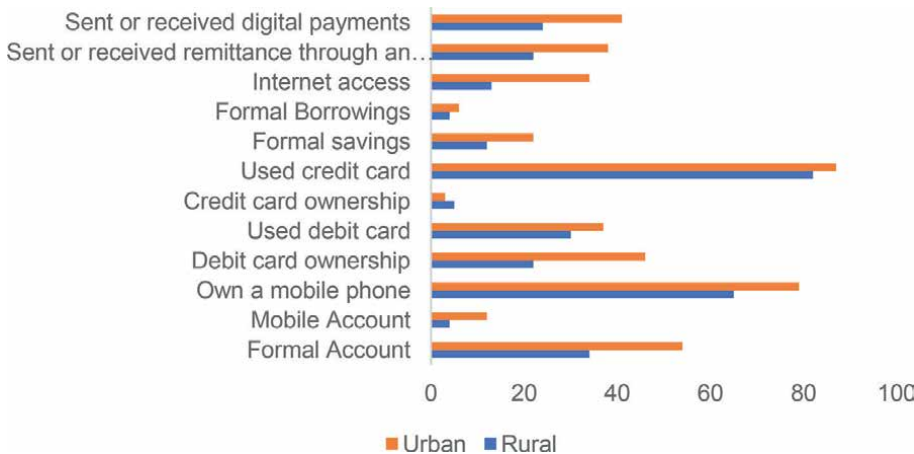


Figure 4.
Rural-urban and digital gaps in financial inclusion.

every third of the urban populace has a mobile account in the rural area. Given the challenges of rural areas such as lack of proximity to physical bank branches, access to mobile phones, mobile accounts, and the Internet in rural areas access to mobile financial services is crucial for digital financial inclusion to facilitate access to and use of financial services securely without the need for physical bank branches. Hence, results imply that the digital financial exclusion between rural and urban areas could disempower rural communities to participate in the digital economy and the financial independence arising from it.

Further analysis on debit ownership and usage (**Figure 4**) shows that 46% of urban dwellers have debit cards and only 37% have used them compared to the rural areas where 22% have debit cards and about 30% have used debit cards. Although only a few own credit cards as of 2021, 5% of the rural population own credit cards compared to the 3% in urban areas. However, 87% of urban dwellers have used a credit card compared to 82% in the rural areas.

Findings show that formal savings (12%) and borrowings (4%) were limited in the rural areas compared to formal savings (22%) and borrowings (6%) in the urban areas. While remittances sent or received through an account reveal a rural-urban divide of 16%, digital payments sent or received also show a significant digital divide (17%) between rural and urban areas. The findings imply that the limited access to formal savings, borrowings, and digital financial services in rural areas compared to urban areas could hinder economic growth by reducing capital availability, limiting investment opportunities, and slowing the adoption of digital financial technologies, all of which are critical for fostering productivity, entrepreneurship, and inclusive economic growth.

3.7 Overview of financial inclusion policy strategies in Nigeria, achievements and challenges

Financial inclusion has been a top priority in Nigeria's economic policy and has seen the Central Bank of Nigeria (CBN) introducing numerous policy strategies for the unbanked to access and use formal financial systems. Over a decade of these policies and frameworks demonstrate commitment to inclusive economic growth and financial inclusion. This section reviews the various policies, highlighting some achievements and challenges that remain, including the uptake of financial technology and digital financial services.

3.7.1 National financial inclusion strategy (NFIS) 2012 and revised NFIS (2018)

The NFIS, launched in 2012 by the Central Bank of Nigeria (CBN), aimed to reduce the financial exclusion rate to 20% by 2020. It focused on expanding access to financial services through mobile banking, agent banking, microfinance, and other innovative channels, targeting underserved groups, including women, rural populations, and small businesses [17]. In 2018, the strategy was revised to address persistent challenges, including low adoption of digital financial services and inadequate infrastructure. The revised NFIS emphasized leveraging fintech, mobile money, and digital payments to accelerate inclusion. It also set new goals, including increasing formal account ownership and promoting financial literacy. The NFIS has been instrumental in driving policies and partnerships to enhance access, usage, and quality of financial services [15]. However, the target of exclusion rate reduction was not achieved [14].

3.7.2 Mobile money services regulation (2009), updated in 2015

The Mobile Money Services Regulation, introduced by the CBN in 2009 and updated in 2015, provides a framework for mobile money operations aimed at increasing digital access to financial services for underserved populations. It established two models: the Bank-led Model, where banks lead mobile money operations, and the non-bank-led Model, where licensed non-bank entities, such as fintechs, operate mobile money services or partner with mobile network operators to provide services. The regulation encourages innovation in delivering services like mobile wallets, fund transfers, and bill payments [34]. The 2015 update clarified licensing requirements, consumer protection measures, and interoperability standards. These regulations have advanced financial inclusion by leveraging mobile platforms to reach rural and low-income individuals [35].

3.7.3 Cashless Nigeria policy 2012

The Cashless Nigeria Policy was introduced in 2012 to reduce the amount of physical cash in circulation and enhance the adoption of digital financial services. The policy placed limits on daily cash withdrawals and deposits for individuals and businesses, encouraging the adoption of electronic channels such as ATMs, point-of-sale (POS) terminals, internet banking, and mobile payments. For individuals, the daily free withdrawal limit was ₦500,000, while for businesses, it was ₦3,000,000. Withdrawals exceeding these limits incurred processing fees: 3% for individuals and 5% for businesses [28]. In December 2024, the CBN introduced new limits specifically for point-of-sale (POS) transactions. Individuals are now restricted to a maximum cash-out of ₦100,000 per day through POS agents, and each agent's total cash-out transactions should not exceed ₦1,200,000 daily [36].

3.7.4 The financial literacy framework 2013

The Financial Literacy Framework (FLF) of 2013 was a landmark initiative targeting knowledge gaps that hinder financial inclusion. Spearheaded by the CBN, it integrated financial education into school curriculums, organized nationwide literacy campaigns, and partnered with fintech and mobile money operators to disseminate information. By enhancing consumer confidence and promoting a behavioral shift from informal to formal financial options, the FLF bolstered the effective use of financial products, addressing critical barriers to financial inclusion [37]. However, this effort has not fully manifested as financial illiteracy persists due to poor educational achievement, thereby impeding financial inclusion progress [14].

3.7.5 Guidelines for agent banking regulation (2013) and the regulatory framework for agent banking (2023)

The Agent Banking Guidelines introduced in 2013 allowed financial institutions to extend services through third-party agents like retail outlets and small businesses. The framework prioritized consumer protection and operational integrity, ensuring compliance with anti-money laundering (AML) and Know Your Customer (KYC) protocols [38]. The 2013 Guidelines for Agent Banking Regulation focused on operational aspects of traditional agent banking, promoting access to financial services in

underserved areas. In contrast, the 2023 Regulatory Framework expands on this by addressing digital agent banking, incorporating new technologies, improving risk management (including cybersecurity), and enhancing consumer protection [39]. It reflects the growing importance of mobile payments and fintech in Nigeria's evolving financial landscape. While the CBN's policies aim to enable financial institutions to extend services to underserved and remote areas, fostering a safe and efficient agent banking system to broaden financial access across Nigeria, northern Nigeria still falls short of the expected agent and network distribution, reflecting gaps in rural-urban inclusion [14].

3.7.6 Guidelines for licensing and regulation of payment service banks (PSBs) 2018

In October 2018, CBN issued guidelines for PSBs to leverage mobile and digital channels to enhance financial inclusion. PSBs are allowed to accept deposits, provide savings accounts, facilitate remittances, issue debit cards, and enable mobile payments, targeting individuals and small businesses without bank accounts. However, they are restricted from offering loans or engaging in foreign exchange trading. The guidelines targeted unbanked and underserved populations, especially in rural areas, by leveraging mobile network operators (MNOs), fintechs, and retail chains as operators. By fostering competition and innovation, PSBs have played a pivotal role in advancing digital financial inclusion in Nigeria [40].

3.7.7 Framework for operation of the shared agent network expansion facility (SANEF) (2018)

SANEF was introduced in 2018 as a joint initiative by the CBN, Deposit Money Banks (DMBs), and licensed mobile money operators (MMOs) to increase the number of financial access points (agent outlets) in underserved rural and semi-urban areas. SANEF aims to expand the agent banking network by providing financial and technical support to agents across the country, to deliver financial services efficiently [41]. It facilitates services such as cash deposits, withdrawals, fund transfers, and bill payments. By increasing the number of financial access points, SANEF exceeded its target in bringing formal financial services closer to unbanked populations [14]. It also supports the Cashless Nigeria Policy by promoting digital financial transactions [28].

3.7.8 The framework for advancing women's financial inclusion in Nigeria (2020)

In 2020, the Framework for Advancing Women's Financial Inclusion addressed Nigeria's persistent gender gap in financial services. Building on the NFIS (Revised) and integrating insights from the Assessment of Women's Financial Inclusion in Nigeria conducted in December 2019, it identified strategic imperatives, including enhancing women's financial literacy, supporting account ownership, fostering gender-sensitive product development, and promoting entrepreneurship. The framework also prioritized data-driven policymaking and partnerships to address gender-specific barriers, making financial services more accessible to women [42]. Efforts of the Nigerian government to advance women's financial inclusion and economic empowerment have also been matched with various partnerships such as the Nigerian for Women Project (NFWP) and the Alliance for Financial Inclusion among others [14, 43].

3.7.9 eNaira launch and digital payment guidelines 2021

The eNaira, Nigeria's Central Bank Digital Currency (CBDC), was launched by the Central Bank of Nigeria (CBN) in October 2021 as a digital payment solution aimed at enhancing financial inclusion and promoting digital transactions [44]. The eNaira operates on a blockchain-based platform, enabling secure, fast, and low-cost transactions. Complemented by the Digital Payment Guidelines [45], eNaira facilitates person-to-person (P2P), person-to-business (P2B), and government-to-person (G2P) payments, ensuring accessibility through smartphones or feature phones. The eNaira enhances financial inclusion by integrating unbanked populations into the digital economy and reducing reliance on cash. It also supports the Cashless Policy [28] and drives innovation in Nigeria's payment ecosystem.

3.7.10 Fintech and innovation regulatory sandbox (2021)

The Fintech and Innovation Regulatory Sandbox introduced in 2021 provided a controlled environment for testing innovative financial products and services. By allowing fintech developers to pilot solutions under regulatory supervision, the sandbox fostered the creation of accessible, affordable products tailored to underserved populations. Initiatives like digital payments and lending platforms tested within this framework have driven financial inclusion, ensuring compliance and enhancing consumer protection [46].

3.7.11 Regulatory framework for open banking 2021

The Regulatory Framework for Open Banking introduced in 2021 facilitated secure data sharing among financial institutions, fintech companies, and service providers. By promoting innovation and competition, open banking enabled third-party providers to access customer data (with consent) through APIs. This framework spurred the development of customer-centric products, improving access to credit and digital services for underserved communities, while adhering to strict security and privacy standards [47].

3.7.12 Achievements and challenges of financial inclusion policies

There has been some notable progress on the policies of financial inclusion in Nigeria, but the effect on real life differs across demographic groups and regions. One of the key success areas has been the progressive growth of financial access points using agent banking and mobile money services. With the launch of SANE, the number of banking agents has expanded to more than 1,300,000 agents as of 2022, though the target was just 500,000 agents by 2020 [14, 48]. However, the case is different in northern Nigeria, where, due to security challenges and inadequate infrastructure, financial service penetration lags [14].

Also, significant advancements in inclusive policy initiatives such as the 2020 Nigeria's Framework for Advancing Women's Financial Inclusion have been evident [42]. However, Nigerian women are 12 percentage points less likely to be financially included than their male counterparts, with projections showing no change to these figures until after 2027 [49]. Many reasons account for the high percentage of unbanked women in Nigeria, including restricted mobility, low literacy levels, institutional factors, legal and regulatory barriers, and cultural and socio-economic

barriers, especially in rural regions [20]. Furthermore, the gender digital divide restricts women from accessing financial services and hampers their ability to interact with digital banking solutions [21, 50].

Fintech policy strategies have been instrumental in popularizing digital financial services. For example, CBN's digital currency, eNaira, was introduced to encourage digital transactions and less reliance on cash [44, 45]. However, its uptake has been slower than expected, even after a 302% hike in circulation over the course of nine months, which hit N10.26 billion as of September 2023 [51]. By March 2024, eNaira had less than a 0.36% share of the total money supply (N13.98 billion out of N3.87 trillion), meaning that no more than 1% of the population actively uses it [52]. A survey conducted in 2021 revealed that 37% of fintech users in Nigeria had concerns regarding the security of their data and cyber fraud, which is undermining trust in digital financial platforms [53]. Likewise, insufficient digital literacy, infrastructural deficits, and regulatory constraints create major setbacks [4, 5]. Even more, financial exclusion is at its highest in rural communities where the internet connectivity and electricity needed for digital financial transactions are often unavailable, which would impact the adoption of mobile banking and fintech solutions [54]. Also, despite the process of implementing Nigeria's cashless policy, many prefer cash payment due to concerns about cyber fraud, unreliable internet connectivity, and a lack of trust in digital payment systems [55]. In addition, low-income groups are reluctant to adopt fintech platforms as they are averse to mobile banking transaction fees and internet usage costs [27]. Lack of interoperability among financial service providers has also been identified as a major obstacle to achieving seamless transactions [56].

To navigate these challenges, a multifaceted approach is needed, including enhanced financial literacy initiatives, gender-responsive fintech innovations, bolstered cybersecurity structures, broadening mobile and internet infrastructure, especially in rural areas, and enforcing consumer protection regulations.

4. Implications for policy and economy

Analysis in this chapter shows that Nigeria made substantial progress; however, there are still major areas that need targeted policy formulation and economic reform. While the rise in access and use of financial services is driven by digital financial innovations and policy strategies, weak mobile account penetration and stagnation in the use of digital technologies among some demographic groups, especially women and rural dwellers, suggest continued exclusion from various financial services. Gender-sensitive policies and rural outreach initiatives that target these disparities are crucial in closing the financial and digital gap between men and women and between urban and rural areas. The practical implications of findings in this chapter suggest that there must be a structured way of implementing financial inclusion policy strategies for it to achieve the objectives of economic advancement.

4.1 Short term strategies

Policy interventions in the near term must aim at capacity-building for financial literacy, strengthening cybersecurity measures, and improving regulatory frameworks. Digital financial services providers should educate the public through outreach campaigns that encourage the adoption of fintech solutions, especially among the marginalized. Stricter cybersecurity policies and fraud prevention mechanisms

are needed to mitigate rising fears of a cyber threat, which discourage digital finance adoption. Immediate regulatory reforms and establishing fair transaction fees, as well as strengthening consumer protection laws, can enable a more sophisticated and accessible financial market ecosystem.

4.2 Medium term strategies

In the medium term, infrastructure building and interoperability among providers of financial services should be prioritized. For fintech adoption, the expansion of mobile and internet connectivity in rural areas is also key, to bridge the digital divide. The ineffectiveness of financial service delivery can be reduced if policymakers facilitate interoperability across banks, fintech, and mobile money operators to ease transactions. Additionally, targeted interventions aimed at enhancing financial inclusion for women and lower-income communities (e.g., gender-focused financial products and microfinance initiatives) can address gender and digital divide gaps. Furthermore, financial innovation and economic resilience can be achieved by strengthening partnerships among various components and stakeholders within public agencies and the private sector.

4.3 Long term strategies

Longer-term interventions should focus on institutional reform, harmonizing efforts in systems of digital identity, and inclusive economic policy. Socio-economic and structural barriers including legal frameworks that prevent women from having equal financial rights must also be addressed to achieve sustainable financial inclusion. Responsive fintech advances need to be considered in sustainable financial policies, complemented by the security of consumer interest and safeguarding of data. Strengthening the financial ecosystem that promotes entrepreneurship, investment, and economic diversification holds the key to achieving long-term economic growth and stability.

4.4 Global implications of financial inclusion efforts in Nigeria

Key lessons from Nigeria's financial inclusion journey present valuable insights for emerging economies facing similar challenges of gender disparity, rural-urban divide, and financial and digital exclusion. Nigeria's approach, which combines the use of fintech, mobile banking, and agent banking, shows that targeted policy measures can still advance financial inclusion even in the face of infrastructural, socio-economic, and socio-cultural limitations. The challenges of forming strategic public-private partnerships, adopting fintech innovations, and addressing gender gaps, urban-rural gaps and digital divide are not unique to Nigeria but are relevant issues for all countries, especially those seeking to reach underserved communities with financial services. Hence, the need for target interventions in the short, medium, and long term, adapted to the needs of each economy, is crucial for sustainable financial inclusion and economic progress.

5. Conclusion

Nigeria's journey toward financial inclusion reflects a blend of notable achievements and ongoing challenges. Financial inclusion is not just a social issue; it has

substantial economic effects as well, impacting savings rates, investment opportunities, entrepreneurship rates, and the economy's overall stability. Closing exclusion gaps to access and use financial services, particularly in gender and rural access, will help Nigeria to harness the full potential of its population, which is crucial in achieving sustainable economic growth and poverty alleviation. Effective policies that leverage gender-sensitive innovation in fintech, and promote financial and digital literacy while addressing structural inequities, will continue to be critical for an inclusive financial ecosystem. In conclusion, regular review and adaptation of financial inclusion policies will be key to ensuring progress is both maintained and amplified. The journey toward universal financial inclusion in Nigeria will involve bridging the digital divide, empowering marginalized groups, and fostering innovation in financial services to ensure that all citizens have access to and use basic financial services like savings accounts and credit, thereby promoting equitable economic development and resilience in an increasingly digital financial landscape.

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Macroeconomic Performance and Its Influence on Education, Investment, and Economic Growth in Sub-Saharan Africa

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Abstract

Sub-Saharan Africa's path to industrialization hinges on the interplay between human capital development, investment, and economic growth. Drawing insights from economic development and growth theories, this study examines the key drivers of educational quality, public investment, and economic growth in the region from 1980 to 2022 using conventional growth models. Findings indicate that while increased capital formation enhances educational quality, current investment levels remain insufficient to sustain long-term growth. Economic growth is primarily driven by capital formation, exports, and electricity consumption, but is constrained by the challenges of rapid urbanization. Public investment, in turn, is influenced by urbanization, industrial employment, electricity consumption, and past investment trends. The study underscores the need for strategic investment planning, energy efficiency, and export diversification to support sustainable economic progress. Policymakers should prioritize optimizing public spending, enhancing capital investments, and improving resource management to strengthen education, economic growth, and the role of public investment in regional development.

Keywords: education, investment, economic development, industrialization, economic growth

1. Introduction

The early 2000s saw rapid global economic growth, largely fueled by advancements in technology during the Fourth Industrial Revolution [1–3]. This period was marked by significant technological progress, building on earlier industrial revolutions that began in Britain in the late eighteenth century and later spread to North America in the nineteenth century [4]. These technological advancements transformed industries, enabling the efficient conversion of raw materials into finished products, adding value to economies, and expanding global trade [5].

By the mid-nineteenth century, industrialization reached Asia, with countries like India, Japan, and China embracing it. Later, the High-Performance Asian Economies (HPAEs)—Singapore, Hong Kong, Taiwan, and South Korea, also known as the Asian Tigers—successfully harnessed industrialization to achieve remarkable economic growth. These early adopters of industrialization benefited from advancements in communication (telegraph lines), transportation (railways and automobiles), power (electricity), and education, which allowed them to become global leaders in high-value industries. Today, these countries dominate global exports of processed and semi-processed goods [4, 6].

The global economy has become more open over time, leading to major advancements in communication (such as telegraph lines), transportation (like railways and automobiles), electricity, and education. The countries that embraced these changes early on have grown into major industrial powers, producing and exporting processed and semi-processed goods worldwide [7]. However, many developing economies, especially in Sub-Saharan Africa (SSA), have not fully integrated into this new wave of industrial transformation, known as the Fourth Industrial Revolution. Instead, they continue to focus on exporting raw materials and natural resources rather than manufacturing finished goods. This is partly due to historical factors—during colonial rule, SSA economies were structured primarily to supply raw materials to industrialized nations, a pattern that has persisted over time [7–9]. In the past, economic activities gave less importance to Environmental, Social, and Governance (ESG) principles than they do today.

In the late 1900s, most Sub-Saharan African (SSA) economies—often referred to as late adopters of industrialization—began transitioning into value-added sectors after decades of reliance on unprocessed agricultural and raw material exports [10, 11]. This shift enabled many SSA economies to become significant producers and exporters of semi-processed goods, expanding economic opportunities and fostering job creation to bridge the employment gap.

Initially, these late-adopting economies faced considerable institutional challenges, including deficiencies in education, governance, and infrastructure, as their economic landscapes were not well-prepared for the technical demands of value-added industries. Countries such as South Africa, Ghana, Nigeria, Kenya, and Ethiopia encountered structural shocks, including skills shortages, inadequate practical training, and limited energy capacity [12, 13]. To address these challenges, several structural reforms were implemented in education, governance, and the energy sector to support industrialization and enhance the value-added economy [14].

Despite these efforts, ongoing struggles in this new economic frontier have underscored the need for further infrastructural development and increased public sector investment. However, insufficient investment in these areas has hindered sustainable industrial growth in the region [15]. Directing more public-sector resources toward education and energy infrastructure is crucial for training a skilled workforce and expanding energy capacity. Nevertheless, the relationship between economic growth, employment, industrial expansion, and educational quality remains complex [16].

Currently, the lack of clarity regarding how public sector investment and economic growth directly impact these critical areas limits policymakers' ability to design and implement effective strategies. Therefore, it is essential to better understand how Gross Public Sector Investment (GPSI) can be leveraged to promote industrial growth, economic diversification, and improvements in educational quality across

SSA. By addressing this knowledge gap, this study seeks to provide valuable insights that can guide policy interventions for more sustainable and inclusive economic development in the region.

Building on the identified gaps, this research analyzes the impact of Gross Public Sector Investment (GPSI), economic growth, and industrial expansion on various macroeconomic indicators in Sub-Saharan Africa (SSA). The primary objectives of this study are: (1) to seek to investigate how public sector investments influence economic growth and employment; (2) to explore the role of educational reforms in supporting industrial growth; (3) to assess the contribution of enhanced energy capacity to industrial development; and (4) to provide policy recommendations for fostering sustainable industrial growth and economic diversification.

The significance of this study lies in its potential to inform policy and investment strategies in Sub-Saharan Africa (SSA), particularly as the region seeks to diversify its economies and reduce dependence on primary resource exports. It also addresses key issues arising from the dynamic relationships between public sector investment, economic growth, and education.

This analysis examines the interaction amid public sector investments, educational quality, energy capacity, and industrial expansion. Using data from the African Development Indicators (ADI) and a robust methodological framework, the study ensures reliable findings that inform effective policy recommendations. These recommendations integrate Environmental, Social, and Governance (ESG) principles, which have become indispensable (*sine qua non*) in contemporary national and regional policy discourse. Given its far-reaching implications, industrialization significantly influences environmental sustainability, social development, and governance structures. The remainder of the study is organized as follows: Section 2 examines the model, Section 3 focuses on data collection, Section 4 presents the analysis of the study objectives, and Section 5 provides the conclusion and recommendations.

2. The model: Generalized Method of Moment (GMM)

The Generalized Method of Moments (GMM), as developed by Roodman [17] and extended by Alvarez and Arellano [18], addresses endogeneity issues that arise when lagged dependent variables are included as regressors. It is appropriate for dynamic panel data models where unobserved heterogeneity and endogeneity need to be controlled. A simple outlook of Roodman [17] and Alvarez and Arellano [18] on Generalized Method of Moment (GMM) is expressed as

$$\ln \mathcal{G}_t = \beta_0 \ln \mathcal{G}_{t-1} + \beta_1 \ln \mathcal{U}_t + \beta_2 \ln X_t + \mu_t \quad (1)$$

Where t denotes the time effect for the Sub-Saharan African economy, $\ln$ denotes the natural logarithm of the variables, $\ln \mathcal{G}_t$ is the dependent variable representing economic activity in the Sub-Saharan African economy, $\ln \mathcal{G}_{t-1}$ is the log-lagged component of the independent variable $\mathcal{G}$. $\mathcal{U}_t$ is a matrix of instrumental variables used to control for endogeneity, X_t denotes the matrix of the control variables, and μ_t is the error term capturing unobserved shocks. Eq. (1) is redefined with the dependent series, the matrix of instrumental and control variables. It represents the three major research questions highlighted above.

$$\ln EQ_t = \beta_0 \ln EQ_{t-1} + (\beta_1 \ln TP_t + \beta_2 \ln RGDP_t) + \beta_3 \ln GPI_t + \beta_4 \ln GFCF_t + \beta_5 \ln EXPORTS_t + \beta_6 \ln EII_t + \mu_t \quad (2)$$

$$\ln GPI_t = \beta_0 \ln GPI_{t-1} + (\beta_1 \ln TP_t + \beta_2 \ln RGDP_t) + \beta_3 \ln EPC_t + \beta_4 \ln GFCF_t + \beta_5 \ln EXPORTS_t + \beta_6 \ln EII_t + \mu_t \quad (3)$$

$$\ln RGDP_t = \beta_0 \ln RGDP_{t-1} + (\beta_1 \ln TP_t + \beta_2 \ln RGDP_t) + \beta_3 \ln EPC_t + \beta_4 \ln GFCF_t + \beta_5 \ln EXPORTS_t + \beta_6 \ln EII_t + \mu_t \quad (4)$$

Where, in Eq. (2), $\ln EQ_t$ and $\ln EQ_{t-1}$ denote the logged component of educational quality and its lagged term at time t , respectively. In Eq. (3), $\ln GPI_t$ and $\ln GPI_{t-1}$ denote the logged component of gross public investment and its lagged term at time t , respectively. In Eq. (5), $\ln GDP_t$ and $\ln GDP_{t-1}$ denote the logged component of Gross Domestic Product and its lagged term at time t , respectively. $\ln EXPORTS_t$ denotes the accelerator trade effect at time t ; $\ln EII_t$ denotes Employment in Industries (as a percentage of total employment) at time t , and $\ln GFCF_t$ denotes Gross Fixed Capital Formation (GFCF), a measure of finance investment at time t .

To address endogeneity concerns (the correlation between the error terms μ_t and control variables), we replaced Total Population (TP) and Real Gross Domestic Product (RGDP) with Urban Population Ratio (UPR) and Consumer's Income (Gross Domestic Product per Capita) in the equations due to their direct association with the error term. The controlled equations are expressed below:

$$\ln EQ_t = \beta_0 \ln EPC_{t-1} + (\beta_1 \ln UPR_{it} + \beta_2 \ln GDPPC_t) + \beta_3 \ln GPI + \beta_4 \ln GFCF_t + \beta_5 \ln EXPORTS_t + \beta_6 \ln EII_t + \mu_t \quad (5)$$

$$\ln GPI_{it} = \beta_0 \ln GPI_{t-1} + (\beta_1 \ln UPR_t + \beta_2 \ln GDPPC_t) + \beta_3 \ln EPC_t + \beta_4 \ln GFCF_t + \beta_5 \ln EXPORTS_t + \beta_6 \ln EII_t + \mu_t \quad (6)$$

$$\ln RGDP_{it} = \beta_0 \ln GDP_{t-1} + (\beta_1 \ln UPR_t + \beta_2 \ln GDPPC_t) + \beta_3 \ln EPC_t + \beta_4 \ln GFCF_t + \beta_5 \ln EXPORTS_t + \beta_6 \ln EII_t + \mu_t \quad (7)$$

Where, $\beta's$ are the unknown parameters for the series.

The GMM model redefined equations for specific economic variables and the steps taken to control for endogeneity in the analysis of the Sub-Saharan African economy.

3. Data

The central variables in this study are educational quality, gross public investment, and economic growth. Eqs. (5), (6), and (7) serve as the models for the econometric analysis, addressing the research questions. This study seeks to test the association between the central dependent variables and major macroeconomic independent variables within the context of Sub-Saharan Africa.

Economic growth, measured by changes in GDP, remains dynamic over the decades due to structural and political shifts in the region. It is extracted from the World Development Indicators (WDI) repository. The quality of education indicator is proxied

by government spending on education, and Gross Public Investment (GPI) shows a consistently rising trend, as depicted in **Figure 1**. Both indicators are sourced from the WDI.

Although this positive trend paints a favorable picture for the SSA economy, a review of human capital quality relative to Scandinavian economies reveals a significant gap in quality. Scandinavian economies allocate substantial resources to the educational sector. Recognizing the critical role of quality education in human capital development and industrial growth, much needs to be done, aligning with observations made by Moretti in [19] and Moretti in 2004 [20]. As Sub-Saharan Africa has a predominantly labor-intensive economy, improving the quality of the educational system will produce a quality labor force, propelling industrial sustainability in the region, as emphasized by Christopher L. Delgado [21].

The General Method of Moments (GMM) model incorporates exogenous variables extracted from the World Bank's Development Indicators database. These variables include industrial growth, Gross Fixed Capital Formation, Real GDP, Goods and Services Exports, and Urban Population. Data originates from the Africa Development Indicators, covering 50 Sub-Saharan African countries over a 40-year time series from 1980 to 2022.

3.1 The trend performance of major macroeconomic indicators in SSA

Over the past four decades, Sub-Saharan Africa (SSA) has experienced significant shifts in key economic indicators. **Figure 1** highlights these trends, showing that Gross Public Investment and government spending on education—often used as a measure of educational quality—have steadily increased with little fluctuation. However, economic growth, a key measure of overall performance, has followed a different path, showing a long-term decline, particularly after the late 2000s. This disconnect has had major implications for education, investment, and the broader industrial sector in SSA.

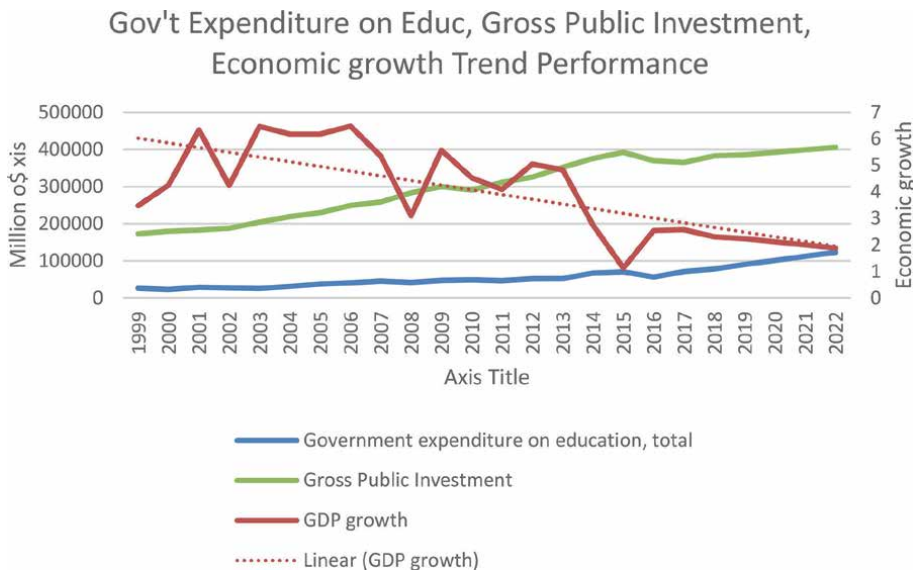


Figure 1.
Macroeconomic indicator trends for Sub-Saharan Africa.

In theory, higher investment leads to an increase in government spending on education and the development of a skilled workforce to drive productivity. Similarly, public investment in infrastructure plays a crucial role in creating a business-friendly environment that supports long-term growth. However, for these investments to translate into sustained economic progress, technology must be leveraged effectively. Digital innovations, automation, and modern infrastructure systems can enhance the impact of public investment, making education more accessible and industries more competitive.

3.2 An extended analysis of SSA major macroeconomic indicators

This section provides a detailed analysis of **Figure 1**, considering additional variables relevant to the study. As shown in **Table 1**, nearly all macroeconomic indicators in SSA have experienced significant growth since the 1960s. The region’s real GDP (at constant 2000 USD) has surged by an impressive 689% since 1970. Over the same period, Gross Public Investment (GPI) and exports of goods and services have grown substantially, increasing eightfold (809%) and sixfold (699%), respectively. Electricity consumption has also seen a dramatic rise, expanding 57 times (5763%), reflecting broader economic expansion and increased urbanization.

However, despite this overall growth, GDP per capita has only increased by 187%, while the region’s population has more than tripled (365%) since 1960. The latter has neutralized the pace of economic growth. This highlights the challenges SSA faces in translating economic gains into widespread improvements in living standards. These trends underscore the complexities of economic development in the region, where rapid growth must be balanced with policies that ensure inclusive and sustainable progress.

3.3 Economic Fitness (EF) performance of the Sub-Saharan African economy with other regions

This section examines the economic fitness of SSA in comparison to other regions globally. Economic Fitness (EF) measures a country’s ability to diversify and produce complex goods competitively on the global market. Nations with high EF scores tend to manufacture a wide range of products, transition into more sophisticated industries, and experience sustained long-term growth. In contrast, countries with lower EF scores often struggle with poverty, limited industrial capabilities, and unpredictable growth, making it harder to produce high-value goods or diversify their economies efficiently.

Africa macroeconomic variables	% Growth
Gross public investment (% of GDP)	809
GDP per capita (constant 2000 US\$)	187
Population, total	365
Exports of goods and services (current US\$)	6995
Electric power consumption (kWh)	5763
GDP (constant 2000 US\$)	689

Source: Author’s own.

Table 1.
The SSA macroeconomic indicators performance from 1960 to 2022.

While SSA has made progress in economic growth over time, its overall performance remains below expectations. According to the World Bank’s Economic Fitness (EF) rankings, SSA currently stands at 112th out of 149 countries, reflecting persistent challenges in industrial competitiveness and economic diversification. To improve this standing, investments in technological innovation, digital infrastructure, and sustainable industrial practices are crucial. Additionally, integrating Environmental, Social, and Governance (ESG) principles into economic policies can enhance long-term resilience, attract responsible investments, and support more inclusive development.

Sub-Saharan Africa faces significant challenges in improving its economic fitness, ranking 112th compared to Northern America’s 16th, Europe and Central Asia’s 44th, East Asia and the Pacific’s 61st, the Middle East and North Africa’s 58th, and Latin America and the Caribbean’s 63rd (Table 2). This gap highlights structural barriers

Region	Economic fitness rankings score
Europe and Central Asia	44
Middle East and Northern Africa	58
Latin America and the Caribbean	63
East Asia and Pacific	61
Northern America	16
Sub-Saharan Africa	112

Source: WDI.COM.

Table 2.
Economic fitness rankings for different regions.

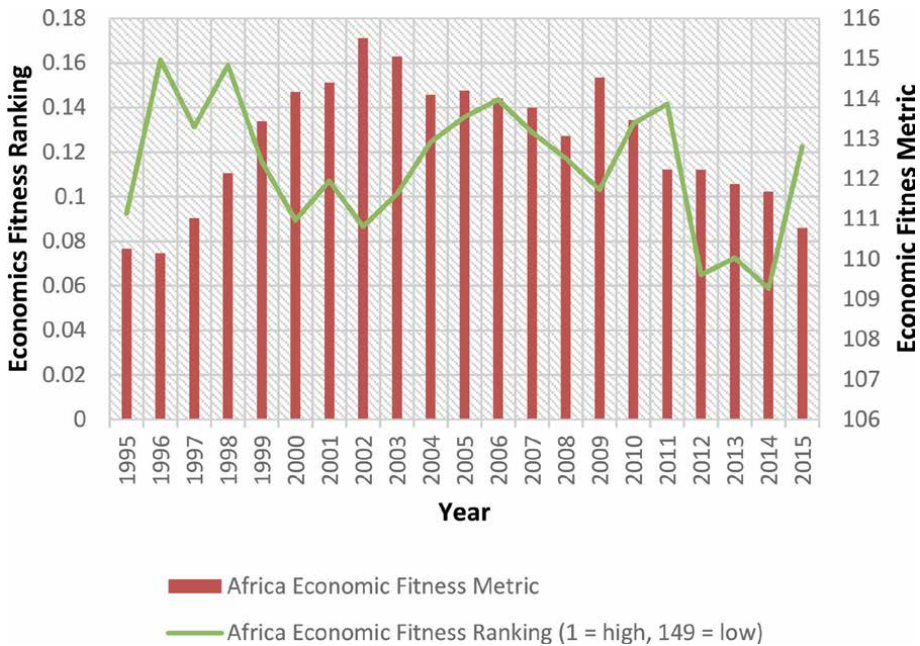


Figure 2.
Africa economic fitness matrix and trending over time. Source: World Bank Data. The current data ends at 2015.

that limit economic stability, industrial competitiveness, and diversification. While foreign direct investment has increased, ineffective regulatory frameworks and institutional weaknesses continue to hinder business operations and long-term growth. Strengthening governance, reducing political instability, and investing in human capital are essential steps toward creating a more business-friendly and resilient economic environment.

Figure 2 illustrates the volatility of economic fitness (EF), revealing fluctuations that point to opportunities for improvement. A key strategy for addressing these challenges is transforming educational systems to align with economic needs. Integrating technology into education can enhance skills development, fostering a workforce that drives innovation and industrial expansion. This approach aligns with the African Union’s Vision 2063, which emphasizes education and infrastructure as pillars of economic progress. With its growing population, Sub-Saharan Africa has the potential to build a strong domestic market and a competitive industrial sector. However, realizing this potential requires addressing economic inefficiencies, modernizing infrastructure, and embedding Environmental, Social, and Governance (ESG) principles into policy frameworks. By prioritizing education, technology, and sustainable investments, the region can cultivate a dynamic economy capable of long-term growth and diversification.

4. Empirical diagnostics of the macroeconomic indicators

This section presents the empirical diagnostics of the data in relation to the research objectives. To ensure the reliability of the results, the model was carefully selected to minimize estimation biases. A preliminary diagnostic assessment was conducted, with the details outlined below. First, multicollinearity among the independent variables was examined using the Variance Inflation Factor (VIF), following the approach recommended by Klein and Prescott [22]. The analysis in **Table 3** indicates that multicollinearity is not a significant concern, ensuring that the model estimates remain robust and reliable.

Variables	VIF-test
Urban Population Ratio (UPR)	1.67
Gross Domestic Product Per Capita (GDPPC)	1.87
Export of goods and services	2.54
Gross Public Investment (GPI)	1.28
Real GDP	1.39
Employment in industry (% of total empl.) (EII)	3.21
Mean VIF	1.99
Breusch-Pagan (LM test)	
t-statistic	Prob.
1094.869	0.000

Source: Authors’ compilations.

Table 3.
Vector Inflation Factor (VIF) test and Breusch-Pagan (LM test).

Variables	CIPS*
Urban Population Ratio (UPR)	−0.787
Gross Domestic Product Per Capita (GDPPC)	−0.807
Export of goods and services	−2.143 [*]
Gross Public Investment (GPI)	−2.460 ^{***}
Real GDP	−1.864
Employment in industry (% of total empl.) (EII)	−2.472 ^{***}

Source: Authors' compilations.

Table 4.
Panel unit root test (CIPS).

Subsequently, panel data was subjected to an LM test to investigate cross-sectional dependence (CSD), a critical consideration given the dataset covers 50 countries across four decades. The null hypothesis assumes cross-sectional independence. The outcomes of the LM test, comprehensively presented in **Table 3**, provide valuable insights into the presence or absence of cross-sectional dependence in the panel data. This empirical analysis serves to validate the robustness of the model and inform subsequent discussions on the study's findings. The outcomes indicate the rejection of the null hypothesis regarding cross-sectional dependence, prompting a deeper investigation into the temporal characteristics of the variables through a panel unit root test proposed by Pesaran et al. [23]. This test evaluates the stationarity of variables, crucial for understanding their stability over time (see **Table 4**).

Table 4 presents the outcomes of our analysis, affirming the stability of all variables at the 1% significance level following first-order differences. Utilizing the Augmented Dickey-Fuller (ADF) technique, we observe that, with the exception of real GDP and urban population, all indicators exhibit stationary behavior at level (0). Urban pollution (UP) and Gross Domestic Product per capita (GDPPC) demonstrate first-order stationarity (I). To address endogeneity concerns within the GMM model, we substituted Urban Population (UP) and Gross Domestic Product per Capita (GDPPC) with Total Population and Real GDP. Diagnostic tests conducted reveal no collinearity issues, reinforcing the robustness of our statistical inferences.

5. Assessing the impact of macroeconomic indicators on educational quality in Sub-Saharan Africa

Education plays a crucial role in driving economic growth and regional development. Numerous studies [24–28] highlight its impact on productivity and economic expansion, showing a strong positive correlation between higher educational attainment and improved economic outcomes [24]. This study explores the relationship between macroeconomic indicators and educational quality in Sub-Saharan Africa, addressing an important research gap. Using Generalized Method of Moments (GMM) and Fixed Effect Ordinary Least Squares (FEOLS), the study examines key factors influencing educational quality. FEOLS helps isolate the effects of variables that change over time [29], while GMM accounts for potential endogeneity issues through instrumental variables [18, 30].

The findings in **Table 5** reveal varying effects of macroeconomic indicators on educational quality, depending on the model used. In the GMM model, only two factors significantly impacted educational quality: the lagged component of public spending on education and gross fixed capital formation. The lagged public spending on education showed a positive effect, emphasizing the long-term benefits of sustained investment in education. In contrast, gross fixed capital formation had a negative impact, possibly due to inefficiencies in capital allocation that did not directly improve educational outcomes. While public sector investments in education have increased over the years, there is still much work to be done to enhance educational quality, particularly given its role in supporting regional industrial development.

Variables	GMM	OLS
Urban Population Ratio (UPR)	-127.172 (207.151)	13.987 (18.486)
Gross Fixed Capital Formation (GFCF)	16.890* (9.890)	9.270 (7.031)
Exports of Goods and Services (EXPORTS)	-7500 (9.809)	-7336 (7.506)
Employment in Industry (% of total empl.) (EII)	11.685 (13.038)	-7.075 (7.068)
Gross Public Investment (% of GDP) (GPI)	-0.612 (10.163)	-2.642 (4.006)
GDP Per Capita (GDPPC)	-21.567 (44.546)	-7.110 (11.547)
Lag Gross Public Investment (% of GDP) (L.GPI)		
Electric Power Consumption(kWh) (EPC)	-8.509 (29.095)	7.178 (12.736)
Lag. Public Spending on Education	0.319* (0.174)	
Lag. GDP (constant 2000 US\$) (RGDP)		
Constant	376.849 (781.406)	7.192 (24.739)
Observations	2983	2983
R-squared		0.086
Number of countries	55	55
Dfres		80
BIC	.	833.4

Source: Author's computation.
Standard errors in parentheses.

*** $p < 0.01$.

** $p < 0.05$.

* $p < 0.1$.

Table 5.
GMM and Ordinary Least Squares (OLS) estimation results: Public spending on education.

However, in the FEOLS model, none of the macroeconomic indicators significantly influenced educational quality. Gross Public Investment (GPI), urban population rate (UPR), exports, and employment in industry (EII) all had insignificant effects. The lack of impact from GPI suggests possible inefficiencies in public spending, governance challenges, or a time lag before investments yield results. Similarly, the urban population rate (UPR) did not show a strong link to educational improvements, indicating that urbanization alone does not necessarily lead to better education [31]. Additionally, the absence of a relationship between exports and educational quality suggests that increased trade does not automatically enhance educational outcomes.

Industrial employment (EII) also showed no significant effect on educational quality, highlighting a disconnect between industrial growth and education. This suggests that employment expansion in the industrial sector does not necessarily lead to improvements in educational access or quality. These findings highlight the need for better allocation and utilization of public funds in education. Policymakers must rethink capital investment strategies to ensure they effectively contribute to improving educational standards. Further research is necessary to investigate potential inefficiencies and other factors that may limit the expected benefits of public investments in education, providing deeper insights into long-term development impacts.

5.1 Key drivers of economic growth in Sub-Saharan Africa: 1980–2022

This study provides a comprehensive analysis of the key drivers of regional economic growth in Sub-Saharan Africa over four decades, shifting the focus from educational quality to broader economic growth indicators. By employing both the Generalized Method of Moments (GMM) and Ordinary Least Squares (OLS) methodologies, the analysis identifies industrial growth—measured by the percentage of total employment in the industrial sector (EII)—as a pivotal factor in regional development. Despite its significance, industrial growth has been underutilized in economic analyses, as emphasized in Keynesian demand-side theory [28, 32].

The study identifies several core drivers of economic growth, including urban population (UP), gross fixed capital formation (GFCF), exports of goods and services (EXPORTS), gross public investment (GPI), electric power consumption (EPC), and industrial growth (IG). Empirical findings (**Table 6**) reveal a strong and positive relationship between gross fixed capital formation (GFCF) and electric power consumption (EPC) with economic growth, underscoring the fundamental role of infrastructure investment and reliable energy supply in fostering industrial expansion. Investments in transport networks, industrial zones, and technological advancements reduce production costs, attract foreign direct investment (FDI), and enhance economic productivity—critical for sustaining long-term growth in Sub-Saharan Africa.

Moreover, the study highlights the positive impact of exports of goods and services (EXPORTS) on economic growth in the GMM model, suggesting that industrial diversification, value addition, and improved competitiveness are essential for strengthening the region's economic resilience. While primary exports continue to be significant, enhancing production efficiency, expanding market access, and fostering technological innovation will be key to unlocking higher economic returns.

Variables	GMM	OLS
Lag. Electric Power Consumption (kWh) (EPC1)		
Public Spending on Education PSE	0.000 (0.000)	−0.001 (0.001)
Urban Population Ratio (UPR)	−0.097 (0.594)	−0.609*** (0.166)
Gross fixed capital formation (GFCF)	0.065** (0.028)	0.173** (0.066)
Exports of goods and services (EXPORTS)	0.052* (0.032)	−0.098 (0.072)
Employment in industry (% of total empl.) (EII)	−0.016 (0.038)	0.192*** (0.065)
Gross Public Investment (% of GDP) (GPI)	0.012 (0.033)	0.050 (0.038)
GDP Per Capita (GDPPC)		
Lag Gross Public Investment (% of GDP) (L.GPI)		
Electric Power Consumption (kWh) (EPC)	0.300*** (0.102)	0.964*** (0.060)
Lag. Public Spending on Education		
Lag. GDP (constant 2000 US\$) (RGDP)	0.372*** (0.129)	
Constant	5.231*** (1.782)	−1.258*** (0.193)
Observations	2983	2983
R-squared		0.997
Number of countries	55	55
Dfres		80
BIC	.	−150.2

Ronald A. Fisher (1890–1962) is widely regarded as the founder of modern statistical significance testing. His work, particularly in *Statistical Methods for Research Workers* (1925), introduced the *p*-value and established the convention of using thresholds like $p < 0.05$ to determine statistical significance.

Source: Author's computation.

Standard errors in parentheses.

*** $p < 0.01$.

** $p < 0.05$.

* $p < 0.1$.

Table 6.

GMM and OLS estimation results: Economic Growth (GDP).

However, the urban population ratio (UP) exhibits a negative effect on economic growth in the OLS model, signaling the challenges posed by rapid urbanization. Without effective urban planning and strategic investments in housing, transportation, and social services, the economic benefits of urban expansion may be outweighed by the pressures on infrastructure and public services. Addressing these challenges requires integrated urban development policies that align with sustainable growth objectives.

Contrary to expectations, public spending on education (PSE) and gross public investment (GPI) show insignificant effects on economic growth, suggesting inefficiencies in resource allocation or governance-related constraints. This underscores the need for enhanced fiscal transparency, improved institutional frameworks, and strategic investment planning to ensure that public funds translate into tangible economic benefits. Strengthening governance mechanisms and promoting efficient public service delivery will be critical to maximizing the developmental impact of these expenditures.

As Sub-Saharan African economies aim for middle-income status, meeting the rising energy demand for key industries—steel production, oil refining, mining, and agriculture—is imperative. A reliable and sustainable energy supply is essential for maintaining industrial competitiveness and economic stability. Policymakers must focus on expanding renewable energy infrastructure, diversifying energy sources, and implementing cost-effective energy policies to support industrialization and long-term economic growth.

Optimizing economic growth in Sub-Saharan Africa requires a holistic approach that integrates industrial growth, infrastructure development, energy security, and urban planning. Strengthening governance frameworks, improving investment efficiency, and fostering innovation-driven economic policies will be essential in ensuring sustainable and inclusive development. By addressing these key areas, the region can position itself for a more resilient and diversified economic future, unlocking its full growth potential in the global economy.

5.2 Assessing the impact of macroeconomic indicators on Gross Public Investment (GPI)

Gross Public Investment (GPI) plays a pivotal role in driving economic growth, particularly in industrial sectors. Theoretical perspectives emphasize its significance in fostering long-term development, and empirical evidence from conventional growth models (Generalized Method of Moments (GMM) and Ordinary Least Squares (OLS)) methodologies supports this assertion. Findings indicate that changes in industrial sector employment significantly enhance regional GPI levels, with increases of 0.40% and 0.28% reported under GMM and OLS estimations, respectively [28]. Furthermore, the lag effect of past GPI investments is evident, as the GMM model shows a 0.35% increase in regional GPI, underscoring the lasting impact of prior investments on current economic activities. These results suggest that employment expansion in the industrial sector and well-planned investment strategies are crucial for sustaining economic growth.

Despite its significance, electricity consumption in Sub-Saharan Africa (SSA) presents challenges to GPI performance. The GMM model indicates that an increase in electricity consumption reduces regional GPI performance by 0.12% [33]. This negative relationship suggests a trade-off in resource allocation, as higher electricity demand diverts public resources away from investment in other productive areas. Since energy is a crucial driver of industrialization, inefficiencies in energy investment strategies could limit SSA's ability to optimize public investment. The trend analysis in **Figure 2** reveals a simultaneous increase in electricity consumption and GPI since the 1980s, highlighting the need for strategic energy policies that balance infrastructure expansion with sustainable resource allocation.

Urban population dynamics further complicate GPI performance, as findings from GMM and OLS yield contrasting results. While the GMM estimator suggests that

urbanization enhances GPI by 8.7%, the OLS estimator indicates a 1.6% decline. This disparity underscores the complexities of urban growth, where rapid urbanization can strain infrastructure, increase public service demands, and divert investments from productive industrial activities. Policymakers must adopt a balanced approach that integrates urban planning with investment strategies to maximize the benefits of urbanization while mitigating its adverse effects on public investment efficiency.

Variables	GMM	OLS
Gross Public Investment (GPI)		
Lag. Electric Power Consumption (kWh) (EPC)		
Public Spending on Education (PSE)	0.000 (0.002)	−0.002 (0.003)
Urban Population Ratio (UPR)	8.790*** (2.077)	−1.688*** (0.481)
Gross Fixed Capital Formation (GFCF)	−0.102 (0.117)	0.904*** (0.170)
Exports of goods and services (EXPORTS)	0.075 (0.130)	−0.580*** (0.200)
Employment in industry (% of total empl.) (EII)	0.288** (0.145)	0.490** (0.190)
GDP Per Capita (GDPPC)	0.545 (0.548)	0.413 (0.319)
Lag Gross Public Investment (% of GDP) (L.GPI)	0.396*** (0.121)	
Electric Power Consumption (kWh) (EPC)	−0.934** (0.399)	−0.753** (0.345)
Lag. Public Spending on Education		
Lag. GDP (constant 2000 US\$) (RGDP)		
Constant	16.317** (7.355)	−0.233 (0.688)
Observations	2983	2983
R-squared		0.489
Number of countries	55	55
Dfres		80
BIC	.	74.1

Ronald A. Fisher (1890–1962) is widely regarded as the founder of modern statistical significance testing. His work, particularly in *Statistical Methods for Research Workers* (1925), introduced the *p*-value and established the convention of using thresholds like $p < 0.05$ to determine statistical significance.

Source: Author's computation.

Standard errors in parentheses.

*** $p < 0.01$.

** $p < 0.05$.

* $p < 0.1$.

Table 7.
GMM and OLS estimation results: Gross public investment.

SSA's economic structure, largely dependent on resource-based exports, also influences GPI outcomes. Unlike processed or value-added goods, raw material exports generate lower fiscal returns and contribute less to long-term public investment growth. **Table 7** reveals a negative correlation between changes in regional exports and GPI performance, challenging the assumption that export-led strategies inherently stimulate regional investment. This finding highlights the need for SSA economies to focus on export diversification, industrialization, and value addition to maximize fiscal revenues and enhance GPI efficiency. By investing in domestic processing industries (technology) and strengthening regional trade partnerships, SSA can reduce its dependence on primary exports and create sustainable growth pathways.

While industrial employment and urbanization present opportunities for GPI expansion, electricity consumption and resource-based exports pose challenges that must be addressed through strategic policymaking. To optimize GPI allocation and ensure sustainable economic growth, SSA governments must implement policies that promote industrial development, energy efficiency, and investment in high-return sectors. Strengthening public-private partnerships, improving financial management systems, and fostering regional cooperation will be crucial in transforming GPI into a robust driver of inclusive and long-term development across SSA.

6. The role of Environmental, Social, and Governance (ESG) principles

From the findings highlighted above, and considering the region's vast resource potential, fully adopting the value-added program across all sectors could overwhelm the economy's ecological space if urgent actions are not taken to integrate Environmental, Social, and Governance (ESG) principles into policy regulations and agreements. Currently, fossil fuels remain an integral part of economic value-added activities in the region. However, over-reliance on them due to full engagement in the value-added sector threatens environmental health. Accelerating the transition to renewable energy is crucial, with green financing (loans and tax incentives) and subsidies helping to sanitize the energy sector in SSA while promoting the widespread use of clean energy.

The industrial sector, as an emerging driver of economic transformation, requires a strong push for a clean energy agenda to mitigate climate change. This can be achieved through the adoption of energy-efficient technologies and the development of sustainable infrastructure to control environmental threats. The study also highlights the significance of urban growth. Rapid urbanization necessitates sustainable urban planning, increased investment in green infrastructure, and comprehensive environmental impact assessments to ensure that economic expansion does not lead to environmental degradation.

The value-added sector must prioritize the social dimension by ensuring equitable access to education, fair labor practices, and job creation. SSA has significant human capital potential; proper training and healthcare access will help promote sustainable development. From the studies, public spending on education has had a limited impact on economic growth due to inefficiencies. Policy plans that focus on strengthening technical and vocational education, integrating digital learning tools, and fostering public-private partnerships in the educational sector will ensure an all-encompassing impact on society. Regional value-added programs must promote inclusive employment opportunities for all, with governments enforcing fair wages, protecting workers' rights, and implementing policies that promote gender equity in the labor market.

Reforms in governance and institutions are essential to maximizing the effectiveness of public investments. Institutional Strength and Governance— Long-term industrial development depends on transparent public sector investments and efficient governance frameworks. The economic gains of industrialization are generally limited by weak governance, which frequently results in inefficient infrastructure investment and resource misallocation. The governments of SSA must implement ESG-compliant investment regulations, bolster financial transparency, and enforce anti-corruption measures. To ensure compliance with regulations and attain sustainable economic growth, governance systems must be strengthened. Early due diligence will be established with the aid of ESG integration into new sectors, avoiding the mistakes made by previous economies that have already resulted in global crises. To maintain sectorial stability and regulatory compliance, governments should keep enforcing ESG standards, especially in highly sought-after public-private partnership agreements.

By adopting a holistic approach that balances industrialization, education, energy efficiency, and governance, SSA can unlock its full economic potential while ensuring long-term resilience and prosperity. This requires aligning investments with sustainability goals, integrating technology into key sectors, and promoting regional cooperation.

7. Conclusion and policy recommendations

Sub-Saharan African (SSA) economies are increasingly focused on industrialization, mobilizing resources to enhance education and public investment as key drivers of economic transformation. This study examines the determinants of educational quality, economic growth, and gross public investment (GPI) in SSA from 1980 to 2022, using Generalized Method of Moments (GMM) and Fixed Effects Ordinary Least Squares (FEOLS) methodologies. The findings provide valuable insights for shaping policies that promote sustainable development.

Education is a cornerstone of economic progress, yet the study finds that most macroeconomic indicators do not significantly impact educational quality, except for gross fixed capital formation. This suggests that capital investments, particularly in infrastructure and learning facilities, are critical for improving education outcomes. However, misallocated funds can hinder progress. To maximize the impact of public investment in education, SSA policymakers must adopt strategic financial planning, prioritize high-return projects, and integrate technology into the education system to enhance learning quality and accessibility.

Economic growth in SSA is primarily driven by gross fixed capital formation, export performance, and electricity consumption. Reliable energy supply and industrial diversification are essential for long-term economic expansion. However, rapid urbanization negatively affects growth, likely due to inadequate infrastructure and poor urban planning. Public spending on education does not show a significant impact on economic growth, indicating inefficiencies in resource allocation. To foster sustainable growth, SSA must improve its industrial policies, invest in energy-efficient infrastructure, and strengthen vocational education programs to develop a skilled workforce.

Public investment in SSA is significantly influenced by urban population growth, industrial sector employment, and past GPI levels. However, increasing energy demands create trade-offs, as higher electricity consumption can strain

public investment budgets. Additionally, reliance on resource-based exports has shown diminishing effects on investment growth, highlighting the need to shift toward value-added industries. Policymakers must prioritize energy efficiency, encourage investment in clean energy, and implement regulatory measures that support industrial diversification. By promoting sustainable energy adoption, SSA can reduce dependency on fossil fuels and create a more resilient economic foundation.

Although the study emphasizes the importance of infrastructure and energy efficiency, the role of technology in economic development remains underexplored. Technological advancements can significantly enhance the effectiveness of educational investments and infrastructure projects. Policymakers should consider integrating digital tools in education, modernizing industrial operations, and expanding internet access to drive innovation and productivity. Encouraging research and development (R&D) collaborations between universities and industries will further strengthen the region's economic competitiveness.

The integration of environmental, social, and governance (ESG) principles into investment strategies is another critical area that requires attention. While SSA's development agenda prioritizes energy efficiency and public investment, a more comprehensive ESG approach is necessary to ensure long-term sustainability. Green financing, corporate accountability, and policies promoting responsible business practices should be embedded into regional development strategies. Additionally, regional trade collaborations and private sector engagement in infrastructure projects can enhance economic stability and resilience.

To achieve sustainable economic growth, SSA must adopt a strategic investment approach that aligns with industrialization goals. This includes ESG principles, implementing long-term investment plans, fostering public-private partnerships (PPPs), and addressing urbanization challenges through modern infrastructure and smart city planning. Strengthening governance frameworks, improving financial transparency, and combating corruption will also be essential to ensuring efficient resource utilization.

Overall, technology is key to expediting sustainable economic activities in SSA. Via artificial intelligence, the working environment has become smarter and more efficient. The value-added and educational sectors require more AI injections to enhance workers' efficiencies and promote a sustainable culture. Clean energy technology is growing very fast, which implies a more feasible approach in the educational and training sector. In this regard, by aligning investments with sustainability goals, integrating technology into key sectors, and promoting regional cooperation, SSA can build a strong foundation for economic transformation. A holistic approach that balances industrialization, education, energy efficiency, and governance will be key to unlocking the region's full economic potential while ensuring long-term resilience and prosperity.

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Conflict of interest

The authors declare no conflict of interest.

Notes/thanks/other declarations

We hereby declare that this research paper, titled ‘Exploring the Interaction between Macroeconomic Performance and Educational Quality, Investment, and Economic Growth in Sub-Saharan Africa,’ is our original work.

Additional information

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Section 3

Finance, Innovation, and Growth Dynamics

Finance, Innovation, and Growth

Danmo Lin

Abstract

This chapter investigates the interrelated roles of finance, competition, and innovation in driving long-run economic growth. It evaluates how financial markets shape the allocation of resources to research and development and influence the commercialization of new technologies. The analysis further considers how market structure and competitive dynamics interact with financing conditions to affect the innovative activity. Particular emphasis is placed on firms' strategic interactions in resolving intellectual property (IP) disputes and on the extent to which legal frameworks and financial incentives determine the litigation outcomes. By integrating insights from finance, industrial organization, and law, the chapter highlights how these institutional and market forces collectively shape technological progress and sustained economic growth.

Keywords: endogenous growth, R&D investment, competition, financial constraints, IP litigation

1. Introduction

Understanding the interplay between innovation, finance, and competition is central to explaining long-run economic growth. This chapter focuses primarily on theoretical frameworks that clarify how financial systems and competitive forces influence firms' incentives to innovate and shape the broader growth process, while drawing selectively on empirical findings to illustrate key mechanisms. Given the breadth of the literature, the review emphasizes depth over coverage, with particular attention to theoretical contributions that illuminate core dynamics. Any omissions of important scholarship reflect constraints of scope rather than judgments of merit.

The chapter is organized as follows. Section 2 reviews classical, neoclassical, and New Growth Theories, with particular emphasis on how innovation-driven dynamics, such as creative destruction and trade, contribute to productivity growth. Section 3 examines the role of finance in shaping innovation, with attention to corporate governance, internal capital, entrepreneurial finance, alternative investment vehicles, and public funding mechanisms. Section 4 analyzes the dual role of market competition, showing how competitive intensity can both stimulate and discourage innovation depending on context and firm characteristics. Section 5 turns to intellectual property litigation, assessing how legal frameworks and strategic litigation shape the innovation incentives. Section 6 shows how the works reviewed connect to each other and points out gaps and unresolved debates. Section 7 concludes.

2. Growth and innovation

Economic growth and innovation are closely linked through the interaction of markets, firms, and institutions. In a rapidly changing global environment, it is increasingly important to revisit New Growth Theory (NGT) to better understand the drivers of long-term development. This section reviews how recent research extends the classical and endogenous growth theories, which continue to provide a valuable framework for analyzing the contemporary challenges, most notably the puzzling slowdown in productivity growth despite ongoing technological progress.

The classical and neoclassical growth frameworks provided the foundation for understanding the determinants of long-run economic development. In classical growth theory, economic growth is driven by capital accumulation, labor, and natural resources such as land, but it is ultimately constrained by diminishing returns and resource scarcity. Neoclassical growth theory recognizes the technological progress as a key driver of long-run growth, given diminishing returns to capital and labor [1, 2]. These models predict the economies converge in income levels if they share similar savings rates, population growth, and technology. While highly influential in explaining aggregate growth patterns, they conceptualize technological change as an exogenous process, and thus offer limited guidance on the economic, institutional, or policy drivers of innovation. Moreover, they fall short in accounting for persistent cross-country growth differentials and the endogenous nature of technological advancement.

The New Growth Theory (NGT, or endogenous growth theory) was proposed by economists such as Romer [3, 4], Lucas Jr. [5], and Aghion and Howitt [6], advanced growth theory by endogenizing technological progress. Unlike earlier frameworks, NGT embeds human capital accumulation, R&D investment, knowledge spillovers, and institutional context directly into formal models of growth. This approach highlights the possibility of increasing returns to scale and path dependence in innovation outcomes, as the decisions of firms, individuals, and policymakers shape the trajectory of technological change. At the core of this framework lies the Schumpeterian process of *creative destruction*, whereby new innovations displace obsolete technologies, firms, and products, thereby driving productivity and long-run growth. This mechanism has proven especially powerful in explaining dynamic productivity patterns in innovation-intensive sectors.

The New Growth Theory (NGT) has expanded to include international trade and financial market frictions as key elements that shape firms' capacity and incentives for innovation. These external factors influence how effectively firms invest in R&D, adapt to technological change, and compete in global markets.

The trade literature within the NGT framework shows how openness alters the incentives and structure of innovative activity. Early contributions demonstrate that larger markets and greater international integration increase the expected returns to R&D, stimulate specialization, and foster knowledge spillovers across borders [7]. Subsequent Schumpeterian models emphasize the disciplinary role of competition: Trade liberalization intensifies rivalry, strengthens incentives for creative destruction, and accelerates frontier innovation [8–10]. At the same time, more recent work highlights the potential trade-offs: While openness spurs innovation among leading firms, it may also increase concentration and markups, raising questions about how the gains from trade-induced innovation are distributed [11, 12].

The relationship between innovation and growth varies systematically with a country's distance from the technological frontier. Developing economies often grow by adapting technologies from advanced nations, where targeted industrial policies, even if they limit competition, can facilitate catch-up by easing credit constraints and coordination failures [13]. As countries approach the frontier, however, the returns to imitation diminish, and sustained growth increasingly depends on frontier innovation. In this setting, restrictive policies that hinder entry and reduce competition become growth-inhibiting, while advanced economies benefit from open markets, strong intellectual property rights, and continued investment in human capital and managerial capabilities to support innovation and efficient reallocation.

Within the growth theory framework, the availability of finance is also a critical determinant of how innovation unfolds, though a fuller discussion of finance and innovation will follow in the next section. Limited access to external capital forces firms to depend on internal funds, discouraging new entry and slowing the replacement of outdated technologies. This dynamic shifts innovation toward incumbents and narrows the scope for more radical, entrant-led growth. Formal models show that financial frictions restrict radical innovation and delay creative destruction, underscoring the importance of robust financial systems and sound regulation for sustaining dynamic growth [14].

3. Finance and innovation

Compared to capital investments, R&D investment entails higher risk, longer payoff horizons, and greater information asymmetry, which often leads firms to rely more heavily on internal financing. Internal funds can insulate firms from market fluctuations and mitigate adverse selection and moral hazard, but they also have limitations: They tend to support incremental rather than radical innovation and can be constrained by managerial short-termism and earnings pressure. Beyond the firm, financial intermediaries and capital markets play a pivotal role in allocating resources to innovative activity. Hall and Lerner [15] provide a foundational survey of how corporate finance mechanisms influence investment in innovation. As a complement to Frésard and Phillips [16] that synthesize theoretical and empirical evidence on the role of financing frictions, governance, and investor composition, my review focuses on more recent theoretical advances in the finance literature.

3.1 Corporate governance

Gustavo [17] paper, *Motivating Innovation* [17], offers a foundational theoretical model that reshapes our understanding of how incentive structures can foster innovation. Using a dynamic principal-agent framework, the paper shows that traditional pay-for-performance contracts discourage innovation because they are intolerant of early failure. By contrast, the optimal contract for promoting innovation requires substantial tolerance for initial failure alongside strong rewards for long-term success. Key mechanisms include long-vesting compensation, job security, and gradual performance evaluation, which collectively encourage experimentation and learning over time. Laboratory evidence supports this framework, showing that contracts with tolerance for early failure and long-term rewards induce greater innovation outcomes [18]. The theory has broad implications for executive compensation, venture capital, startup incubation, and public R&D policy.

Subsequent research has expanded on these insights. Institutional ownership can enhance innovation by reducing managerial short-termism and encouraging sustained R&D through stronger governance [19]. Investor tolerance of failure further enables innovative activity, with evidence that patient investors foster more exploratory research and risk-taking [20]. Ownership structure also matters: Private firms, insulated from short-term market pressures, display greater tolerance for early failure and pursue riskier innovation projects than comparable public firms [21]. Corporate governance protections play a similar role. Firms with stronger anti-takeover provisions provide managers with security to undertake riskier R&D, resulting in more numerous and higher-quality patents [22]. Consistent with these mechanisms, recent evidence shows that greater director job insecurity leads to sharp declines in innovation, particularly in exploratory patents, underscoring the importance of shielding decision-makers from short-term pressures [23].

3.2 Capital markets and financial intermediaries

A growing body of research highlights how capital markets and financial intermediaries shape the direction, quality, and intensity of corporate innovation.

Equity markets can alleviate financing frictions for intangible, high-risk projects, particularly at young firms, where access to external equity strongly supports R&D [24]. Yet public equity also embeds short-term pressures that reshape both the scale and direction of innovation. Greater stock liquidity discourages innovation, as managers facing stronger monitoring from blockholders and takeover threats become more myopic in their investment horizons [25]. Similarly, the transition to public ownership dampens innovative activity: going public lowers the quality of internal innovation, increases inventor departures, and leaves the listed firms investing less and responding less to new opportunities compared to matched private firms [26, 27]. Concerns about “killer acquisitions,” in which incumbents acquire startups to shut down competing projects, highlight the darker side of equity-financed consolidation [28]. Consistent with these dynamics, private firms are found to pursue more exploratory innovation strategies than public firms, in part because public equity markets impose the shorter investment horizons [29]. Taken together, these findings suggest that while equity financing can be indispensable for supporting innovation, its design and institutional features may introduce distortions.

Theoretical models grounded in real options provide key insights into how financing frictions shape investment under uncertainty and long horizons. A central implication is that liquidity constraints and limited internal cash flow reduce the option value of waiting, making constrained firms more impatient and prone to investing earlier or more aggressively to preserve the future opportunities [30–32]. This mechanism is especially relevant for R&D-intensive firms, whose projects are irreversible and expose them to higher risk when external financing is limited. Evidence supports this view: R&D intensity predicts higher expected stock returns primarily among constrained firms, reflecting the premium required to compensate for financing risk [33]. Real-options models also link innovation opportunities to firm valuation and asset returns. Growth options embedded in risky projects drive investment timing and expected returns [34], while later work highlights how learning about project quality and uncertainty over profitability shape the valuation and return dynamics of new ventures [35]. Building on these foundations, dynamic capital structure models emphasize how broader financing conditions affect innovation. Firms optimally time equity issuance and investment to buffer against anticipated financing frictions,

underscoring the role of precautionary savings and risk management [36]. When heterogeneity in constraints is considered, financially constrained firms may overinvest or invest early to hedge against future liquidity shocks, producing inefficiencies in capital allocation and innovation outcomes [30, 37]. Overall, this body of work shows that financing frictions not only determine the scale of R&D but also critically shape its timing, intensity, and risk profile.

Credit market conditions also play a central role in shaping innovation outcomes. Greater credit availability increases firms' R&D spending and innovative output, with the effects particularly strong for financially constrained firms [38]. Fuente and Marin [39] develop a theoretical framework showing how bank monitoring and financial development jointly influence innovation dynamics. Credit rating downgrades can lead to significant reductions in firm-level R&D [40]. Meanwhile, adverse bank shocks substantially curtail firm-level patenting and R&D activities, underscoring the sensitivity of innovation to credit availability [41, 42]. The design of bankruptcy regimes also matters: Debtor-friendly codes that preserve continuation value encourage riskier, more innovative projects, while creditor-friendly codes that raise liquidation risk deter them [43]. The structure of banking competition further highlights borrower heterogeneity. Expanded access to bank finance promotes innovation by private firms that depend heavily on banks, yet it can crowd out innovation in public firms that already enjoy broader financing channels [44]. Similarly, deregulation that increases local bank market power has been shown to reduce both the level and riskiness of innovation, especially among young private firms [45]. As a whole, these studies underscore that both the supply of credit and the institutional design of debt markets jointly provide the incentives and capacity for firms to innovate.

3.3 Alternative investments

Alternative investments have become increasingly important for financing innovation beyond traditional corporate or public sources. Broadly, alternative sources of innovation finance can be classified into entrepreneurial finance, which include venture capital, crowdfunding, and corporate venture capital as a corporate variant of entrepreneurial finance, and institutional asset management, which is primarily composed of private equity, sovereign wealth funds, and hedge funds. While entrepreneurial finance is marked by illiquidity, valuation uncertainty, and hands-on expertise, institutional investors bring larger capital pools and more structured pricing, shaping the different patterns of innovation.

Venture capital (VC) has long played a key role in funding high-risk, high-growth startups, especially in tech industries. Its use of staged financing, active monitoring, and control rights helps manage uncertainty and align incentives [46]. VC firms also provide strategic support, often helping startups innovate faster and professionalize more quickly [47]. However, concerns remain about VC's narrow focus and concentration, raising questions about inclusion and broader societal outcomes [48]. Additionally, the investment horizon of VC funds matters: VCs with shorter horizons may steer portfolio firms toward quicker, potentially less transformative innovations.

Corporate venture capital (CVC) serves both financial and strategic goals. CVC often complements internal R&D by investing in startups in related technologies, especially when internal innovation slows [49, 50]. This allows the established firms to explore new markets and absorb external knowledge.

Crowdfunding provides early-stage ventures with alternative access to capital. It enables startups to test ideas, build communities, and raise funding outside traditional investors [51]. Different models serve different needs—reward-based crowdfunding supports validation, while equity crowdfunding is better for scaling R&D [52]. Blockchain-based models like ICOs offer decentralized alternatives, though they depend heavily on sound regulation [53].

Private equity (PE) has a mixed but evolving impact on innovation. While often seen as focused on cost-cutting, PE can enhance innovation efficiency, such as producing more patents per R&D dollar, especially in underperforming or distressed firms [54, 55]. The effects depend on the type of PE investment and firm characteristics. Buyouts of mature or financially constrained firms may channel resources toward more efficient R&D processes, improving output without expanding input, whereas growth equity investments often provide capital that enables portfolio companies to scale innovation and pursue riskier projects. The governance structures introduced by PE investors, including stronger monitoring and performance-based incentives, can further shape innovation outcomes. At the same time, concerns persist that short investment horizons and a focus on financial returns may discourage long-term, exploratory R&D, suggesting that PE's impact on innovation is heterogeneous and context dependent.

Sovereign wealth funds (SWFs), once primarily conservative investors, are increasingly channeling capital into high-innovation sectors such as AI, biotechnology, and clean energy to support national strategic goals and long-term economic diversification [56, 57]. Recent evidence shows that such state-backed investments can significantly enhance corporate innovation, particularly by easing financing constraints [58].

Hedge fund activism is a more aggressive but impactful form of engagement with innovation. Activists push for governance changes and resource reallocation to improve firm performance. While some worry about short-termism, research finds that activism can increase innovation efficiency and have broader effects as peer firms adjust their strategies [59–61].

3.4 Public funding

Despite significant private investment in R&D, public funding remains essential to correct market failures and support innovation with broad societal benefits, such as knowledge spillovers [6, 62]. While firms often focus on applied research, basic research, which is typically funded by the public sector, produces long-term and wide-ranging gains [63, 64]. Policy tools like tax credits and subsidies can boost private R&D, though their effectiveness varies: Tax credits offer flexibility, whereas direct subsidies are more effective at encouraging breakthrough innovation [65, 66]. Howell [67] highlights the catalytic role of public funding in high-risk, high-reward projects. Similarly, Babina et al. [68] find that federal funding shocks significantly reduce university patenting, entrepreneurship, and scientific publications, underscoring the systemic dependence of innovation ecosystems on the sustained public investment. Public policy can also steer innovation toward socially important areas, such as green energy or public health, through targeted interventions [69, 70]. Moreover, patent approvals, often linked to public R&D, help startups grow and influence the direction of innovation [71]. Programs such as the Small Business Innovation Research (SBIR) program in the United States and Horizon Europe in the European Union exemplify how public initiatives can support both firm-level and

mission-driven innovation [72]. Well-designed public funding, especially for basic research, remains vital for sustaining long-term innovation and economic growth.

4. Competition, finance, and innovation

Historically, there have been two main perspectives on the relationship between market competition and innovation. One, rooted in Schumpeterian theory [73, 74], argues that the prospect of temporary market power incentivizes firms to innovate. In this view, firms in concentrated markets are better positioned to finance R&D, and competition reduces the post-innovation rents that motivate such investments. In contrast, Arrow's perspective suggests that monopolists have weaker incentives to innovate because they already enjoy high profits, whereas competitive firms are more motivated to disrupt the status quo [75].

To reconcile these views, Aghion et al. [76] propose an inverted-U relationship between competition and innovation. At low levels of competition, increasing rivalry encourages innovation as firms seek to escape their competitors. But beyond a threshold, higher competition reduces the payoff from innovation, discouraging further R&D. Follow-up work by the same authors extends this insight to macroeconomic dynamics, demonstrating how policy interventions, from intellectual property protections to labor regulations, can influence innovation and long-run growth [77, 78]. Building on this foundation, Shapiro [79] introduces the concepts of contestability and appropriability to bridge the Arrow and Schumpeter frameworks. Contestability refers to how easily new entrants can challenge incumbents after innovation, while appropriability concerns a firm's ability to capture the returns from its innovation. When contestability is low, both incumbents and entrants may have lower incentives to innovate, as market dominance persists. Similarly, low appropriability, often due to rapid imitation, weakens R&D incentives. Conversely, strong appropriability mechanisms, such as patents, complementary assets, and network effects, can strengthen incentives by protecting innovation rents.

These forces play out differently across industries. The pharmaceutical sector, for instance, exhibits high appropriability and low contestability, with strong IP protections, regulatory exclusivity, and steep entry barriers creating powerful innovation incentives. In contrast, the fast fashion industry is highly contestable and features low appropriability, pushing firms to prioritize speed and replication over novel innovation. Digital platforms often operate in environments with high contestability but also retain high appropriability due to network effects and switching costs, requiring continuous innovation to retain users. The commercial aerospace industry represents a case of both low contestability and low appropriability, where innovation is constrained by high fixed costs, stringent regulations, and limited competition. These examples highlight how industry structure, particularly the interaction of contestability and appropriability, shapes firm-level R&D incentives and strategic innovation choices. They also underscore the need for tailored policy that fosters innovation while maintaining healthy competitive dynamics [16].

How does finance interact with competition in R&D investment decisions? Complementing the traditional framework linking competition and innovation, a stream of theoretical work in the finance literature uses real options models to study R&D investment under uncertainty and rivalry. Competitive interactions generally erode the option value of waiting, prompting firms to accelerate R&D investment [80–82]. Financial constraints intensify how firms adjust their R&D strategies in

response to product market rivalry. Constrained firms react more strongly than unconstrained rivals when facing competitive pressure [83]. Building on this literature, Lin [37] develop a patent-race model with heterogeneous financial constraints, distinguishing between scalable and accelerable R&D projects depending on whether investment intensity increases discovery payoff or speed. Their analysis shows that financing constraints and project characteristics jointly shape R&D strategies: Financially constrained firms may invest more aggressively in accelerable projects than their unconstrained rivals, particularly when anticipating funding shortfalls. Industrial organization research further emphasizes that a firm's technological position, whether it leads or lags, critically influences its response to market rivalry [84–86]. Weaker firms may innovate strategically and more heavily to increase their acquisition value, underscoring the importance of exit opportunities in shaping innovation incentives [87].

Extending the competition perspective to macro-level patterns, two major hypotheses explain the rising market power in the U.S. by innovation and competition [88]. The *intangible asset hypothesis* suggests that firms relying more on intangible capital, such as software and brand, can scale quickly and dominate markets, which increases concentration and makes it harder for new entrants. The *superstar firm hypothesis* argues that the most productive firms gain larger market shares because they innovate more effectively, leading to greater concentration and a lower labor share of income. Both explain how innovation can strengthen market positions and reshape competition. De Ridder [89] further formalizes these mechanisms by showing that the rise of intangible-intensive firms increases fixed costs and deters entry, concentrating market power. While this enhances productivity in the short run, it can reduce long-run innovation incentives and contribute to a decline in productivity growth.

5. Intellectual property protection and innovation

While prior research has examined how financial frictions and product market competition shape innovation outcomes and drive macroeconomic growth, the role of legal institutions, particularly intellectual property (IP) litigation, remains an under-explored yet crucial part of the innovation ecosystem. Innovation generates intangible assets whose value depends on their enforceability and protection under law. As firms invest more heavily in knowledge-based capital, the legal environment governing intellectual property disputes significantly influences both incentives to innovate in the corporate sector and the competitive dynamics among corporations following breakthrough discoveries. Understanding how IP litigation affects corporate innovation incentives thus provides important insights into how legal frictions interact with economic forces in shaping technological progress.

Patent litigation exerts a complex influence on corporate innovation. On one hand, the anticipation of costly legal disputes can deter R&D investment or discourage entry into technology areas perceived as legally risky. Legal uncertainty or the threat of litigation can stifle cumulative innovation and disproportionately burden smaller and financially constrained firms, serving as a significant barrier to sustained innovative activity [90–92]. On the other hand, litigation promotes innovation by strengthening the appropriability of returns: Enforcing intellectual property rights protects inventors from imitation, encouraging firms to invest in novel technologies with the confidence of capturing future economic gains. Patent

invalidation, such as the one triggered by *Alice Corp. v. CLS Bank*, can also lower entry barriers and stimulate follow-on R&D, and the direction of the impact on firm values depends on firm size [90]. In addition, litigation serves strategic purposes by enabling firms to signal strength, negotiating licenses, and defending market positions, therefore fostering a more vibrant innovation environment under the right conditions [93]. Expected future litigation activity can itself influence firm-level innovation incentive, and defendant-friendly litigation reforms may promote innovation and raise welfare by up to 3.29% [94]. The overall impact of litigation on innovation ultimately depends on the resolution of IP disputes and the institutional conditions under which they occur.

Theoretical models identify several key determinants of whether firms litigate or settle patent disputes, and these choices in turn shape their ex-ante innovation incentives. A central factor is asymmetric information regarding patent validity or the strength of infringement claims. Under information asymmetry, settlement becomes less likely because private information distorts settlement bargaining. Stronger parties may prefer litigation to credibly signal case strength [95], while patentees may use litigation as a screening device when validity or infringement prospects are privately known [96]. Noisy or divergent private signals further exacerbate disagreements over expected outcomes, making mutually acceptable settlements harder to achieve [97, 98]. Cost asymmetries also matter: Differences in legal or financial resources can affect bargaining power, enabling stronger parties to pursue litigation or extract more favorable settlement terms [99, 100].

Technological overlap and product market competition further influence how firms resolve IP disputes. Firms facing denser patent thickets, which are represented by fragmented ownership of overlapping rights, are more frequently drawn into litigation, either defensively or offensively to delay rivals' innovation or protect their own technological edge [91]. Such firms also tend to launch the fewer new products, suffer declining profitability, and experience lower subsequent stock returns [101]. To mitigate these risks, firms strategically expand their patent portfolios to enhance bargaining power and reduce the likelihood of exclusion from critical technologies, as seen in industries such as semiconductors [102]. Litigation and settlement choices can also be understood through a real options framework: Under market uncertainty, firms delay initiating disputes until expected benefits outweigh costs, with similar considerations shaping settlement decisions [103, 104]. Extending this dynamic view, Lin, Liu, and Whalley [105] show that intensifying competitive pressure from potential entrants shifts equilibrium outcomes, moving firms from peaceful licensing, to post-litigation settlements, and ultimately to aggressive litigation. The impact of competition on litigation outcome also depends on legal institutions, such as cost allocation rules in the legal system (the *American Rule* vs. the *English Rule*) and the stringency of patent approval. Besides, the authors show that firms' relative incentive to finance litigation can also be crucial to the litigation outcomes. In addition, competition across patented technologies influences commercialization strategies *via* litigation considerations, as patent holders must decide whether to commercialize directly or sell their patents, and, if selling, whether to transfer them to buyers who themselves hold patents [98].

The literature on growth, finance, competition, and intellectual property law highlight the distinct mechanisms shaping innovation, yet their interactions remain insufficiently integrated. The following discussion synthesizes these strands, emphasizing common themes, tensions, and unresolved questions.

6. Discussion

Innovation remains central to long-run economic growth, but corporate decisions on innovation is increasingly shaped by uncertainty, whether from shifting trade policies, technological breakthroughs such as artificial intelligence and biotechnology, or institutional changes that affect global markets. Understanding how firms innovate under such new uncertainty and competitive pressure is therefore more important than ever. For instance, rising protectionism and fluctuating trade barriers may slow creative destruction, reduce firm turnover, and limit cross-border knowledge diffusion, raising questions about how policy uncertainty influences firms' incentives to invest in frontier technologies.

The reviewed literatures on growth theory, finance, competition, and intellectual property litigation collectively highlight that innovation incentives are shaped by a complex interaction of financial, market, and institutional forces. A consistent pattern across the literature is that the same mechanism can both foster and hinder innovation depending on context. For example, equity markets provide essential financing for young firms but can also impose short-term pressures that discourage long-horizon R&D. Similarly, product-market rivalry can accelerate innovative activity by eroding the option value of waiting, yet excessive competition may reduce post-innovation rents and discourage investment. The impact of intellectual property litigation is ambivalent, as it simultaneously strengthens appropriability while potentially constraining cumulative innovation. As each force can both foster and hinder innovation, their interaction ultimately determines whether and how firms undertake R&D. This interdependence highlights the need for an integrative perspective that accounts for financial, competitive, and institutional factors simultaneously.

Besides more integrated approaches, several gaps in the literature suggest fruitful avenues for future research. The impact of debt financing on innovation, not only in technology-intensive industries but also in manufacturing and services, remains underexplored. The role of trade uncertainty in shaping firms' long-horizon R&D incentives also requires deeper investigation, with existing studies demonstrating that liberalization can stimulate creative destruction. The growing importance of alternative investment vehicles, such as private equity, sovereign wealth funds, and hedge funds, raises new questions about how heterogeneous investor objectives influence the scale and direction of innovative activity. Moreover, future studies could examine how firms use financial tools, such as hedging, cross-holdings, or corporate venture capital, for risk management in R&D projects, particularly under competitive pressures and macroeconomic uncertainty. Research is also needed on how capital structure decisions affect innovative projects, and whether the effects differ across types of innovation, such as exploratory versus exploitative or incremental versus radical. Relatedly, distinguishing among types of technologies, for example, scalable versus accelerable projects, may offer sharper insights into how financial and competitive conditions shape innovation strategies across industries. From a corporate governance perspective, the influence of human capital mobility and team dynamics on R&D performance and incentives deserves closer attention. Finally, future work should move beyond patents to consider copyright and trademark protections as equally important in shaping innovation incentives, while also addressing whether the rise of artificial intelligence enhances or constrains innovation, and under what conditions these effects occur.

7. Conclusion

This chapter has examined how financial market, competition, and legal institutions shape the scale, direction, and timing of innovative activity, with implications for long-run economic growth. By reviewing theoretical and empirical contributions across these themes, the analyses demonstrate the dynamics of innovation emerge from the interplay of financing conditions, competitive pressures, and institutional design.

A central implication is that innovation should be understood as the outcome of interdependent forces rather than as the product of isolated firm-level or industry-specific decisions. Financial frictions, product-market rivalry, and intellectual property enforcement jointly determine whether firms pursue the incremental improvements, radical breakthroughs, or forego innovation altogether. Recognizing the interdependence advances our understanding of the drivers of technological progress and clarifies why policy interventions in finance, competition, or law cannot be evaluated in isolation.

Future research would benefit from models and empirical analyses that explicitly integrate these forces, moving beyond segmented literature toward a more unified framework of innovation and growth. Such integration is especially important in the current time, where financial globalization, rapid technological disruption, and institutional change jointly shape both the risks and opportunities associated with innovation, and where a more comprehensive framework can guide both theoretical development and the design of effective policies.

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Evaluating Alternative Creative Accounting Mining Techniques: Empirical Evidence from Greece

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Abstract

Earnings management is a constant challenge to the credibility and transparency of financial reporting. Detecting earnings management is crucial for supporting economic growth and maintaining investor confidence, especially in economies dominated by small and medium-sized enterprises like Greece. Although numerous models have been developed to detect such practices, their effectiveness often varies depending on the institutional and economic context in which they are applied. This study provides a comparative assessment of four prominent detection models—the Altman Z-Score model, the Spathis model (S1), the Spathis Z-Score model (S2Z), and the Beneish M-Score model, focusing on companies listed on the Athens Stock Exchange (ASE). Using financial data for 2017–2018 for a sample of 31 companies, the analysis reveals significant differences in the detection results. The Altman model identifies distress rather than manipulation directly, the simplified Spathis model offers a leaner alternative, the Spathis Z-Score incorporates broader financial risk signals, and the Beneish model emphasizes accrual manipulation. All four models indicated a generally low likelihood of earnings misreporting less than 10%, suggesting that large firms increasingly adhere to legal accounting practices that build stakeholder trust. Nevertheless, no single model demonstrated universal reliability. These findings highlight the need for a multimodel analytical approach, particularly in countries such as Greece where regulatory and institutional complexity or structural opacity can mask financial misrepresentation.

Keywords: earnings management, financial statement fraud, Beneish M-score, Altman Z-score, creative accounting, Greece

1. Introduction

Earnings management detection is essential for ensuring economic stability, particularly in countries dominated by small and medium-sized enterprises (SMEs),

such as Greece. SMEs often face challenges in accessing finance and navigating complex regulatory environments, making transparent financial reporting vital for their sustainability and growth. Earnings manipulation undermines stakeholder confidence, distorts market signals, and can lead to misallocation of resources, ultimately hindering economic progress. Strengthening detection mechanisms is therefore not only a technical accounting issue but a strategic imperative for enhancing economic resilience and supporting SME expansion.

Earnings management involves the deliberate intervention of management in financial reporting to achieve specific objectives—often not aligned with shareholders' or regulators' interests. According to Schipper [1], it is “the deliberate intervention of management in the process of profit determination, usually to achieve self-serving goals.” Creative accounting, closely related, exploits flexibility within accounting standards to manipulate results, sometimes called “juggling the books” or “window dressing” [2].

Numerous high-profile scandals, including Enron and the Greek Follie-Follie case, illustrate the serious consequences of earnings manipulation. Recent studies on SMEs show that creative accounting often arises from systemic constraints such as limited credit access and regulatory burdens, making earnings manipulation a perceived necessity rather than purely deceptive [3].

This chapter examines these issues by applying four fraud detection models—the Altman Z-score, the Spathis Model S1, the Spathis Z-score Model S2Z, and the Beneish M-score Model—to companies listed on the Athens Stock Exchange. Combining behavioral theory with empirical analysis, the study seeks to improve understanding of how financial manipulation is conducted and detected, contributing to corporate governance and accounting integrity. The chapter is organized as follows: First, there is a literature overview that offers the basic insights for addressing the issue. Then, the methodological approaches applied in the study are briefly presented, followed by a brief description of the dataset used. Accordingly, the main findings are illustrated and comparatively evaluated. Finally, the epitome of the main conclusions of the comparative analysis is conferred, accompanied by a brief overview of the main practical implications and a discussion for potential future research.

2. Literature review

Recent empirical studies focusing on small and medium-sized enterprises (SMEs) have shown that creative accounting in this context is often not only opportunistic but stems from systemic constraints, including limited access to credit, inadequate internal controls and increased regulatory burdens. These factors make earnings manipulation a perceived necessity for survival rather than a strategy of deception [3].

Understanding earnings manipulation requires behavioral and contextual frameworks, such as Cressey's [4] fraud triangle (opportunity, pressure, and rationalization) and Rezaee's [5] 3C model (conditions, capital structure, and decisions), which highlight the complex motives and structures behind manipulation (**Figure 1**).

While the fraud triangle focuses on individual behavior, more recent literature has emphasized the role of structural and organizational factors. In this sense, [5], the 3C model provides an extended framework by identifying three systemic pillars that facilitate manipulation: conditions (e.g., governance weaknesses and ethical climate), capital structure (e.g., debt pressure or financial distress), and decisions

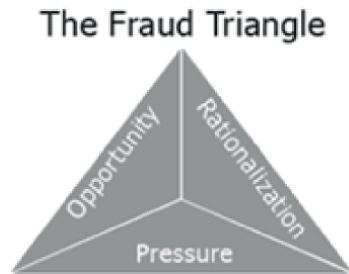


Figure 1.
The fraud triangle developed by Cressey [4].

(e.g., ethical judgment and managerial discretion). This triadic model captures both the macro- and microeconomic drivers of earnings management and has proven to be particularly relevant in the context of financial instability (**Figure 2**) [5].

This framework highlights the complex web of motives, structures, and constraints that contribute to earnings manipulation. As such, they provide a useful theoretical foundation for analyzing the motives behind misreporting and the effectiveness of models developed to detect it. Further, earnings management needs to be understood not only through individual or organizational incentives but also through national contexts. In countries such as Greece, where institutional inefficiencies, low tax compliance, and regulatory arbitrage are prevalent, the risks of creative accounting are magnified [3, 6]. Quantitative assessment of financial behavior in Greek public institutions has also shown that performance discrepancies often arise due to structural inefficiencies and inconsistent resource allocation strategies [7].

Beyond detection, research emphasized the need to understand why profit management occurred in the first place. A combination of contractual obligations, market pressures, external influences and personal incentives drove managers. These included the desire to meet debt obligations or influence performance-based compensation, meet investor expectations or maintain socio-emotional wealth in family businesses [8–13]. Understanding these motivations was essential for contextualizing the detection results and evaluating the effectiveness of the model.

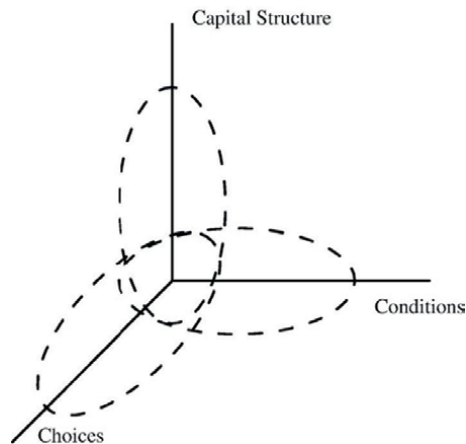


Figure 2.
Rezaee's 3C model [5].

Complementary evidence from Greek listed companies suggested that working capital management strategies might have been directly linked to earnings manipulation. Companies suffering from liquidity stress may alter their accruals or reclassified assets to present stronger short-term performance metrics, thus distorting their profitability and risk profiles. Prior research on Greek healthcare units indicated that operational efficiency and financial misreporting are often interconnected, with earnings management used to mask underperformance [14] temporarily.

A significant body of literature has also addressed the question of how earnings management and tax evasion were related. These behaviors often coexisted and were facilitated by common factors, such as weak enforcement and misaligned incentives [15]. In the Greek context, this overlap was particularly relevant as persistent tax compliance issues and regulatory loopholes exacerbated the risks of misreporting.

The consequences of earnings management were equally critical. It undermined investor confidence by increasing information asymmetry and misrepresenting a company's financial health [16–18], distorted capital market efficiency by affecting the cost of capital and the pricing of risk [17, 19], and challenged corporate governance structures by reducing transparency and enabling managerial opportunism [20, 21]. Studies suggested that managerial discretion in budget planning and reporting within Greek public sectors frequently exploited information asymmetries, further complicating accurate performance assessment [7]. Long-term organizational effects included reputational damage, diminished innovation, legal sanctions, and decreased survivability, especially in cases of sustained manipulation [22–26].

Despite their widespread use, traditional recognition models had notable limitations. Theoretically, they were based on rigid assumptions and narrowly defined financial ratios. As a result, benign business practices were often misclassified as manipulative or new forms of manipulation, such as earnings management based on real activities, and were not recognized [27–29]. In practice, their effectiveness varied across regions, industries, and regulatory environments, with weaker performance in emerging markets or when developing manipulation techniques [30]. This highlighted the need for models that could adapt to dynamic environments.

Data mining techniques such as decision trees [31, 32], neural networks [33], and Naïve Bayes classifiers were also widely applied. Decision trees used a flowchart-like structure to split data based on feature values, making classification decisions at each branch. Neural networks were computational models inspired by the human brain that learned complex patterns through interconnected layers of nodes. Naïve Bayes classifiers applied probabilistic rules based on Bayes' theorem, assuming independence between features to estimate class probabilities. Additionally, Bayesian Belief Networks extended probabilistic modeling by representing dependencies among variables, while support vector machines (SVMs) provided robust classification by finding optimal boundaries that separated different classes [34, 35]. Recent advances in machine learning, artificial intelligence (AI), and big data analytics were changing the landscape of fraud detection. AI-powered models, such as those used in stock exchange surveillance systems, provided enhanced predictive capabilities and the ability to analyze unstructured data in real time, including earnings announcements and managerial language patterns [29, 36]. These tools not only improved accuracy but also increased the interpretability of financial patterns for both regulators and investors. Nevertheless, the implementation of AI models was not without its challenges. These included imbalanced data sets, privacy and security concerns, algorithmic biases, difficulties in integrating with legacy systems, and ethical concerns regarding transparency and explainability [37–39]. These were needed to be addressed in order to exploit the potential of intelligent fraud detection systems.

Furthermore, institutional and legal frameworks significantly shaped the prevalence and style of earnings management across countries. The adoption of IFRS, while theoretically reducing manipulation, produced mixed results depending on national enforcement capacities and firm incentives [40–43]. Strong legal systems, consistent enforcement mechanisms, and investor pressure were associated with reduced manipulation, while lax regulation and private ownership structures tended to increase it [44–46].

Tax policy research further highlighted the importance of real-time monitoring, algorithmic analysis and digital audits, which were increasingly converging with the mechanisms used to detect profit management [47, 48]. This technological convergence was particularly relevant for developing jurisdictions transitioning toward more automated regulatory frameworks.

Among the many models that had been developed for detecting earnings management, the following proved particularly influential in both academic and applied contexts: the Altman Z-Score, the Spathis model and the Beneish M-Score. Hence, in the present study, we focused on their comparative evaluation, applied on Greek data. Each reflected a distinct theoretical foundation and methodological focus for identifying manipulation or financial distress within corporate financial statements.

The Altman Z-Score model, originally introduced in 1968 to predict corporate bankruptcy, was also utilized in this study as a complementary measure of overall financial health. The model combined five key ratios—working capital, retained earnings, EBITDA, market value of equity, and total assets—to assess financial distress. Although not a manipulation detection tool per se, firms with Z-scores below 1.81 were considered to be in significant financial trouble, potentially increasing their incentive to engage in earnings manipulation to mask distress [49].

Spathis' Z-score model was specifically developed using data from Greek firms to address characteristics of the local regulatory and financial environment [50]. This model applied a logistic regression framework to estimate the probability that a company had falsified its financial statements. It relied on 10 financial ratios related to liquidity, profitability, and leverage, including metrics such as total liabilities to equity, receivables to sales, and a composite Altman Z-Score. A probability above 10% was generally used as the benchmark for identifying potentially manipulative behavior.

The Beneish M-Score was a probabilistic model based on eight financial ratios derived from accrual and income statement data. These included indicators such as the Days' Sales in Receivables Index (DSRI), the Gross Margin Index (GMI) and the Asset Quality Index (AQI). The model was originally developed to identify companies that had manipulated their earnings prior to issuing public equity, but it had since been widely used as a general fraud detection tool. The threshold value of -2.22 is used to distinguish manipulative from non-manipulative companies, with higher values indicating a higher probability of manipulation [51].

Overall, the existing literature reveals that financial fraud detection relies heavily on quantitative models such as the Altman Z-Score and Beneish M-Score, each with distinct strengths and limitations. While the Altman Z-Score is effective in forecasting financial distress, it tends to generate false positives when applied to manipulation detection. The Beneish M-Score, focused on accrual-based earnings management, offers a more conservative but narrower detection scope. Studies also highlight the importance of combining multiple models to capture a broader spectrum of creative accounting behaviors. Moreover, institutional factors, sector-specific characteristics, and evolving digital tools significantly influence both the prevalence of earnings

manipulation and the effectiveness of detection methods. This body of research underscores the need for integrated, context-aware approaches to enhance fraud detection and prevention. This chapter examines earnings management through the comparative lens of four models—the Altman Z-score Model, the Spathis Model without Z-Score (S1), the Spathis Z-score Model (S2Z) and the Beneish M-score Model, applying them to a dataset of companies listed on the Athens Stock Exchange.

3. Methods and materials

The empirical analysis conducted in this study aimed to assess the likelihood of earnings manipulation in companies listed on the Athens Stock Exchange by applying four distinct models: the Altman Z-Score, the Spathis model without Z-score (S1), the Spathis Z-Score (S2Z) and the Beneish M-Score. The research was based on a sample of 31 Greek companies operating across 12 sectors, including furniture, food, oil, technology, publishing, construction, and healthcare, using financial data from the fiscal years 2017 and 2018. All data were retrieved from the official website of the Athens Stock Exchange. These techniques have been applied in previous studies to detect earnings management for addressing potential manipulation both for public and private companies in various countries.

The use of four distinct models in this study is grounded in the principle of methodological complementarity. Each model brings unique strengths to detecting earnings manipulation and financial irregularities. The Altman Z-Score offers a general assessment of financial health, particularly bankruptcy risk, serving as a foundational indicator of structural viability. The Spathis model (S1) provides a conservative, narrowly focused perspective that minimizes overfitting while highlighting basic distortions in capital and inventory management. The Beneish M-Score, widely used in international contexts, is finely tuned to capture accrual-based manipulations and income-smoothing practices. Finally, the Spathis Z-Score (S2Z) synthesizes broader financial indicators within a logistic regression framework explicitly calibrated to the Greek institutional and economic environment.

By applying all four models to the same dataset, the study facilitates a multidimensional evaluation of earnings management risk. This comparative framework not only enhances the robustness of the findings but also sheds light on the contextual strengths and limitations of each model. It underscores the value of integrating multiple analytical perspectives when assessing financial statement integrity, especially in settings marked by regulatory complexity and economic volatility.

3.1 Altman Z-score model

Developed initially to predict corporate bankruptcy the Altman Z-Score [49], combines five key financial ratios that reflect liquidity, profitability, leverage, and operational efficiency. While it was not designed for earnings manipulation detection, its ability to classify firms into healthy, gray, or distress zones provides a useful baseline of financial stability.

Despite its empirical robustness in bankruptcy forecasting, the Altman model has clear limitations when applied to fraud detection. Its broad focus may result in a high rate of false positives in contexts where distress does not necessarily equate to manipulation. This pessimistic bias may overshadow subtler indicators of creative accounting, particularly in economies like Greece, where financial volatility is common occurrence.

3.2 Spathis model (without Z-Score): S1

This simplified version of the Spathis model [50] – referred to as S1 – focuses on three financial ratios related to inventory management, capital structure, and asset allocation. It was the first the first model for bankruptcy forecasting developed specifically for the Greek economic environment. By excluding the Altman Z-Score, this approach narrows the analytical lens, providing a cleaner and more conservative signal.

Its strength lies in its simplicity and reduced dimensionality, which minimizes the risk of overfitting and multicollinearity. However, this very parsimony limits its capacity to detect complex manipulation schemes, especially those involving profitability smoothing or hidden leverage. As such, it is better suited as a diagnostic baseline or comparative control rather than a stand-alone detection tool.

3.3 Spathis Z-score model: S2Z

The full Spathis Model [50] – referred to as S2Z – uses a logistic regression framework and is based on 10 financial ratios that collectively capture aspects of leverage, profitability, liquidity and financial distress. The core ratios include the following:

- Total liabilities to equity
- Total liabilities to total assets
- Receivables to sales
- Inventories to sales
- Net profit to total assets
- Gross profit to total assets
- Sales to total assets
- Net profit to sales
- Working capital to sales
- Altman Z-Score (based on liquidity, solvency, leverage, profitability, and activity).

The model estimates the probability of financial statement falsification through a logistic regression equation. Companies with a calculated probability of over 10% are at high risk of earnings manipulation. The formula containing Altman's Z is as follows:

$$FFS = 0.23 + 2.659 * (\text{inventories} / \text{sales}) + 6.685 * (\text{total liabilities} / \text{total assets}) - 3.327 * Z - \text{Score}$$

The strength of the model lies in its contextual specificity—it captures both leverage-related pressures and operational anomalies that are more likely to signal manipulation in the Greek setting. By using logistic regression, it translates these indicators into an interpretable probability of falsification. However, its dependency on the Altman Z-Score may create internal redundancy, and its generalizability to other jurisdictions is limited. Additionally, its relatively broad scope may increase the likelihood of false positives in less volatile financial environments.

3.4 Beneish M-Score model

The second model implemented was the Beneish M-Score [51], which utilizes eight financial ratios to identify distortions in revenues, expenses, and leverage that may indicate earnings manipulation. The specific variables included in this model are as follows:

1. Days' Sales in Receivables Index (DSRI)
2. Gross Margin Index (GMI)
3. Asset Quality Index (AQI)
4. Sales Growth Index (SGI)
5. Depreciation Index (DEPI)
6. Sales, General and Administrative Expenses Index (SGAI)
7. Total Accruals to Total Assets (TATA)
8. Leverage Index (LVGI).

The M-score is calculated from a weighted linear combination of these indicators. A threshold value of -2.22 is typically used: Companies with an M-Score above this threshold are considered more likely to have manipulated their financial statements, while companies with an M-Score below this threshold are not.

Its key advantage is its sensitivity to aggressive revenue recognition and cost deferral practices, which are central to many earnings management cases. However, its reliance on accrual-based metrics renders it less effective in contexts where manipulation is carried out through real activities or structural financial engineering. Moreover, its calibration to the U.S. capital market environment may reduce its effectiveness when applied in jurisdictions with different regulatory and accounting standards, such as Greece.

4. Main findings

This section presents the empirical findings derived from the application of four detection models—Altman Z-Score, Spathis without Z-Score (S1), Spathis Z-Score (S2Z), and Beneish M-Score—to a dataset of 31 companies listed on the Athens Stock Exchange. The analysis is based on financial statement data for the fiscal years 2017 and 2018 aiming to identify potential indicators of earnings manipulation and

financial distress. The study period was specially selected as it portrays the Greek reality after the financial crisis and just before the pandemic (therefore data and results are COVID-19-effect free).

4.1 Altman Z-score findings

While the Altman Z-Score model was applied in this study to assess the financial health of firms and indirectly infer potential incentives for earnings manipulation, it is important to recognize that the model was originally developed solely to predict bankruptcy risk—not to detect manipulation itself. Using the Altman Z-Score as a proxy for earnings management or manipulation risk can be problematic, as financial distress does not necessarily equate to fraudulent reporting, and the model may misclassify financially healthy firms or fail to identify manipulative behavior that does not correlate with bankruptcy risk.

Therefore, caution should be exercised in interpreting Altman Z-Score results as indicators of earnings manipulation, and such findings should ideally be complemented with more targeted detection models—such as the Beneish M-Score or the Spathis models—that are explicitly designed to identify accounting anomalies and manipulation.

According to the model, firms with a Z-Score greater than 2.99 are considered financially healthy, those with a score between 1.81 and 2.99 fall into a gray zone of moderate risk, and those with a Z-Score below 1.81 are classified as being in financial distress.

For both fiscal years, the results were strikingly pessimistic:

- 23 out of 31 firms (74.19%) fell into the financial distress zone
- Five firms (16.13%) were in the gray zone
- Only three firms (9.68%) were classified as healthy

These results, depicted in **Figure 3** below, suggest that the Altman model may overestimate financial risk in the context of the sampled Greek firms. The estimated Type I error rate – misclassifying a non-manipulative firm as distressed – was 90.32%, raising concerns about the suitability of the model for earnings manipulation detection in this environment (**Figure 3**).

4.2 Spathis model without Z-score (S1) findings

Initially, a version of the Spathis model, excluding the Altman Z-Score, was tested. This variant, referred to as S1, uses only three financial ratios: inventories to sales, shareholders' equity to total assets, and fixed assets to total assets. None of the companies in the sample surpassed the 10% manipulation probability threshold. The model produced results that closely mirrored those of the Beneish M-Score, indicating a relatively conservative approach to flagging irregularities. While limited in scope, this version avoids overfitting and provides a baseline measure of manipulation risk. **Figure 4** illustrates the manipulation probabilities generated by this simplified model across the sample.

Although simplified, this S1 version of the Spathis model offers a dependable baseline because it focuses on fundamental financial ratios that reflect the company's

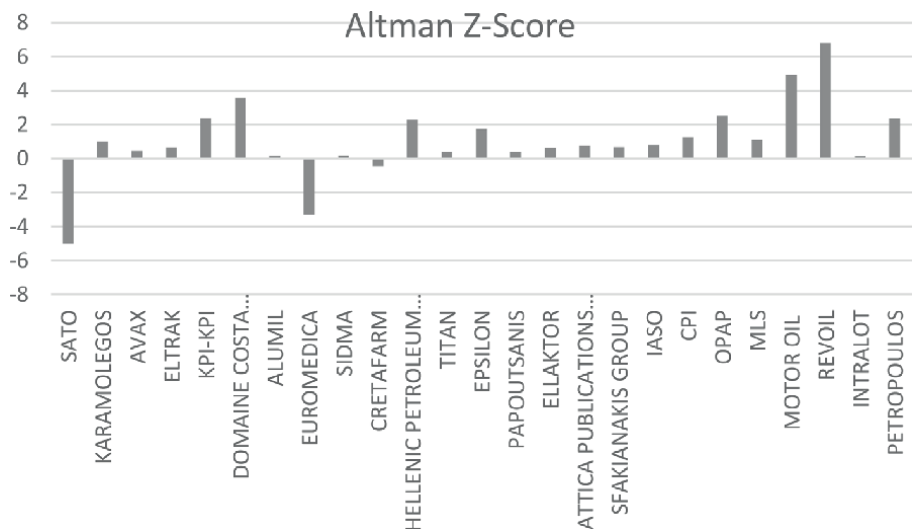


Figure 3.
Altman Z-score findings.

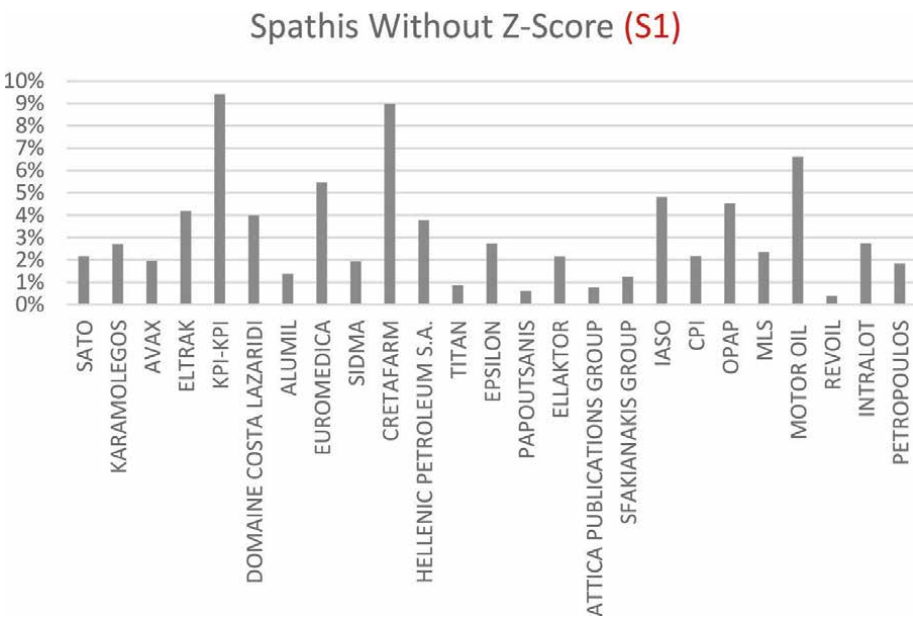


Figure 4.
Spathis model without Z-Score (S1) findings.

underlying structure rather than short-term performance fluctuations. These ratios are less susceptible to manipulation and provide a more stable view of financial health. By excluding the Altman Z-Score, the model avoids conflating financial distress with earnings manipulation, allowing for a clearer and more targeted assessment of potential irregularities.

4.3 Spathis Z-score (S2F) findings

Next, the Spathis Z-score model (S2F) was employed to assess earnings management risks. This model uses a probabilistic threshold of 10% above which a company is flagged as potentially engaging in manipulation. Based on this criterion, four companies in the sample exceeded the threshold:

- SATO (34.57%)
- Euromedica (27.81%)
- Revoil (16.51%)
- Motor Oil (12.28%).

These companies exhibited characteristics in their financial ratios that were consistent with an elevated manipulation risk of manipulation. **Figure 5**, illustrates the firms whose probabilities surpassed the 10% threshold, showing SATO and Euromedica as particularly high-risk cases.

4.4 Beneish M-score findings

The first stage of the analysis involved applying the Beneish M-Score model. According to this model, a company is considered likely to have manipulated its earnings if its M-Score exceeds the threshold value of -2.22 . Of the 31 companies analyzed, only Domain Lazaridis, with an M-Score of 5.32, had a value above this threshold, indicating a high probability of earnings manipulation. The remaining companies showed M-Scores well below the threshold, indicating no signs of fraudulent activity under this model.

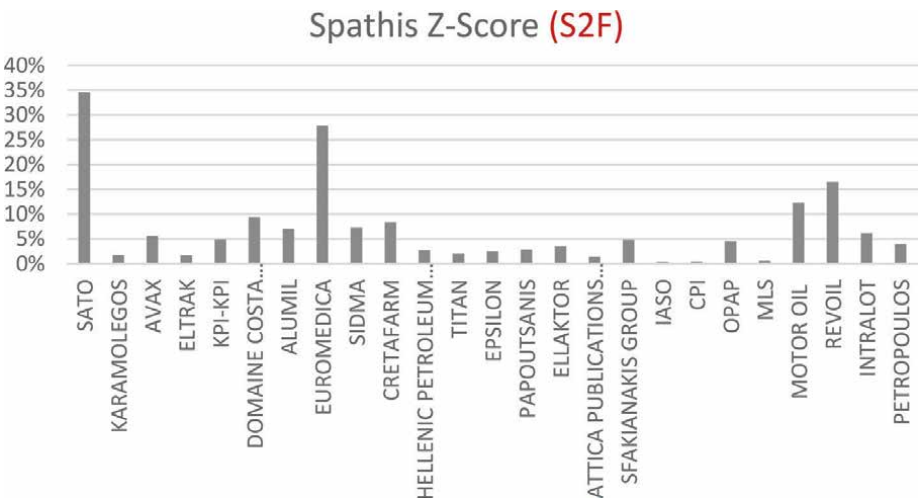


Figure 5.
Spathis Z-score (S2F) model findings.

The distribution of M-Scores across the sample is visualized in **Figure 6**, where the distinct deviation of Domain Lazaridis is readily apparent. The clustering of the remaining firms around safer values underscores the model’s conservative assessment.

4.5 Comparative evaluation of the four models’ findings

The main statistics of the findings relating to the four models assessed are presented in **Table 1**.

To further assess the reliability and diagnostic scope of the models, the results of each company’s evaluation were compiled side by side. **Table 2**, presents the manipulation probabilities or risk indicators for all 31 companies based on the Altman Z-Score Model, the Spathis Model without Z-Score (S1), the Spathis Z-Score Model (S2Z), and the Beneish M-Score Model.

A comparative inspection reveals considerable divergence in the identification of high-risk firms. Ktima Lazaridis, for instance, was flagged only by the Beneish M-Score, with a result of 5.32, well above the conservative threshold of -2.22 . However, this company was not classified as suspicious by either the Spathis Z-Score

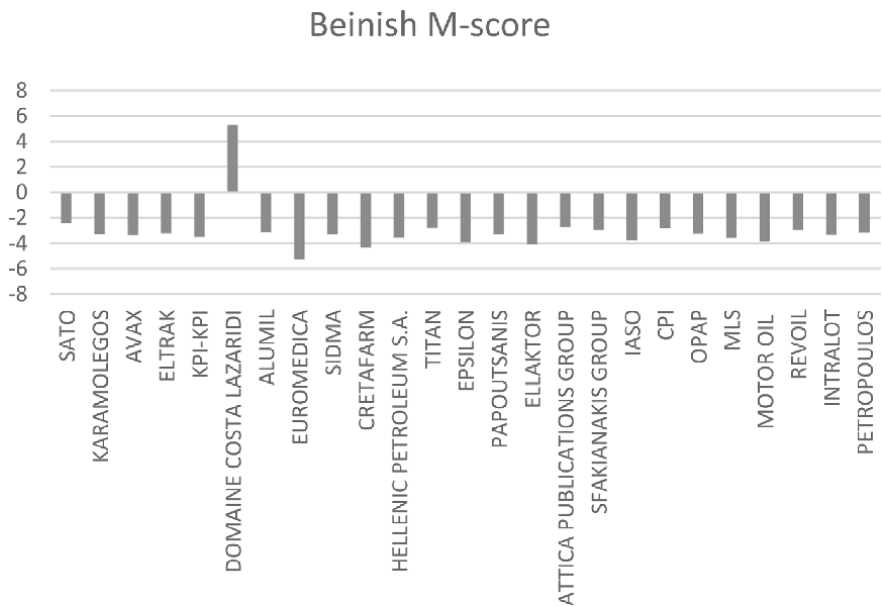


Figure 6.
Beneish M-Score findings.

	Altman Z-Score	Spathis Without Z-Score (S1)	Spathis Z-Score (S2Z)	Beneish M-Score
Average	1.86	0.03	0.07	-3.15
Min	-5.00	0.00	0.00	-5.26
Max	6.81	9.00	34.00	5.32

Table 1.
Main statistics of all four models assessed.

Companies	Altman Z-Score	Spathis without Z-Score (S1)	Spathis Z-Score (S2Z)	Beneish M-Score
SATO	-5.00	0.02	0.35	-2.42
KARAMOLEGOS	0.99	0.03	0.02	-3.25
AVAX	0.45	0.02	0.06	-3.35
ELTRAK	0.66	0.04	0.02	-3.20
KPI-KPI	2.37	0.09	0.05	-3.49
DOMAINE LAZARIDIS	3.57	0.04	0.09	5.32
ALUMIL	0.15	0.01	0.07	-3.15
EUROMEDICA	-3.31	0.05	0.28	-5.26
SIDMA	0.16	0.02	0.07	-3.30
CRETAFARM	-0.45	0.09	0.08	-4.37
HELLENIC PETROLEUM	2.30	0.04	0.03	-3.57
TITAN	0.42	0.01	0.02	-2.77
EPSILON	1.73	0.03	0.02	-3.91
PAPOUTSANIS	0.41	0.01	0.03	-3.30
ELLAKTOR	0.64	0.02	0.03	-4.07
ATTICA PUBLICATIONS	0.76	0.01	0.01	-2.70
SFAKIANAKIS GROUP	0.67	0.01	0.05	-2.93
IASO	0.80	0.05	0.00	-3.78
CPI	1.25	0.02	0.00	-2.81
OPAP	2.52	0.05	0.05	-3.21
MLS	1.12	0.02	0.01	-3.58
MOTOR OIL	4.93	0.07	0.12	-3.85
REVOIL	6.81	0.00	0.17	-2.93
INTRALOT	0.14	0.03	0.06	-3.34
PETROPOULOS	2.36	0.02	0.04	-3.17

Table 2.
Company scores based on all four models assessed.

S2F (9.37%, just below the 10% risk limit), the Spathis without Z model S1 (3.98%), or the Altman Z-Score (3.57, classified as “healthy”).

Conversely, companies such as SATO, Euromedica, Revoil, and Motor Oil were flagged by the Spathis Z-Score model (S2Z), but not by Beneish, as their M-Scores remained well below the risk cutoff. Notably, Euromedica was also classified as distressed by the Altman model, while Revoil was flagged by Altman as well, with a Z-Score of 6.81. On the other hand, the Spathis model without Z (S1) did not classify any company as exceeding the 10% manipulation threshold, supporting its conservative profile.

We have rigorously re-examined the Beneish M Score calculation for Ktima Lazaridis (5.32) using source data directly extracted from its audited 2018 financial statements. All eight index components—DSRI, GMI, AQI, SGI, DEPI, SGAI, TATA,

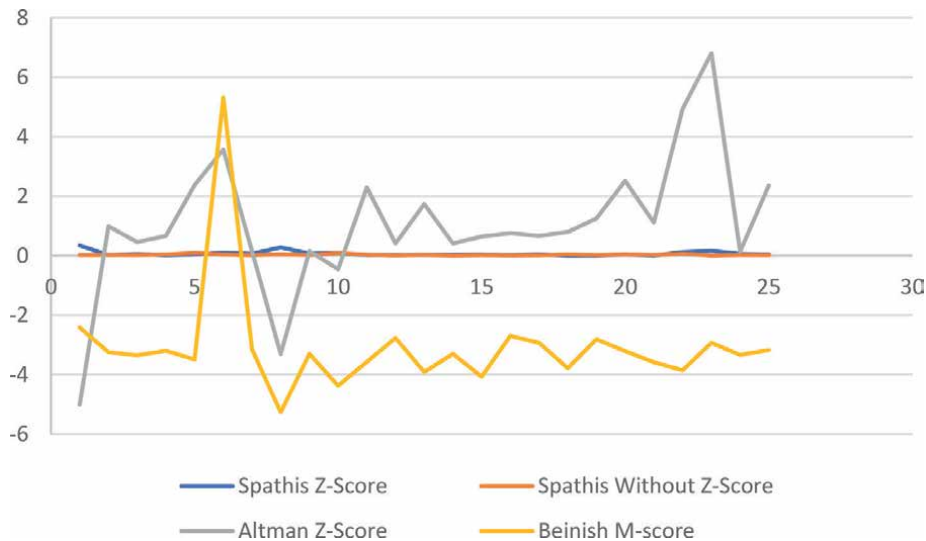


Figure 7. Comparative line chart illustrating the output values of the four detection models (Altman Z-Score, Spathis without Z-Score S1, Spathis Z-Score S2Z, and Beneish M-Score) across all sampled companies. The figure highlights differences in sensitivity, variation, and detection patterns among the models.

and LVGI—were computed in strict accordance with Beneish’s original methodology and coefficients. The result was validated using both manual calculation and automated spreadsheet checks, confirming its accuracy. Notably, such a high M Score is not without precedent. Several financial studies have documented similar outcomes in firms exhibiting sharp changes in receivables, gross margins, or asset quality [52, 53]. These studies illustrate that high M Scores can occur in cases of substantial financial irregularities and are not necessarily indicative of miscalculation. Therefore, the M-Score of 5.32 for Ktima Lazaridis is a valid outcome and reflects the company’s unique financial profile during the assessed period rather than a data entry or formula error.

These discrepancies highlighted how each model captures distinct dimensions of financial risk-accrual-based anomalies, structural weaknesses, or broader indicators of financial distress.

Figure 7 presents a comparative line chart illustrating the model outputs across all sampled companies. The visual spread of the Spathis Z-Score Model (S2Z) line indicates greater responsiveness to financial anomalies, while the flatter Beneish M-Score line reflects its restrained detection behavior. The Spathis without Z Model (S1) line remains relatively subdued across firms, and the Altman Z-Score line shows sharp dips, aligning with its high distress classification rate. Collectively, the chart demonstrates the differing sensitivities and evaluative focuses of each model.

5. Conclusions: Discussion

The comparative analysis of the four models applied in this study -the Altman Z-Score, the Spathis model without Z (S1), the Spathis Z-Score model (S2Z), and the Beneish M-Score- provides important insights into the detection of earnings management and financial distress among Greek listed companies. Overall, the findings

indicate a low probability of manipulation across the sample, especially in the Beneish M-Score and both the two Spathis models. This suggests that most companies in the dataset appear to follow legitimate financial reporting practices, supporting a broader sense of trust and reliability.

The Altman Z-Score Model showed that only 3 out of the 31 companies were in the “safe” zone. Most firms were found to be either in the “gray zone” or at high financial risk. While this result may seem pessimistic, it reflects a broader assessment of financial stability rather than direct evidence of manipulation. This highlights the model’s usefulness in identifying firms that should improve their liquidity or reduce debt to avoid long-term solvency risks.

The simplified Spathis model S1 which excludes the Altman Z-Score, produced results nearly identical to those of the Beneish M-Score, reinforcing the idea that both reflect more conservative detection logics.

The Beneish M-Score flagged only one company, Domain Lazaridis, as highly suspicious of earnings manipulation. Its M-Score of 5.32 is well above the conservative threshold of -2.22 , indicating the potential presence of aggressive earnings management practices. However, the same company did not exceed the 10% probability threshold of the Spathis Z-Score S2Z model (9.37%), highlighting an important tension between accrual-based detection (Beneish) and broader financial anomalies (Spathis S2Z). Conversely, four companies-SATO, Euromedica, Revoil, and Motor Oil-were flagged by the Spathis Z-Score S2Z model but showed no risk of manipulation under the Beneish method. This suggests that these companies may exhibit financial stress signals-such as excessive leverage or poor working capital ratios-that are not necessarily due to accrual manipulation but nevertheless warrant regulatory scrutiny or closer examination.

The statistical summaries of the models highlight their different sensitivity. The Spathis Z-Score S2Z model exhibits greater variability in results, suggesting that it is more sensitive to general financial instability. In contrast, the Beneish model produces more concentrated results, indicating its conservative stance in detecting manipulation risk. This characteristic makes Beneish suitable for detecting serious anomalies, while Spathis S2Z is more suitable for early warning diagnosis in a broader governance context.

Importantly, the discrepancies between the models also reveal the multidimensional nature of earnings management. Manipulation does not always manifest itself only in accrual accounting but may also involve changes in capital structure, unusual patterns in working capital, or pressure-related distortions in financial ratios. The Beneish model may miss these if the accrual-based distortions are not pronounced.

Additionally, sectoral differences may contribute to some of the variations. For example, companies in industries such as healthcare or energy, such as Euromedica or Motor Oil, may exhibit inherently volatile financial ratios or be exposed to market-specific risks that amplify their Z-score, without necessarily indicating an intention to deceive.

Moreover, the effectiveness of these models is likely to be shaped by sectoral dynamics and macroeconomic pressures, which may explain why companies from sectors such as healthcare, energy, or construction exhibit different results under the same models. This supports previous findings that earnings management practices are influenced by both market-specific and firm-level characteristics [54].

The discrepancies observed between the models also raise deeper questions about how corporate behavior, regulatory structures, and enforcement capacity influence the effectiveness of detection methods. For instance, a firm’s ability to obscure earnings manipulation may depend not only on its internal reporting strategies but also on the broader institutional tolerance for aggressive accounting behavior [20].

Lastly, the role of tax-related incentives cannot be ignored. Studies from the Greek context reveal a significant overlap between firms engaging in tax avoidance and those manipulating earnings for cosmetic or regulatory reasons. The proximity of tax evasion and financial statement distortion points to a shared behavioral and infra-structural foundation [6].

From a policy and auditing perspective, the results support the use of multi-model valuations in fraud detection. A company that is not flagged by one model may still be detected by another. Regulators, investors, and auditors are therefore encouraged to triangulate between models to obtain a more robust picture of corporate financial behavior.

Nevertheless, it is important to stress that all these models are probabilistic tools. They offer useful indications, but do not serve as definitive proof of manipulation. The final judgment must always rest with auditors and investigators, who can contextualize findings with qualitative insights and additional information.

Finally, in the Greek context, where issues such as low tax compliance and weak enforcement capacity are well documented, such analytical tools are particularly valuable. They can serve not only as tools for forensic accounting but also as policy tools that feed into risk-based monitoring frameworks to prioritize audits where model results deviate or signal high risk.

The findings suggest that while each model offers unique strengths, their standalone application may not capture the full spectrum of creative accounting tactics, thus underlining the importance of hybrid, context-aware approaches. Despite their widespread use, accounting fraud detection models such as the Altman Z-Score and the Beneish M-Score exhibit notable limitations when applied to detect creative accounting practices or fraudulent financial reporting. The Beneish M-Score, while useful in identifying accrual-based manipulation, is considered less predictable and less effective in detecting broader types of fraud compared to the Altman Z-Score, particularly when used as a standalone tool [55]. Similarly, the Altman Z-Score, designed initially to forecast bankruptcy risk, often flags companies as distressed without necessarily indicating manipulation, leading to false positives and limited interpretability for fraud detection [56]. Comparative studies have also demonstrated inconsistencies in the models' predictive capabilities across industries and jurisdictions, with effectiveness often increasing when models are used in combination [57, 58]. For instance, in manufacturing firms, the Altman and Beneish models proved useful for flagging red flags, but their accuracy improved significantly when used together or alongside newer data mining techniques [59]. Furthermore, in complex environments such as Ghana's banking and consumer sectors, the combination of Beneish and Altman models revealed sector-dependent sensitivities, with the Beneish model better suited for early red flags and the Altman model for bankruptcy risk.

However, as recent empirical findings have shown, these models—when used individually—may fail to detect certain forms of creative accounting, particularly those based on real activities or sector-specific strategies [55, 57, 59]. Their predictive power improves significantly when used in combination with machine learning tools.

Moreover, recent developments in tax administration and digital governance are reshaping the field of fraud detection. Research in the Greek context has highlighted the increasing importance of real-time data analytics, algorithmic surveillance, and digital auditing systems in identifying financial irregularities [47]. These innovations challenge the limits of traditional *ex post* statistical models and suggest a shift toward proactive, automated compliance infrastructures.

Looking forward, future research should explore hybrid frameworks that integrate conventional financial ratios with digital tax enforcement mechanisms. Such an approach

could enhance both the timeliness and accuracy of fraud detection while contributing to more efficient public revenue collection and stronger corporate accountability. Additionally, cross-country comparisons and sector-specific studies could further clarify how institutional factors shape earnings management practices and model efficacy [48].

Ultimately, it is crucial to acknowledge that fraud detection is inherently probabilistic. Analytical models raise red flags, but only human auditors and regulatory authorities can contextualize those warnings and verify intent. This reinforces the importance of embedding technical tools within a broader governance and ethical framework, while also promoting a cultural shift away from opportunistic accounting. Preventing manipulation – rather than simply detecting it – must become the central focus of both policy and practice.

This study, while offering valuable insights, is subject to certain limitations. The dataset is relatively small, encompassing only 31 companies. However, this reflects a deliberate methodological choice: the data analyzed pertains to the pre-COVID-19 period, thus avoiding distortions introduced by the pandemic-related economic crisis. Expanding the sample to include post-pandemic data might have introduced volatility not attributable to typical accounting behavior, thereby compromising result reliability. Furthermore, comparative cross-country analyses, particularly those focusing on nations that have experienced bailout programs or fiscal consolidation processes like Greece's (e.g., Portugal, Cyprus, and Ireland), could provide additional context for understanding how institutional pressures affect creative accounting practices. Such research could further strengthen the empirical basis for policy design and enhance early warning mechanisms in vulnerable economies.

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Carbon Finance: Empowering Carbon Emission Reduction with the Power of Finance

Xiaojing Yi

Abstract

At this stage, it has become an international consensus that human activities lead to an increase in carbon dioxide emissions, which in turn affects socioeconomic development. Finance is the core of the contemporary economy, and the financialization of the economy is a process that accompanies the development of the market economy and the deepening of finance, a process that is inevitably accompanied by the generation of carbon emissions. Therefore, we have reason to believe that there is an important linkage between economic financialization and carbon emissions. Taking China as an example, it is of great significance for the transformation of the world's low-carbon economy to explore in depth the linking role of carbon finance in the relationship between economic financialization and carbon emission efficiency, from the purpose of realizing the co-optimization of economic and ecological benefits.

Keywords: financialization of the economy, carbon emission efficiency, inverted N-type, carbon financial instruments, opportunities and challenges

1. Introduction

The most significant environmental concern is climate change, which is caused by the excessive emission of greenhouse gases such as carbon dioxide. These gases impede the sustainable development of humanity, either directly or indirectly [1]. A growing body of evidence indicates that the Earth's temperature is on an upward trajectory due to the intensification of human activities and industrial processes throughout the development process. This has led to an increase in greenhouse gases, such as carbon dioxide, which is ultimately having a detrimental impact on society as a whole [2]. As posited by Rubashkina et al. [3], carbon dioxide represents the primary greenhouse gas responsible for global climate change [4]. Consequently, the issue of global warming caused by carbon emissions has become a matter of international concern [5] and several countries have convened conferences with the objective of supporting low-carbon development and limiting carbon emissions [6].

Finance plays an instrumental role in a country's economic development, serving as a pivotal component of the modern economy [7]. The financial sector can facilitate the reduction of transaction costs associated with investment and financing

activities, thereby enabling both parties to secure the necessary financial resources. Furthermore, the financial sector has the potential to optimize the allocation of resources, facilitate the flow of financial funds to more efficient areas, stimulate economic growth, and enhance social welfare. Nevertheless, the financialization of the economy is not wholly conducive to social development and economic growth. In practice, the optimization of resource allocation and the promotion of economic growth are not the outcomes of the financial sector's development. Instead, inefficient resource allocation and the hindrance of economic growth are the consequences. Furthermore, the inequitable distribution of income in society is an additional consequence that is not conducive to the increase of social welfare.

With the development of each country's economy, the further deepening of industrialization and urbanization, pulling the traditional energy consumption, bringing the increase of carbon emissions, ecological problems are becoming more and more serious, but is not conducive to the development of the economy, to break the contradiction between the energy consumption triggered by the needs of economic development and the carbon emission reduction target accompanied by the government's commitment is of great practical significance. As the financial market has also received widespread attention, the continuous innovation of financial instruments has triggered the prosperity of the financial market, which in turn has caused the financialization of the economy, and the financialization of the economy has a close relationship with the development of the national economy and carbon emissions, and the financial capital can play a supportive role in scientific and technological innovation and the formation of new industries, and ultimately realize the green and low-carbon development, therefore, it is very important to rationally utilize the financial instruments to provide the cause of carbon emission reduction with a more. Therefore, it is very important to rationally utilize financial instruments to provide a more efficient market for the cause of carbon emission reduction. In this context, carbon finance has been widely noticed because it has both emission reduction and financial attributes.

Carbon finance refers to financial activities related to the reduction of greenhouse gas emissions, and its purpose is to promote the development of low-carbon economy through financial means. Specific financial instruments and policies related to carbon finance mainly include carbon emissions trading systems (ETS), carbon taxes, carbon credits and bonds, carbon insurance, green funds and climate investment funds, green supply chain finance, carbon neutral and carbon offset projects, standardization of corporate carbon emissions reporting, regulatory framework and policy support for green finance, environmental and social governance (ESG) investment strategies, carbon disclosure requirements, and policy support and incentives through government subsidies, tax incentives, and low-interest loans. Through the above carbon financial tools and policies, the global community is gradually establishing a multi-level and multi-dimensional carbon financial market system, which not only promotes the global transition to a low-carbon economy but also provides new value and investment opportunities for the international community, and this chapter argues that carbon finance will play an even more critical role in the global sustainable development process.

Therefore, studying the development of economic financialization and focusing on the relationship between economic financialization and carbon emission efficiency with China as an example will help to understand the trend and reasons for the change of carbon emission efficiency with the deepening of financialization, and thus propose the linkage role of carbon finance between the financial market and the

emission reduction market, which is of far-reaching significance for the international community to achieve carbon emission reduction.

2. Linkages between financialization of the economy, carbon finance, and carbon emission efficiency

2.1 An empirical study on the impact of economic Financialization on carbon emission efficiency: A case study of China

The reduction of carbon emissions is a complex, multifaceted issue that requires the involvement of numerous factors. Finance plays an indispensable role in the process of carbon emission reduction. The continuous development of the financial industry in recent years has resulted in a deviation of financial investment in both financial and non-financial sectors. This has led to a high price, which has affected the development of the real economy. This, in turn, has resulted in the phenomenon of “de-realization to virtualization,” which has further brought about problems related to environmental pollution. In this study, we take China as an illustrative case to explore the relationship between the two and to develop the subsequent analysis. This study explores the relationship between the two in the context of China and then expands on it.

This study employs a case study approach, with China as the exemplar, to investigate the relationship between the two and to develop subsequent insights. Building on the environmental Kuznets curve (EKC) model, we construct an empirical model to examine the influence of economic financialization on carbon emission efficiency:

$$tfce_{it} = \alpha_1 + \beta_1 \ln vfin_{it} + \gamma con_{it} + \mu_i + \phi_t + \varepsilon_{it} \quad (1)$$

$$tfce_{it} = \alpha_2 + \beta_1 \ln vfin_{it} + \beta_2 \ln vfin_{it}^2 + \gamma con_{it} + \mu_i + \phi_t + \varepsilon_{it} \quad (2)$$

$$tfce_{it} = \alpha_3 + \beta_1 \ln vfin_{it} + \beta_2 \ln vfin_{it}^2 + \beta_3 \ln vfin_{it}^3 + \gamma con_{it} + \mu_i + \phi_t + \varepsilon_{it} \quad (3)$$

In this chapter, the variable “i” denotes provinces and cities, while “t” denotes the year. Additionally, “i” represents individual fixed effects, region fixed effects (including provinces, autonomous regions, and municipalities directly under the central government), time fixed effects, and random error terms. Meanwhile, “α” denotes the intercept term and, in turn, the coefficients. The primary, secondary, and tertiary terms of economic financialization are represented by α, while the coefficients of each control variable are represented by γ. The total factor carbon emission efficiency (hereinafter referred to as the carbon emission efficiency) is represented by tfce, and lnvfin denotes economic financialization. The control variables are represented by con. In order to eliminate the effect of magnitude and according to the STIRPAT model, this chapter carries out a logarithmic process for the basic control variables.

Description of variables:

2.1.1 Explained variable: Carbon emission efficiency (tfce)

Carbon emission efficiency indicates that it can produce maximum economic benefits while generating carbon emissions, which is expressed by the actual output

per unit of carbon dioxide emissions over the optimal output, and can be divided into single-factor carbon emission efficiency and full-factor carbon emission efficiency. The single-factor carbon emission efficiency (incc) is only used as the stimulus equation of the basic regression in this chapter, which is expressed as the ratio of carbon emission to GDP; the full-factor carbon emission rate is the main research variable in this chapter, which is obtained through multiple inputs and multiple outputs, in which the input factors include the consumption of labor, capital, and energy, and the output factors include the desired output of GDP and the undesired output of carbon dioxide emission.

2.1.2 Explanatory variable: Financialization of the economy (lnvfin)

The degree of financialization of the economy is measured by a composite indicator synthesized from the principal component analysis of the financial sector-related indicators and the value added of the financial sector, where the principal component factors of the composite indicator are the share of the value added of the financial sector in GDP (vfingdp), the share of the sum of deposits and loans in GDP (lodegdp), the share of employment in the financial sector in the total number of employed (nfiemp), and the wage of financial sector employment of total employment wages (nfinsal). Higher levels of financialization of the economy are associated with greater profitability, which can increase financial support for emission reduction targets, as well as improve energy efficiency by promoting technological innovation, which can also lead to a reduction in carbon emissions. However, expanding the financialization of the economy may also lead to an increase in energy consumption by high-carbon firms as a result of loosening financing constraints, which ultimately leads to an increase in carbon emissions.

2.1.3 Control variables

Gross fixed capital formation (lngfcf): the difference between fixed assets produced and purchased by a unit and those disposed of during a certain period of time, which not only obtains outputs through production activities but also generates a certain amount of carbon emissions, for example, heavy polluters obtain outputs through, for example, resource exploitation, and at the same time emit carbon dioxide; government support (lngov): measured by the general budget expenditures, it is the planned allocation of budget revenues, and the general budget expenditures are mainly used in the areas of economic construction, national defense construction, and subsidies, etc., especially in the area of economic construction, which can promote the development of the economy but inevitably affect the environment. Inevitably have an impact on the environment, which in turn has an impact on the efficiency of carbon emissions; foreign trade dependence (lnopen): that is, the degree of openness to the outside world, measured by the ratio of a region's imports and exports to the GDP, the higher the degree of foreign trade dependence, the more trade friction will be generated, which will also cause some of the production activities to be shifted, resulting in the reduction of China's carbon emission efficiency. The higher the degree of foreign trade dependence, the more trade frictions will be generated, will also cause some of the transfer of production activities, resulting in an increase in China's carbon emissions, the carbon emission rate decreased; regional economic development level (lnpgdp): expressed as GDP per capita, GDP per capita is an important macroeconomic indicator, indicating the level of regional economic

development, with the rapid development of the regional economy will bring about an increase in energy consumption and carbon emissions. Accessibility (road): measured by the ratio of the number of kilometers of regional highway to the area of the region, transportation has become the main carbon emission industry after industry and energy industry, of which the road is the main mode of transportation, and is the main source of national and even global carbon emissions, so it has an impact on carbon emissions, the more developed the highway transportation of a region, the more carbon emissions will be generated, which will lead to the lower efficiency of carbon emissions; population size (lnpeo): expressed in terms of the year-end population size of a region, a small population size in the process of economic development will lead to too low a population density, which in turn will result in an imbalance in the spatial structure of the economy and will not be conducive to the rational use of energy. However, too large a population size is also detrimental to economic development and can lead to excessive consumption of energy resources.

In order to eliminate heteroskedasticity and correlation, this chapter employs the xtsc command to establish robust standard errors with a lag order of 2 for "heteroskedasticity-serial correlation-cross-section correlation." The results are presented in **Table 1**, which demonstrates that the coefficient of the primary term and the coefficient of the cubic term are significantly negative after the addition of the cubic term. The coefficient of the quadratic term is significantly positive, and the U-type and inverted N-type relationships between economic financialization and carbon emission efficiency are significant, indicating that the carbon emission efficiency decreases, then increases, and then decreases again with the development of economic financialization. In the U-shaped relationship, the initial development of economic financialization will result in economic growth, which may be accompanied by the rapid development of polluting industries or may occur at the expense of the over-exploitation of energy resources. In either case, this will inevitably lead to an increase in carbon emissions, which will in turn result in a decrease in carbon emission efficiency. This is an example of the scale effect brought about by economic financialization. As economic financialization has developed, economic growth has been achieved to a certain extent, living standards have improved, and the public has increasingly demanded a healthy ecological environment. In response, the state has implemented a series of industrial structure adjustments and optimizations, leading to a decline in the secondary industry and an increase in the green environmental protection industry. This has resulted in a reduction in carbon emissions and an improvement in the efficiency of carbon emissions, representing a structural effect brought about by the financialization of the economy. Furthermore, the growth of economic financialization has provided society with the necessary resources to support technological innovation and research and development in enterprises, thereby promoting technological progress. This progress can be achieved in two ways: firstly, by optimizing the consumption of resources and energy in production processes, thus improving energy efficiency and reducing carbon emissions; and secondly, by enhancing the technical support available for the management of carbon emissions, thereby reducing emissions and increasing their efficiency. This is the technical effect brought about by economic financialization. This is the technical effect resulting from the financialization of the economy.

In the initial phase of the U-shaped curve, the scale effect of economic financialization is more pronounced than the structural and technological effects. Conversely, in the subsequent phase, the structural and technological effects emerge as the dominant forces. With regard to the prospective evolution of the inverted N-shape,

	<i>tfce</i>		
	(1)	(2)	(3)
<i>lnvfin</i>	0.0046* (1.80)	−0.0440*** (−3.23)	−0.6315*** (−4.50)
<i>lnvfin</i> ²		0.0016*** (3.64)	0.0405*** (4.35)
<i>lnvfin</i> ³			−0.0009*** (−4.18)
<i>lngcf</i>	−0.0158*** (−3.70)	−0.0069 (−1.43)	−0.0119** (−2.40)
<i>lngov</i>	0.0030 (0.94)	0.0044 (1.31)	0.0065* (1.80)
<i>lnopen</i>	−0.0155*** (−9.19)	−0.0145*** (−8.00)	−0.0155*** (−8.31)
<i>lnpgdp</i>	0.0365*** (4.56)	0.0221** (2.52)	0.0289*** (3.17)
<i>road</i>	0.0067** (2.41)	0.0050* (1.77)	0.0018 (0.60)
<i>lnpeo</i>	0.0363*** (6.84)	0.0292*** (5.17)	0.0353*** (5.86)
<i>city</i>	0.0595*** (3.04)	0.0773*** (3.94)	0.0836*** (4.07)
<i>_cons</i>	0.4955*** (10.14)	0.9506*** (7.12)	3.7953*** (5.47)
<i>Wald</i>	725.77***	707.13***	664.35***
<i>N</i>	570	570	570

Note: *, **, and *** denote 10%, 5%, and 1% significance levels, respectively; Wald denotes the significance of the overall model and the degree of fit.

Table 1.
This study examines the empirical evidence concerning the impact of financialization on the efficiency of carbon emissions.

which represents an excessive expansion of economic financialization on the foundation of the U-shape, this phenomenon has resulted in a societal shift toward a virtual economy, accompanied by a continuous influx of capital into the financial sector and a concomitant reduction in investments in technology and environmental management. This, in turn, has led to a decline in carbon emission efficiency.

2.2 Carbon finance: Financial instruments linking financialization of the economy and carbon efficiency

In the contemporary global financial market, the nexus between financialization and carbon emission targets has become increasingly robust. To gain a deeper understanding of this linkage, researchers and financial institutions have developed a variety of analytical approaches. Among these, carbon finance helps to better consider carbon emissions in investment decisions and promote low-carbon economic development. Additionally, it provides new investment opportunities and financial

sustainability, reveals the complex relationship between the financialization of the economy and carbon emissions, and provides strong support for the development of effective risk management strategies. The provision of support is a crucial aspect of this process.

The nexus between economic financialization and carbon emission efficiency and carbon finance represents a topic of significant interest within the broader fields of global economic transformation and environmental protection. In this process, it is possible to observe not only the interaction between financial innovation and environmental policies, but also the complex interaction between enterprises, financial institutions, and governments.

First and foremost, the enhancement of carbon emission efficiency signifies to financial institutions that enterprises will confront diminished environmental risks and more stable operating costs. In the evaluation of prospective loan or investment targets, financial institutions will give considerable weight to the carbon emission efficiency of the enterprises in question. Financial institutions frequently accord a preference to enterprises that are able to effectively control carbon emissions and enhance the efficiency of their energy utilization. Consequently, financial institutions will be more likely to extend support to those enterprises that demonstrate superior carbon emission efficiency when providing financial services such as loans and investments to enterprises, thereby facilitating the low-carbon transformation of society as a whole.

Secondly, the development of carbon finance, as a nexus between finance and the environment, has a pivotal role to play in promoting the efficiency of carbon emissions. Financial products related to carbon, including carbon credits, carbon futures, and carbon options, offer businesses flexible financial instruments for managing their carbon emission costs and risks. As the carbon financial market continues to evolve and enhance its capabilities, the efficiency of carbon emissions will become a crucial factor in determining the financial resources available to enterprises. This, in turn, will facilitate the growth of the entire economic system in a low-carbon and environmentally conscious direction. The growth of the carbon financial market offers new avenues for investment while also providing financial backing for environmental initiatives and technological advancement.

Moreover, the financialization of the economy offers a vast opportunity for the growth of carbon finance. The term “financialization” is used to describe the increasing prevalence of financial activities within the economy, as well as the expansion of the depth and breadth of financial markets. In this context, financial institutions and financial products continue to innovate, providing the necessary financial support and risk management tools for the construction and development of the carbon financial market. The issuance of green bonds and the establishment of carbon funds by financial institutions provide funding for low-carbon projects and the research and development of environmental protection technologies. Furthermore, there is a significant correlation between carbon emission efficiency and carbon finance with respect to risk management. When engaging in the carbon finance market, financial institutions are obliged to evaluate the carbon emission efficiency of prospective investments in order to guarantee the security and profitability of their portfolios. The enhancement of carbon emission efficiency enables enterprises to mitigate the risk associated with environmental policy shifts. Financial institutions, in turn, can mitigate their own risk by investing in projects that demonstrate high-carbon emission efficiency. Consequently, the enhancement of carbon emission efficiency represents not only a social obligation for financial institutions, but also a crucial

instrument of risk management. Financial institutions assume a dual role in this process, serving both as risk assessors and risk diversifiers.

Ultimately, policy support serves as a crucial assurance for the advancement of carbon emission efficiency and the growth of carbon finance. The government can facilitate the advancement of low-carbon industries by implementing policies that provide incentives, subsidies, and other forms of support to financial institutions. Concurrently, the government can facilitate the sound advancement of the carbon financial market through the enactment of legislation and the implementation of supervisory measures, thereby establishing a conducive external context for the enhancement of carbon emission efficiency. The implementation of policies will facilitate the participation of financial institutions and enterprises in carbon finance activities, thereby promoting the development of a green and low-carbon economy. These government measures will not only stimulate market vitality but also ensure the long-term stability and sustainable development of the carbon financial market.

In conclusion, the financialization of the economy exerts a complex influence on both carbon efficiency and carbon finance. In the context of addressing climate change and promoting sustainable development, the interconnectivity between these three elements will become increasingly evident. By means of financial innovation and policy guidance, the efficiency of carbon emissions can be significantly enhanced, the prosperity of the carbon finance market can be promoted, and, in the long term, the green transformation of the economy and sustainable development can be achieved. This process necessitates the active involvement of financial institutions, the robust endorsement of the government, and the collaborative endeavors of enterprises to collectively construct a low-carbon, environmentally benign, and sustainable future.

3. Concepts related to carbon finance

3.1 Background and evolution of carbon finance

The concept of carbon finance emerged against the backdrop of increasingly serious global climate change problems. It involves a range of financial activities such as trading, investing, and financing in carbon emission rights. Its core objective is to use market mechanisms to reduce greenhouse gas emissions and thereby combat global climate change. Carbon finance is not just a financial innovation; it also integrates knowledge and practices from environmental policy, energy economics, and sustainable development. The development of carbon finance began with international climate change negotiations in the 1990s, in particular the signing of the Kyoto Protocol, which marked the beginning of international carbon market trading. Subsequently, the establishment of the European Union Emissions Trading Scheme (EU ETS) set a benchmark for the development of global carbon finance. In the twenty-first century, with the adoption of the Paris Agreement, carbon finance entered a phase of rapid development, with countries establishing their own carbon markets and promoting the diversification of carbon finance products and services. Carbon finance will play an increasingly important role in the global economy. It not only contributes to the development of a low-carbon economy but will also become an important economic tool for achieving global greenhouse gas emission reduction targets. With the continued development and improvement of the carbon finance

market, its status and influence in the global economy will continue to grow. In terms of the policy environment, governments around the world are strongly supporting the development of carbon finance through legislation and policy guidance. At the same time, international organizations such as the World Bank and the International Monetary Fund are promoting the integration and cooperation of the global carbon finance market. The relationship between carbon finance and climate change is inextricably linked. Carbon finance provides financial support for emission reduction projects, thereby incentivizing companies to reduce greenhouse gas emissions and combat global climate change. In addition, carbon finance has also supported the research, development, and deployment of clean energy technologies, driving the development of a low-carbon economy and providing an important economic means to achieve global greenhouse gas emission reduction targets.

3.2 Carbon finance instruments

1. Emissions trading scheme (ETS): This is a market-based emission reduction mechanism that allows companies to buy and sell carbon emission allowances by putting a price on carbon emissions. This system incentivizes companies to reduce carbon emissions through technological innovation and improvements in production processes, thereby reducing their carbon costs. The European Union Emissions Trading Scheme (EU ETS) is the largest carbon market in the world. This mechanism not only promotes the reduction of carbon emissions but also provides economic incentives for companies.
2. Carbon tax: This is a direct economic instrument whereby governments levy taxes on the carbon emissions of companies or individuals. The purpose of a carbon tax is to encourage companies and individuals to reduce carbon emissions by increasing the cost of carbon emissions.
3. Carbon credits and carbon bonds: Carbon credits are allowances that companies earn by investing in emission reduction projects, which can be sold on the market to companies that need to emit more carbon. Carbon bonds are bonds issued by companies to raise funds for emission reduction projects. These financial instruments provide sources of finance for low-carbon projects and also offer new investment opportunities for investors.
4. Carbon insurance: This type of insurance provides risk protection for low-carbon projects and assets, reducing losses caused by climate change.
5. Green funds and climate investment funds: These funds invest specifically in low-carbon technologies and renewable energy projects, such as wind, solar, and electric vehicles. These funds not only support the development of a low-carbon economy but also provide sustainable investment returns for investors.
6. Green supply chain finance: Financial institutions provide loans and credit by assessing the environmental performance of a company's supply chain. Companies with low-carbon, sustainable supply chains are more likely to receive preferential financing terms. This practice encourages companies to environmentally manage their entire supply chain to ensure that their products and production processes meet the requirements of green finance.

7. Carbon neutrality and carbon offset projects: Individuals and companies can offset their carbon emissions by participating in carbon neutral projects. These projects typically include reforestation, renewable energy projects, or forest protection. By investing in these projects, participants can earn carbon credits to offset their carbon footprint. Carbon offset projects focus on compensating for emissions that cannot be avoided, thereby ensuring a reduction in overall emissions.
8. Environmental, social, and governance (ESG) investment strategies: Investors are increasingly incorporating environmental, social, and governance (ESG) factors into their investment decision-making processes. ESG investment strategies consider a company's carbon emissions, resource use, labor rights, corporate governance, and other aspects of performance and use these factors as important indicators for evaluating investment risks and opportunities. Through ESG investing, investors seek not only financial returns but also to promote sustainable development in companies and society.

4. Carbon finance risk management

4.1 Carbon price risk and management

Carbon price risk is the risk to market participants from fluctuations in the price of carbon emission allowances. As the price of carbon emission rights is influenced by various factors such as policy changes, market supply and demand relationships, and technological progress carbon price fluctuations are significant. Market participants can manage carbon price risk by purchasing carbon financial derivatives and diversifying investment portfolios.

4.2 Credit risk and management

Credit risk is the risk that market participants face if a counterparty is unable to meet its contractual obligations. In the carbon market, credit risk mainly manifests itself in the fraudulent or repeated use of carbon credits. To manage credit risk, market participants need to perform credit assessments of counterparties and verify carbon credits through third-party certification bodies.

4.3 Liquidity risk and management

Liquidity risk is the risk that market participants will be unable to buy or sell carbon assets quickly and at a reasonable price when they need to do so. As the carbon market is in a developmental stage with limited market depth and breadth, liquidity risk is high. Market participants can improve the liquidity of carbon assets by trading in multiple carbon markets and using market maker services.

4.4 Operational risk and management

Operational risk is the risk of loss resulting from failure of internal processes, people, systems, or external events. In the carbon market, operational risk mainly manifests itself through errors in transaction records and system failures. To manage

operational risk, market participants must establish comprehensive internal control mechanisms, regularly maintain and upgrade systems, and provide professional training for staff.

5. Carbon finance innovation and practice

5.1 Drivers of carbon finance innovation

Driving factors for carbon finance innovation include the urgency of addressing climate change, the rapid development of the carbon market, technological advances, and changes in the policy environment. As the global climate change problem becomes more serious, carbon finance innovation has become an important means to achieve greenhouse gas emission reduction targets. At the same time, the rapid development of the carbon market and technological progress have also provided a broad stage for carbon finance innovation.

5.2 Case analysis of carbon finance innovation

Cases of carbon finance innovation are emerging around the world. For example, the application of blockchain technology in the issuance and trading of carbon credit certificates has improved the transparency and efficiency of the carbon market. In addition, the application of big data technology in the monitoring and management of carbon emissions has also provided new ideas and methods for carbon finance innovation.

5.3 Application of carbon finance technology: Blockchain and big data

Blockchain technology, with its characteristics of decentralization, immutability, and transparency, has great application potential in the field of carbon finance. Through blockchain technology, the real-time recording and verification of carbon credits can be achieved, preventing the reuse of carbon credits and fraudulent transactions. Big data technology plays an important role in carbon emission monitoring and carbon market analysis, improving the operational efficiency and decision-making quality of the carbon market.

6. Challenges and opportunities for carbon finance

Carbon finance faces complex environmental and economic challenges, the main environmental challenges being the uncertainty of climate change, the volatility of the carbon market, and the limitations of carbon abatement technologies. To meet these challenges, carbon finance must continue to innovate and evolve, improving its adaptability and flexibility. The main economic challenges are the insufficient depth and breadth of the carbon market, the low liquidity of carbon finance products and the low level of international integration of the carbon finance market. To address these challenges, carbon finance needs to strengthen the construction of market infrastructure and improve market efficiency and transparency.

Correspondingly, carbon finance also has development opportunities, mainly including the increasingly severe global climate change problems, the rapid development of the

carbon market and the widespread application of carbon finance technology. The future development direction of carbon finance will mainly focus on the innovation of carbon finance products, the internationalization and integration of the carbon market, and the application of carbon finance technology. To achieve the long-term sustainable development of carbon finance, it is necessary to formulate long-term strategic plans, which include strengthening the research and formulation of carbon finance policies, promoting the internationalization and integration of the carbon finance market, facilitating the innovation and application of carbon finance technology, and improving the transparency and efficiency of the carbon finance market.

7. Cases

The diversity and innovation of carbon finance in practice at home and abroad. With the growing global concern about climate change, carbon finance will become an important means of promoting the development of a low-carbon economy and addressing climate change. This section will introduce several relevant cases at home and abroad.

7.1 Domestic cases

7.1.1 The Shenzhen carbon quota pledge financing and repurchase

Shenzhen Emission Rights Exchange (SERX) has launched carbon quota pledge financing and repurchase business for the purpose of implementing the goal of “double carbon.” For example, with the support of Shenzhen Emission Rights Exchange, Taiping P&C Insurance Company (Shenzhen Branch), together with Bank of China Limited (Shenzhen Branch), provided “Carbon Quota Pledge + Insurance” financing service for Guangdong Xialong Telecom Company Limited, which is the first carbon quota pledge loan guarantee insurance in Guangdong, Hong Kong and Macao Greater Bay Area. In addition, ICBC Shenzhen Branch launched the “Science and Innovation Dual Carbon Loan” financing product, which is an innovative mode of carbon emission quota pledge financing to revitalize the “carbon assets” of enterprises and broaden the path of corporate financing for them.

7.1.2 CCER pledge loan

Shanghai BaoCarbon is one of the earliest companies engaged in carbon trading and carbon asset management in China, and in December 2014, BaoCarbon cooperated with the Bank of Shanghai and Shanghai Environmental Energy Exchange to complete the first CCER (China Certified Emission Reduction) pledge loan in China, with a total amount of 5 million RMB. The loan utilizes CCERs held by Treasure Carbon as a pledge to obtain low-cost financing services.

7.2 Foreign cases

7.2.1 International carbon funds

Over the past two decades, the number and size of international carbon funds has continued to grow. These funds are usually co-financed by governments, private

enterprises, or international financial institutions and aim to support carbon emission reduction projects and promote the development and application of low-carbon technologies. For example, the UK Carbon Fund is a public welfare fund invested by the UK government and operated in accordance with the enterprise model, with its operating funds mainly coming from the Climate Change Levy, which is mainly used to support projects to address climate change.

7.2.2 Carbon emission reduction purchase agreements (ERPAs)

This is a kind of international carbon financial investment method; through the purchase agreement, investors can directly participate in carbon emission reduction projects, obtain carbon emission reductions, and trade in the carbon market. This approach helps to promote the development and implementation of carbon emission reduction projects and also provides investors with the opportunity to participate in the carbon market.

8. Conclusion and outlook

Through in-depth research on the content of carbon finance, we can draw the following main conclusions: Carbon finance is an important economic tool to cope with climate change, and its development is of great significance to achieving greenhouse gas emission reduction targets; the development of carbon finance requires policy support, technological innovation and the joint efforts of market participants; the future development trend of carbon finance will mainly focus on product innovation, market integration, and technology application. In order to promote the healthy development of carbon finance, the following policy recommendations are proposed: First, strengthen the research and formulation of carbon finance policy to improve the scientific nature and operability of the policy; second, promote the internationalization and integration of the carbon finance market to improve market efficiency and transparency; third, promote the innovation and application of carbon finance technology to enhance the competitiveness of the carbon finance market.

Carbon finance will play an increasingly important role in the global economy. It will not only contribute to the development of a low-carbon economy but will also become an important economic tool for achieving global greenhouse gas emission reduction targets. With the continued development and improvement of the carbon finance market, its status and influence in the global economy will continue to grow.

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The New Silk Route for Chinese Foreign Investment

Adelina Quintero Sánchez and Pastora Melgar Manzanilla

Abstract

The Belt and Road Initiative (BRI) is more than just a massive cooperation project; it is a geoeconomic initiative designed to secure China's position as a global power while advancing its path of expansion and dominance through economic strength, with its multinational corporations as the driving force. To achieve this, it requires the establishment of norms, rules, and procedures for foreign investment that align with its strategic interests. Since the 1978 reforms under Deng Xiaoping, China has been steadily pursuing this goal through the negotiation and signing of international investment agreements.

Keywords: foreign investment, BRI, china, BIT, TIP, international investment regime

1. Introduction

A decade after Xi Jinping's government announced the Belt and Road Initiative, significant progress has been made on many of China's projects and objectives, despite nearly insuperable challenges such as the COVID-19 pandemic. Foreign investment is no exception. The initiative was introduced as a series of large-scale projects aimed at enhancing connectivity, boosting trade, and fostering international cooperation, inspired by the spirit of the historic Silk Road that once facilitated commerce between Asia and Europe via Central Asia.

What remains unsaid in China's official rhetoric is that, alongside the advancement of the Belt and Road projects, a parallel route for foreign investment has been steadily constructed. This involves the establishment of a regulatory framework through bilateral investment agreements and trade treaties with foreign investment chapters. This investment route is supported by the development of norms, rules, and procedures, effectively creating an international regime derived from bilateral investment treaties and Treaties with Investment Provisions signed with nearly all partners of the initiative.

Unlike the prevailing international investment regime primarily shaped by the United States, China's approach lacks uniformity. Instead, it operates under two distinct models: one that enhances the existing framework and another, more moderate, which mirrors the European investment treaty model predating the U.S. approach. The choice of model depends on the partner country or region and China's geostrategic interests, whether extracting natural resources, expanding markets, developing expertise, or pursuing a combination of these goals.

China's Bilateral Investment Treaty (BIT) model has evolved through various stages, reflecting its historical and international context, economic conditions, and the growing strength of its multinational corporations. The BRI represents a turning point in this evolution, serving as a global geoeconomic project that positions China as a pivotal player in capital flows while addressing its expansion needs.

In recent years, China has emerged as one of the world's leading sources and recipients of foreign investment, as well as its largest producer. This necessitates access to raw materials, ideas, and markets beyond its borders, supported by a robust foreign investment regime. Since adopting the market socialism model under Deng Xiaoping, China has steadily advanced its international investment agreements to pave the way for the BRI.

The primary aim of this study is to identify the existence of a Chinese investment route within the BRI framework and analyze its features to understand China's geoeconomic interests and the role of its counterpart nations.

The research hypothesis suggests that since the 1978 reforms and the adoption of China's new economic system, the country has pursued a path to global hegemony through a soft power economic strategy. This strategy relies on the liberalization, protection, and promotion of foreign investment as critical elements. To achieve this, China has had to reshape international regimes to align with its interests, with the BRI serving as a cornerstone for this effort. The BRI enables the creation of a foreign investment route by establishing China's own regulatory and protective framework for its investments and companies, utilizing a "hybrid" model that blends elements of the European and U.S. approaches

2. From market socialism to the new silk road

Since the 1978 reforms under Deng Xiaoping, China has radically transformed its economic model, as well as its vision and strategy for foreign investment—both domestically and, more importantly, internationally. As a result, China has shifted from being an isolated player in the dominant international economic regimes to becoming a highly active participant, now even creating its own international foreign investment framework.

It was during Deng Xiaoping's government, through the famous "Four Modernizations," that China definitively broke with remnants of Maoism to radically restructure its economic model by adopting what is known as market socialism.

Historically, 1978 marked a turning point when the Chinese Communist Party, led by Deng Xiaoping, introduced the Four Modernizations policy: industry, agriculture, science and technology, and national defense, listed in order of priority [1]. These reforms initiated a market-opening strategy aimed at revitalizing socialism and adapting it to the demands of the historical moment. China's transition from a centrally planned economy to a more open one has been distinctly different from the transitions undertaken in Eastern Europe and Russia, which adopted more Western-style market economies and transitioned rapidly. China, on the other hand, resisted deep political reforms and charted its own gradual course to restructure its socialist economic institutions—what Deng Xiaoping famously described as crossing the river by feeling the stones [2].

The economic reforms carried out between 1978 and 1989 formed the core of this transition [3]. However, this process remains incomplete and has arguably entered a new phase with the Belt and Road Initiative (BRI). It is important to note that

although China never ceased to identify as socialist, it officially adopted the designation of a “socialist market economy” in 1992 [4], creating a hybrid system that blends elements of capitalism and socialism.

The New Silk Road represents a second phase of China’s opening to the global economy—one far more ambitious than the first. This phase aims not only to expand China’s global presence but also to reshape international economic regimes to align with its interests. Foreign investment plays a crucial role in this effort, as transnational corporations are the primary vehicle for the entire initiative.

According to scholar Shirley Yu, the New Silk Road aspires to reconfigure the international system on a scale comparable to the post-World War II restructuring led by the United States. This highlights the critical importance of investment rules [5]. After two global conflicts and a fractured international system, the U.S. leveraged the unprecedented institutional framework of the United Nations (UN) to create new international norms for the most significant aspects of the global system. This reestablished international relations and positioned the U.S. as the hegemonic power. Similarly, just as the Bretton Woods institutions, the International Monetary Fund (IMF) and the International Bank for Reconstruction and Development (IBRD)—the precursor to the World Bank—along with the General Agreement on Tariffs and Trade (GATT) established postwar regimes for finance, trade, and investment [6], China is now building its own frameworks through the BRI.

The term “Silk Road,” coined by German geographer Ferdinand von Richthofen to describe the network of trade routes connecting China with Europe through Central Asia and the Middle East [7], became a global symbol of intercontinental connectivity. The New Silk Road draws inspiration from this historic route, aiming to expand Chinese trade globally and promote its products, among other objectives [8] (Xinru Liu). However, the modern initiative is rooted in the presence of Chinese transnational corporations, which require rules to facilitate their entry, establishment, operation, and resource extraction in a secure and unimpeded manner.

The New Silk Road initiative, or the Belt and Road Initiative, far surpasses its historical predecessor by encompassing nearly all continents and including maritime routes alongside overland pathways. This makes it the most ambitious international geoeconomic project of recent decades, both in scope and implications, led by a single nation. To date, the Chinese mega-initiative spans Eurasia, Africa, and Latin America. It involves not only cooperative and infrastructure projects—ranging from roads, ports, and airports to economic corridors and industrial parks—but also an extensive regulatory framework for opening markets to Chinese trade and investment. This regulatory aspect, while relatively understated in Chinese leaders’ rhetoric, deserves greater scrutiny and reflection, especially by developing countries.

The Belt and Road Initiative, announced in 2013 through speeches by President Xi Jinping in Kazakhstan and Indonesia, encompasses both domestic and international components. Domestically, it seeks to connect China’s regions more effectively through enhanced road and rail networks, which in turn integrate resources and markets to project them outward. Internationally, it aims to establish an economic belt alongside the Silk Road and a twenty-first-century Maritime Silk Road.

The economic belt seeks to connect Europe, the Middle East, and Asia through a multimodal network of infrastructure projects that enable the free flow of trade and people. This includes the construction of a terrestrial economic corridor along the Silk Road, stretching from China’s northeastern coastal regions through Central Asia and the Middle East to Europe. The Maritime Silk Road focuses on expanding maritime routes to improve connectivity across South Asia, East Asia, the Middle East, and

Africa [9, 10]. The BRI outlines five priorities: policy coordination, infrastructure connectivity, unimpeded trade, financial integration, and closer people-to-people ties (with information connectivity added later) [11].

Over a decade into its implementation, as noted by Xi Jinping during the opening ceremony of the Third Belt and Road Forum for International Cooperation in 2023 “Belt and Road international cooperation has gotten off the ground, grown rapidly, and produced fruitful outcomes.” He also noted that the BRI has made significant progress “covering the land, the ocean, the sky, and the Internet, this network has boosted the flow of goods, capital, technologies, and human resources among countries involved and injected fresh vitality into the millennia-old Silk Road in the new era” [12].

In summary, the BRI represents China’s next step towards asserting its dominance within its natural sphere of influence in the Asia-Pacific region and expanding its economic ties across the globe.

3. The Chinese hybrid regime for foreign investment: Between the American and European models

For several years, China has been a key player in global trade and investment flows, as well as in global production chains. This is a direct result of a long-term governmental strategy that began with the reforms of the late 1970s, as discussed earlier.

Specifically in the realm of foreign investment, China has undergone profound transformation as part of its market socialism model. This shift involved a change in official discourse, a gradual relaxation of entry regulations for foreign investors within China, and the adoption and expansion of international foreign investment frameworks abroad.

Domestically, China’s foreign investment policies have become more flexible in recent years, but they remain restrictive. The country has opened its markets incrementally—starting with special economic zones and then expanding to other regions and specific sectors. However, this process has been carefully controlled to maintain state dominance and enforce performance requirements, as reflected in current regulations. China’s Foreign Investment Law of the People’s Republic of China (2021) [13] is built on two main pillars: the promotion and protection of foreign investment. This framework aligns more closely with the traditional European Bilateral Investment Treaty (BIT) model than with the American approach.

The internal economic shift was accompanied by a reformulation of China’s foreign policy. The country transitioned from a largely domestic focus to an active international presence, strengthening its role in global organizations and building relationships with countries worldwide through numerous trade and investment agreements. Landmark moments, such as China’s accession to the World Trade Organization (WTO) in 2001 and its signing of numerous bilateral free trade and investment agreements, have solidified its position on the global geoeconomic stage. Emerging from temporary isolation, China has returned to its historical role as an influential empire, now cloaked in soft power and economic leadership.

China’s outward-facing foreign investment regulations have evolved in tandem with historical contexts, domestic economic conditions, and the development of its corporations’ capacity to compete internationally. Beginning with the reforms of 1979, China started signing BITs and Treaties with Investment Provisions (TIPs). In fact, China’s program for international investment agreements was launched in 1982

with the signing of its first bilateral investment treaty with Sweden. This marked the beginning of China's first generation of foreign investment agreements as part of its initial foray into the international foreign investment regime.

China's first-generation BITs adhered to the classical European model [14]. These agreements were cautious, focusing more on promoting investment than on protecting or liberalizing it. For instance, the national treatment clause was rarely included, and investor-state dispute settlement mechanisms were generally excluded, except in cases of unlawful expropriation. At the time, China was a net capital importer and avoided mechanisms that could compromise its sovereignty over foreign investments.

During the initial phase, China's agreements were signed slowly, limited to European countries, such as Germany, France, BLEU (Belgium-Luxembourg Economic Union), Finland, Norway, Italy, Denmark, the Netherlands, Austria, Switzerland, and the United Kingdom. However, as China gained familiarity with international instruments, the pace of negotiation, signing, and ratification of these treaties accelerated. Between 1988 and 1998, over 60 BITs were signed, primarily with developing countries, especially in Eastern Europe and Asia—geographically proximate regions [15]. Examples include agreements with Poland, Slovakia, Czechia, Pakistan, Turkmenistan, Uzbekistan, Kyrgyzstan, Kazakhstan, Tajikistan, Vietnam, Mongolia, Laos, Moldova, South Korea, Russia, Belarus, and Armenia. Notably, agreements were also signed with all Central Asian countries, the historical heart of the Silk Road. China also extended its reach to Latin America during this period, signing BITs with Bolivia, Uruguay, Argentina, Ecuador, Chile, Peru, and Cuba, while showing less interest in Africa, where only three agreements were signed (Ghana, Egypt, and Nigeria).

The second phase of China's outward foreign investment regulation began in 2000 with the going out strategy, which had two main objectives: first, to create an internal regulatory framework that would enhance the global competitiveness of Chinese firms by building a network to secure access to vital resources, including know-how; and second, to promote overseas investments that align with national development goals, such as boosting exports, acquiring natural resources, and advancing technological capabilities [16]. The strategy emerged from a favorable domestic context in which the government determined that Chinese firms were ready to "go global." While the strategy prioritized exhausting domestic courts for investor-state disputes, it significantly expanded the scope of disputes eligible for international arbitration. Between 1998 and 2008, China's investment agreements increasingly mirrored the American model rather than the classical European approach.

Geopolitically, this second phase was closely tied to the pursuit of natural resources. The rapid growth of China's GDP, driven by its industrial production boom in the early 2000s, required vast quantities of raw materials. Consequently, BITs were signed with a strong presence in Africa and the Middle East—regions critical for China's oil supply. African agreements include those with Zimbabwe, Zambia, Algeria, Syria, Gabon, Cameroon, Congo, South Africa, Ethiopia, Botswana, Sierra Leone, Mozambique, Kenya, Côte d'Ivoire, Uganda, and Namibia. In the Middle East, agreements were signed with Yemen, Sudan, Qatar, Bahrain, Iran, and Brunei.

The third phase of China's foreign investment regulation began with the launch of the BRI in 2009. This phase reflects China's role as a global leader in both the inflow and outflow of foreign investment [17]. From 2009 onward, China has adopted differentiated investment agreements depending on its counterparts. For other continents, it often uses the American model, focusing on protection and liberalization, while for neighboring Asian countries, it adopts a more balanced approach.

Examples of BITs following the American model—prioritizing protection and liberalization with neoliberal rules and minimal mechanisms for technology transfer or workforce training—include agreements with Costa Rica, Mexico, Colombia, Mali, the Bahamas, Libya, the Democratic Republic of the Congo, Chad, Tanzania, and Angola (signed in 2023). Similarly structured TIPs include agreements like the China-Peru FTA (Free Trade Agreement) (2009), China-Costa Rica FTA (2010), Chile-China FTA Investment Agreement (2012), Cambodia-China FTA (2020), China-Ecuador FTA (2023), China-Nicaragua FTA (2023), and China-Serbia FTA (2023). In contrast, agreements resembling the traditional European model—emphasizing investment promotion with less stringent protection—include the China-Malta BIT (2009), China-Switzerland BIT (2009), ASEAN-China Investment Agreement (2009), and Regional Comprehensive Economic Partnership (RCEP) (2020).

Since Deng Xiaoping introduced the pragmatic market socialism model, China has undergone a remarkable transformation, evolving from a closed economy with limited participation in international regimes to a global powerhouse with significant influence over the international agenda, particularly in crafting norms, rules, and procedures for foreign investment.

4. The silk road initiative and foreign investment

The concept and groundwork for what would later be launched as the BRI began long before its official announcement. In 1994, Premier Li Peng referred to a new Silk Road as part of an economic cooperation project, and subsequent Chinese presidents Jiang Zemin and Hu Jintao reiterated the idea [18]. However, the difference with Xi Jinping's formal proposal lies in its holistic and global scope. More than just promoting trade, the initiative aims to create a pathway for the internationalization of Chinese enterprises—essentially, a framework for foreign investment.

Foreign investment has become a main pillar of the BRI, integral to China's foreign policy and the global positioning of its multinational corporations. Over the years, China has emerged as one of the leading recipients and sources of foreign capital flows [19–24].

In 2023, China ranked as the second-largest recipient of global investments, following only the United States, attracting 21% of worldwide investment. It also became the third-largest investor globally, behind the U.S. and Japan [24]. This growth is part of a broader geopolitical investment strategy aimed at securing raw materials, expanding global markets for Chinese goods, and acquiring scientific and technological advancements from leading innovation hubs.

China's outward foreign investment has seen remarkable growth, increasing from \$7 billion in 2001 to \$101 billion in 2013, \$116 billion in 2014, and \$130 billion in 2018 [19, 25]. Chinese multinational corporations have dramatically expanded their global presence. For example, in 2011, China invested \$60 billion in non-financial sectors and established 3391 foreign enterprises across 123 countries and regions [26]. By the end of 2012, 16,000 Chinese multinational corporations had established approximately 22,000 subsidiaries in 179 countries and territories [16]. From 2005 to 2015, the total value of Chinese outward investments surpassed \$1.2 trillion [27]. By 2017, according to Rui Torres Oliveira, Jane Menzies, Daniel Borgia, and Sandra Figueira, Chinese investments could already be considered a global phenomenon [28].

According to the Ministry of Commerce of the People's Republic of China (MOFCOM), between January and November 2020, Chinese enterprises made

non-financial direct investments totaling 110.68 billion yuan in 57 Belt and Road countries—a year-over-year increase of 25.7% (equivalent to \$15.96 billion, a 24.9% increase). These investments represented 16.3% of China's total outbound investments during the same period, a 3.6 percentage point increase compared to the previous year. The primary destinations were Singapore, Indonesia, Vietnam, Laos, Malaysia, Cambodia, Thailand, the United Arab Emirates, Kazakhstan, and Israel [29].

Compared to 2022, the number of new projects initiated under the BRI nearly doubled in 2023, rebounding after a slowdown during the pandemic. Most of these projects were concentrated in Southeast Asia and focused on high-value-added manufacturing, including computers, electronic equipment, transportation, and motor vehicles [24].

Notably, just a few decades ago, Chinese companies were absent from international rankings of the largest multinational corporations. Today, China boasts 133 companies on the 2024 Fortune Global 500 list, compared to 129 in 2019. These companies are among the largest globally by revenue, trailing only the U.S., which has 139 companies on the list. For the first time since 2018, the U.S. surpassed China in this ranking. Three Chinese firms are ranked in the top ten: State Grid at 3rd, Sinopec Group at 5th, and China National Petroleum at 6th [30]. These companies, focused on natural resource extraction, highlight the central role of Chinese multinationals in foreign investment, resource acquisition, and market expansion.

MOFCOM, UNCTAD (United Nations Conference on Trade and Development), and Fortune all indicate that infrastructure projects, which are crucial to the so-called “virtuous cycle of investment,” are primarily concentrated in Asia—China's sphere of influence and the historical Silk Road route. Similarly, BITs and TIPs favoring investment promotion are also prevalent in this region. This aligns with Dunning's classification of foreign investment motivations: the extraction of raw materials, market expansion, or efficiency gains (including technological advancement). Often, these objectives overlap [31]. Chinese investments abroad reflect diverse motivations, such as acquiring natural resources (primarily in Africa, Oceania, and Latin America), expanding markets (in Africa, Latin America, and Asia), and pursuing technology and know-how (in North America, Europe, and Asia).

China's investment agreements follow the same logic. In regions or countries where the goal is merely to secure natural resources or expand basic markets, China signs BITs or TIPs modeled after the American approach. These agreements prioritize liberalizing market access for foreign companies and maximizing protections for multinational corporations. Key provisions include national treatment, most-favored-nation status, prohibitions in expropriation or equivalent measures, restrictions on performance requirements, digital trade regulations, access to government procurement, and unrestricted investor-state dispute mechanisms. In contrast, regions where China seeks to develop know-how or open markets for high-value-added products are governed by European-style agreements. These include limited and conditional dispute resolution mechanisms, technology transfer promotion, support for small and medium-sized enterprises, and emphasis on corporate social responsibility or compliance measures.

As Xi Jinping stated: “China will establish pilot zones for Silk Road e-commerce cooperation, enter into free trade agreements and investment protection treaties with more countries. We will remove all restrictions on foreign investment access in the manufacturing sector. In light of international high-standard economic and trade rules, we will further advance high-standard opening up in cross-border service trade and investment, expand market access for digital and other products, and deepen

reform in areas including the state-owned enterprises, digital economy, intellectual property, and government procurement” [12].

In sum, the Silk Road initiative has been accompanied by a parallel investment route for Chinese multinational corporations. This route now spans to 150 of the 194 United Nations-recognized countries and includes 30 international organizations that have signed cooperation agreements under the BRI. China currently has 146 bilateral investment treaties, 108 of which are in force, and 21 TIPs, meaning that most BRI member countries are covered by investment regulations. According to UNCTAD, only one such agreement was signed in the past 3 years—with Angola in December 2023. This does not signal declining interest but rather suggests that China has reached a point where few potential partners remain without an investment agreement.

All these norms, rules, and procedures embedded within these agreements form an international foreign investment regime consistent with Krasner’s concept [32]. However, this regime differs from the prevailing neoliberal model, in that it is not homogeneous in its content.

Some second-generation BITs are now being restructured to align with China’s investment regime for developing countries outside its sphere of influence. For example, the renegotiation and update of the 2009 Free Trade Agreement between China and Peru began in 2018 and concluded in June 2024. According to MOFCOM, this agreement “optimizes seven existing provisions, including rules of origin, customs procedures and trade facilitation, sanitary and phytosanitary measures, intellectual property rights, trade in services, temporary entry of business personnel, and investment. Five new provisions are added: standards and conformity assessment cooperation, competition policy, e-commerce, global supply chains, and environment and trade” [33].

China’s position regarding the dominant neoliberal foreign investment regime is ambivalent. It avoids the radical strategies adopted by some developing nations like Bolivia, Venezuela, and South Africa, while also diverging from the current trend identified in UNCTAD’s World Investment Report 2024, which favors policies and agreements promoting investment. Instead, China takes a *sui generis* approach. It has both replicated and refined the formula developed by the U.S. with NAFTA (North American Free Trade Agreement), which successfully integrated foreign investment with trade and numerous complementary provisions to protect multinational corporations. Simultaneously, China has revived more traditional European regulatory frameworks, applying them strategically within its natural sphere of influence to foster more productive foreign investment aligned with development goals.

5. Conclusions

China’s strategy for investment abroad is part of a long-term geopolitical and geoeconomic vision, which seeks the best positioning of the country by first consolidating itself in its natural zone of influence, Southeast Asia, to later achieve global leadership based on economic power, supported by military and ideological power. In this scheme, recently, the BRI has become the backbone of the institutional, regulatory, and infrastructure scaffolding of Chinese growth and development; however, the path had already been prepared long before and this included the design of the Silk Road for investment.

It was after the reforms of 1979, with the drastic change in the economic model and the opening of the Asian giant to the outside, that the accelerated Chinese

economic growth was triggered, placing the nation as one of the new emerging economies part of the BRICS and turning it into a regional leader and the so-called world factory. However, this also meant an extensive use of natural resources and labor, which its vast territory could not cover, not even through imports, so the only way to obtain more territories, resources, human capital, and technological innovation was the establishment of companies in other countries, that is, foreign investment. Hence, BITs and TIPs began to be signed and in less than five decades, China had already become the second country with the most BITs in force, only behind Germany and had gone from being a participant in the prevailing international investment regime, essentially built by the United States with the support of the European Union, to beginning to create its own version of the same and competing with these leaders for attraction and placement of investments.

Specifically, the Chinese program for international investment agreements was born since 1982, but has become much more dynamic in the last 15 years thanks to the BRI, in correspondence with the evolution of Chinese foreign policy towards foreign investment. In fact, China has gradually become a nation that not only imports, but also exports capital, which requires creating a protection framework for its investments, which means companies abroad.

International investment agreements constitute essential instruments for the Chinese strategy of creating the New Silk Road for foreign investment, whether in its bilateral version, that is, BITs, or as chapters within the broader free trade agreements, TIPs. Hence, China has gone from being a country completely on the sidelines to the international foreign investment regime, with no agreement signed in this area until the end of the 1970s, to a country extremely active in the construction of guidelines for foreign capital, in direct competition with the United States and the European Union.

The Chinese BITs and TIPs differ from the traditional ones by not having a single structure, but rather they have two models that respond to a dual purpose. On the one hand, in the Southeast Asian region they seek to build regional integration from below, that is, not in the Western way through the signing of government instruments that evolve in the different stages of integration such as the European Union, but through the integration of business networks from below; and on the other hand, towards non-Asian regions, it does not seek to promote sustainable economic associations; rather, its purpose is to open the economies of the countries to their companies and have regulations to protect themselves against any action by the hosts against them.

In the long run, all these international regulatory instruments for foreign investment generated by China are inserted into a larger geostrategy that aims to expand its hegemony at a global level. So the Chinese strategy, while responding and adapting to the conditions of the contemporary geopolitical situation and therefore, to the existing tensions between the main poles of power, at the same time affects the generation of local, regional, and global geopolitical conflicts. The more power China gains and, therefore, expands its influence towards different areas of the world economy, the more it produces clashes with the interests of other actors and their respective international regimes. Specifically, with regard to the international investment regime, the main confrontation that occurs is with the United States and secondarily, with the European Union, since while these actors share fairly similar investment strategies that converge with the preexisting international regime for foreign investment, Chinese actions do not match. Thus, the new Chinese investment route has differentiated effects; while in East Asia it is helping to consolidate the region with strategic alliances and beneficial exchanges for the participating parties, in other geographical

areas, far from generating harmony with the dominant powers, they are creating confrontations, since they compete for the same spaces and resources. In the case of the United States, beyond the trade war, the fight is for raw materials in Latin America and Africa; while in the European Union, the confrontation with China takes place over hydrocarbons and water in Eastern Europe, Central Asia, and the Caucasus.

The complex and intricate global geoeconomic situation, which focuses on the securing of resources and alliances by the great powers, where China is advancing rapidly, implies great risks not only for the participating actors, but for the system itself. The main interest of the current Chinese strategy for the international regulation of foreign investment is to sustain Chinese exponential growth, which requires the constant extraction of an exorbitant amount of natural resources. However, this excessive growth cannot be sustainable in the long term and can lead to the collapse of the environment and the capitalist consumption system. Furthermore, the Chinese model for regulating investment does not have environmental or sustainable development considerations that try to promote responsible consumption or corporate social responsibility guidelines; unlike the new generation agreements signed by the United States and the European Union, they include very sophisticated sections for the environment and corporate compliance and are aligned with the Sustainable Development Goals (SDGs) of the 2030 Agenda.

Finally, it is necessary to point out that the BRI has not yet reached its zenith, but it has taken great steps towards its consolidation and since the new Silk Road is one of its main pillars that has large transnational companies as its driving force, the need for a deep geopolitical analysis of its implications, characteristics, and challenges is evident, which allows the different international actors to take conscientious actions in this regard.

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Section 4

The Digital and Sustainable Transformation Frontier

The Age of Twin Transition: The Case of MENA and Turkey

Canan Ozkan, Yusuf Yildirim and Abdullah Sultan Al Shammre

Abstract

Financial inclusion is defined as the accessibility of financial services without price or non-price barriers. It plays a crucial role in reducing poverty and promoting inclusive growth. Recently, the contemporary landscape of financial inclusion has undergone a paradigm shift due to the twin transition—a simultaneous transition toward digitalization and sustainability. Fintech, particularly mobile banking and digital financial services, has become a pivotal driver of financial inclusion, also enhancing access to finance across the MENA region and Turkey. However, the extent of how financial inclusion and digitalization contribute to sustainability remains underexplored. This chapter investigates the interplay between financial inclusion, Fintech-driven innovation, and sustainability efforts, highlighting key challenges and policy recommendations. Using data from the World Bank Global Findex Database, World Bank Enterprise Survey, and the Global Innovation Index (GII), the chapter assesses financial inclusion landscape and the effectiveness of digital financial technologies. It is argued that fostering an enabling environment for Fintech, coupled with regulatory frameworks that support green finance, might accelerate the twin transition in both MENA and Turkey.

Keywords: twin transition, digital transition, Fintech, sustainability, green finance, financial inclusion, access to finance, regulatory environment

1. Introduction

Financial inclusion ensures that individuals and businesses have access to affordable and useful financial products and services, including payments, savings, remittances, credit, and insurance. It is a key driver of economic growth, reducing inequalities and facilitating social mobility.

In the last decade, the digital revolution, particularly Fintech innovations, has transformed the financial sector, enabling greater accessibility and convenience, specifically for the unbanked. Concurrently, the sustainability agenda has gained momentum, emphasizing the need for climate resilience and green practices. The intersection of these transitions, termed as the “twin transition,” raises critical questions on how digitalization and financial inclusion could contribute to global sustainability, and for our specific purposes to the MENA region and Turkey.

From a digital transition perspective, the widespread adoption of mobile phones has enabled millions in developing economies to gain access to the formal financial

system for the first time. Studies indicate that digital financial services, including mobile money and electronic payments, significantly enhance economic participation and social well-being. For instance, the authors of [1] argues that in Kenya, access to mobile money services enabled women-headed households to increase their savings by more than a fifth, allowed 185,000 women to leave farming and develop business or retail activities, and helped reduce extreme poverty among women-headed households by 22%. Another benefit of financial inclusion is for governments. Switching from cash to digital governmental payments can reduce corruption and improve efficiency, decreasing informal financial transactions. Moreover, digital financial services are able to lower cost of making and receiving payments, *via* peer-to-peer lending, eliminating intermediaries and validators such as credit card authorizers. All these benefits are expected to pave the way to create an all-inclusive financial system around the world.

From a green transition perspective, we acknowledge the fact that global sustainability agenda is strongly interrelated with digital inclusion and financial inclusion has close relationship with climate action. This is mainly because of the fact that improved financial inclusion supports individual businesses to invest in environmentally friendly technologies and practices. For instance, microfinance helps smallholder farmers to implement climate adaptation projects and adopt eco-friendly farming techniques that promote sustainable agriculture, such as organic farming or water-efficient irrigation system [2].

In our study, we start with evaluating the current state of financial inclusion in MENA and Turkey. Second, we analyze the role of Fintech in enhancing financial inclusion. Third, we examine some indicators regarding the overall innovativeness of MENA and Turkey, stressing the fact that innovation might support digital transition. Fourth, we evaluate the green transition landscape of both regions, and discuss how financial inclusion and digitalization might drive sustainability. Fifth, we propose policy measures to enhance financial inclusion and increase green finance in both MENA and Turkey. Finally, we conclude.

2. Financial inclusion landscape in MENA countries and Turkey

Access to finance allows individuals and businesses to use financial services in everything from day-to-day living to long-term plans and thus has an important role in helping people build better lives. Based on a global survey applied to 128,000 randomly selected adults in 123 different economies, the World Bank Global Findex [3] Report emphasizes the recent increase in account penetration levels worldwide. Being a major indicator of financial inclusion, account penetration is the proportion of adults (age 15+) who have an account at a bank or another type of financial institution or with a mobile money provider. Account penetration worldwide has been 51, 62, 69, and 76% in 2011, 2014, 2017, and 2021, respectively. As seen from the numbers, there is a 50% increase in global account penetration levels in the 10 years spanning from 2011 to 2021.

While the increase in account ownership was concentrated in financial institutions in most regions, recent penetration levels of mobile money providers also seem striking. Global figures indicate that mobile money account ownership has increased from 2% in 2014 to a 10% in 2021. The increased penetration of mobile money accounts across regions indicates the positive implications of the evolution of new technologies such as Fintech as well as the removal of barriers to financial inclusion.

Despite the increase in account penetration levels worldwide, from 2011 to 2021, there are substantial variations in account ownership among different regions of the

world. For instance, while 96% of adults in high-income OECD economies have an account at a financial institution or with a mobile money provider, the share is only 71% in developing economies. The recent data have also indicated that gender gap in account ownership across developing economies has fallen to 6 percentage points from 9 percentage points. **Figure 1** depicts variations in account ownership across different regions of the world. We note that although 55% of adults in sub-Saharan Africa have an account in a financial institution or with a mobile money provider, the region by far takes the lead in global mobile money account ownership levels, with 33% of adults having a mobile money account.

Shifting our attention to MENA region, it is striking to see that 48% of adults have an account, while most of the accounts (46%) owned are at financial institutions (**Figure 1**). This finding implies that traditional providers of financial services are preferred to digital providers. In addition, overall account ownership levels are not only below the global average of 76% but also below the average of developing countries, where average account ownership level is 71%. We might also argue that the region has still a long way to achieve digital inclusion, as only 6% of adults have an account with a mobile money service provider. The data excludes high-income countries in the MENA region, in order to make meaningful comparisons. This is because of the fact that the penetration levels of high-income OECD economies are much higher than developing ones, with an average of 96%. Finally, account ownership levels in Turkey are totally in line with world average, with a 74% overall account ownership and 73% financial account ownership. As for mobile account ownership of Turkey, it is 8 percentage points higher than world average. About 18% of adults in Turkey have a mobile money account. Thanks to its young and dynamic population, digital inclusion in Turkey has witnessed recent positive improvements.

Furthermore, there is substantial variation in the mobile money account ownership levels of individual countries within MENA region. Utilizing available data, **Figure 2** depicts mobile money account ownership levels of selected MENA countries. On average, while 13, 12, and 10% of adults in United Arab Emirates, Iran, and Jordan, respectively, have an account with a mobile money provider, the share is only 6, 5, 4, and 3% in Morocco, Iraq, Tunisia, and Egypt respectively. As for Turkey, 18% mobile money account ownership proposes a promising potential for the future of Fintech companies in the country (**Figure 2**).

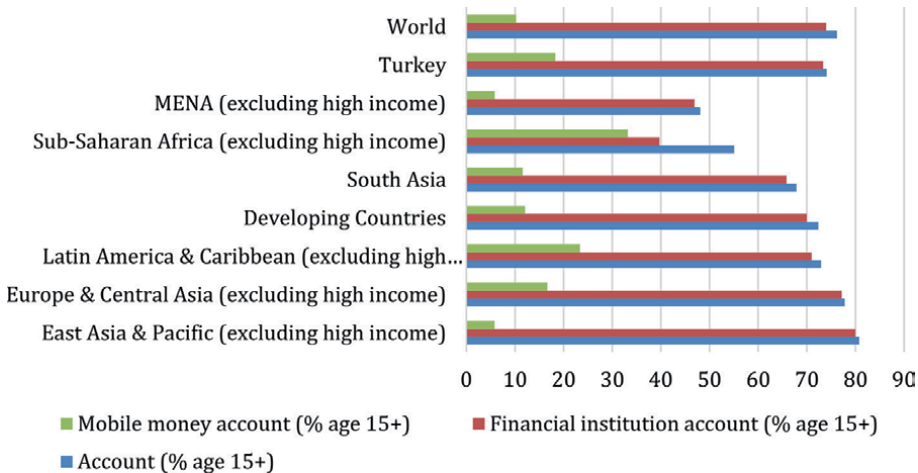


Figure 1. Account Penetration by Region (Adults with an account, %). Source: World Bank Global Findex Database [3].

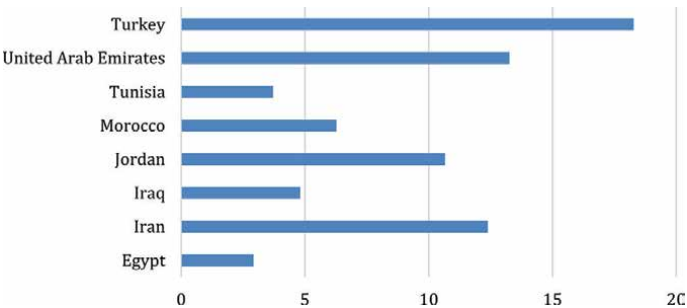


Figure 2.
Mobile Money Account Ownership in MENA Countries (Adults with an account, %). Source: World Bank Global Findex Database [3].

Despite the stated variations above, mobile money account ownership is much higher in developing countries compared to high-income OECD economies. This finding persuasively indicates the power of technology to expand access to finance. In fact, millions of people living in less developed regions of the world have gained access to the formal financial system for the first time, *via* the help of mobile phones.

World Bank Global Findex [3] data also reveal that there is a 4% gender gap in global account penetration levels, with a rate of 74% for women and 78% for men. Gender-based account penetration levels also vary by different regions of the world. For instance, account ownership levels are almost similar among men and women in high-income OECD economies, with 97% and 98% respectively. However, in developing countries, there is a 6% gender gap in the account ownership levels, in favor of men. This situation indicates that the global gender gap mostly stems from developing countries. The gender gap is also persistent in MENA countries (excluding high income ones) with a 12% (**Figure 3**).

Unfortunately, in Turkey, there is a significant (22%) gender gap in account penetration levels. The account penetration level is only 63% among females while being 85% among males (**Figure 3**). However, the comparison of 2017 and 2021 Global Findex figures reveals that 29% gender gap has been lowered to 22%, as women’s access to finance has recently been increasing in Turkey. In fact, we see many efforts along the lines of improvement of financial inclusion in Turkey, such as the publication of National Strategy and Action Plans on Financial Access, Financial Literacy and Protection of Financial Consumers [4]. Another effort comes from the Central Bank of Republic of Turkey (CBRT) with a campaign called “Economy for Everyone.” This effort includes

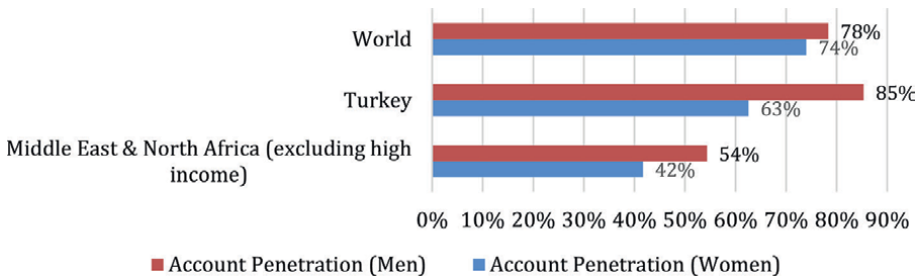


Figure 3.
Account Ownership Level of Men or Women in MENA, World and Turkey (Adults with an account, %). Source: World Bank Global Findex Database [3].

conducting activities in order to increase the financial literacy among various social groups, such as college and primary school students. Improvement of digital inclusion by increased digital financial services would also help women's access to finance.

Having access to a transaction account serves as a first step toward broader financial inclusion since a transaction account is a gateway to other financial services. Despite the recent local and global improvements in account penetration levels between 2011 and 2017, 1.7 billion people worldwide (was 2 billion, based on 2014 data) are still not a part of the financial system. This group is called “unbanked” and includes people who do not have any account or access to financial services in any financial institution or mobile money provider. This excessive number of unbanked people causes the financial inclusion to be one of the major socioeconomic challenges on the agendas of international institutions, policymakers, central banks, financial institutions, governments, and the overall G-20. In order to enable adults to have access to a transaction account or an electronic instrument to store money and send and receive payments in order to manage their financial lives and help to manage risks and escape poverty, World Bank announced the goal of achieving Universal Financial Access (UFA) by 2020. World Bank adopts an approach that focuses on introducing transaction accounts, expanding access points, improving financial literacy, and driving scale and viability through high-volume government programs, such as social transfers into those transaction accounts [5]. The G20 also expresses its interest in promoting financial inclusion in both G20 and non-G20 countries through the Global Partnership for Financial Inclusion (GPFI) initiative. The G20 recognizes financial inclusion as one of the main pillars of the global development agenda, launching its Financial Inclusion Action Plan [6]. There are also some other platforms, which do not directly focus on financial inclusion but indirectly help improving it worldwide. The OECD and its International Network on Financial Education (INFE) might be considered as one of the most influential platforms on this regard. It provides a unique policy forum for governments to exchange views and experiences on the awareness of the importance of financial education [7].

All these facts highlight that financial inclusion remains a pressing issue in MENA and Turkey, with significant disparities in access to financial services. Common challenges for MENA and Turkey include a high reliance on traditional financial institutions and limited access to credit, particularly for SMEs and women-led enterprises. Low mobile money account ownership might be considered as the additional challenge for the MENA region.

3. Fintech and innovation: Catalysts for financial inclusion

The rise of digital financial services has significantly expanded financial inclusion. Mobile banking, peer-to-peer lending, and blockchain-based financial services have transformed the landscape. Digital financial services reduce transaction costs, eliminate the need for physical banking infrastructure, and create alternative lending models through peer-to-peer transactions. Moreover, AI-powered credit scoring improves access to loans for underserved populations. To give an example, Alipay and WeChatPay in China processed almost \$10 trillion worth of transactions in 2017, with 502 million users. Another important aspect is that retailers in 28 countries accept these Fintech solutions [8]. Fintech sector also remains strong in the eyes of investors, even with the increased volatility in global financial markets and ongoing macroeconomic concerns. The growing demand for Fintech innovations is associated not only

with end users but also with banks or other financial services companies as they are faced with increased competition spurred by “Open Banking” from new entrants including Big Techs [9]. This is mainly resulting from the two-sides of the sword. On the one hand, technology start-ups challenge financial institutions by promising their customers faster, cheaper, more convenient, and innovative financial services and reshape the finance industry by changing the way individuals and businesses utilize financial services, including banking services, loans, and credit to individuals or payments. However, on the other hand, there exists a wide-ranging collaboration landscape, which brings traditional and digital financial service providers together and helps overcome costs and the barriers to financial inclusion.

Another phenomenon regarding the Fintech revolution is the distributed ledger technology (DLT), so called as the disintermediation feature of Fintech. DLT has been reducing the need for intermediaries or validators (such as credit card authorizers) and facilitating access to financial services. Disintermediation enables lending without an intermediary and provides products and services directly to end users, mostly through online and mobile channels. Fintech offerings provide solutions to customers who are unserved by traditional financial service providers due to their perceived high risk or lack of credit histories. These peer-to-peer lending platforms, as a result, help these unserved customers access to finance. One other advantage of Fintech is that it can help mitigate risks and deal with asymmetric information at a lower cost than traditional banks. Contrary to the lengthy processes the banks go through in order to assess the creditworthiness of potential customers, peer-to-peer lenders (specifically mobile-based financial service providers) utilize the big data and design products that suit the needs of unbanked adults. In the era of big data, borrowers with a computer or smartphone generate data by anything they do, including e-commerce purchases, the number of connections on social media, or Internet surfing behavior. The information that is gathered allows lenders to assess credit risk of borrowers more efficiently than a bank, increasing transparency and reducing information asymmetry [10]. For example, Zidisha is a crowdfunding platform that allows ordinary web users to lend directly to individual borrowers in developing countries without an intermediary. Kabbage is another example that focuses on online lending for SMEs. Kabbage goes through a wide range of data sources to evaluate the creditworthiness

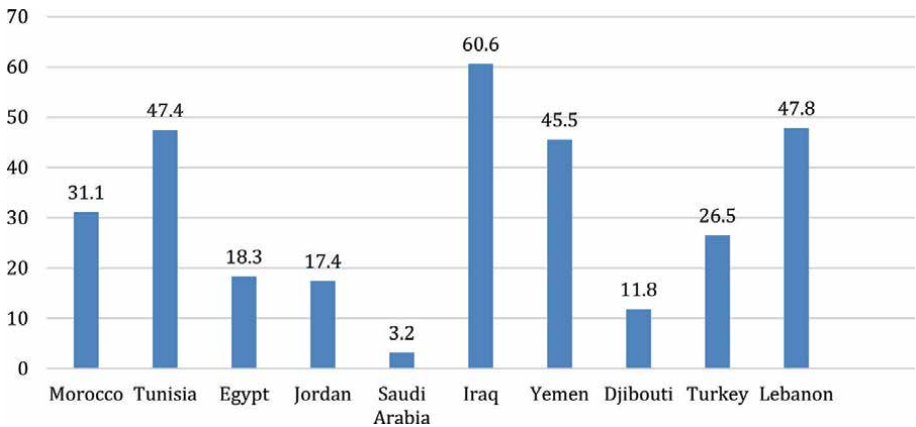


Figure 4. Percentage of Firms in MENA Region, Identifying Access to Finance as a Major Constraint (%). Source: World Bank Enterprise Survey [13].

of a small business applying for a loan [11]. This data-driven approach helps Kabbage reduce risks and mitigate asymmetric information that is a problem faced by lenders offering loans to small businesses [12]. Similar types of online lending platforms for SMEs are quite beneficial for SMEs, as most of the SMEs are having difficulties in access to finance. Based on World Bank Enterprise Survey [13], it is undeniable that a good chunk of small and medium firms identify access to finance as the major constraint. Survey data reveal that access to finance arises as the major constraint, also for the firms in MENA region, specifically for the ones domiciled in Iraq, Lebanon, Tunisia, Yemen, and Morocco (Figure 4). The firms in these countries have a higher degree of difficulty in accessing to finance compared to the ones in Saudi Arabia, where access to finance is not considered as a challenge by firms of any size.

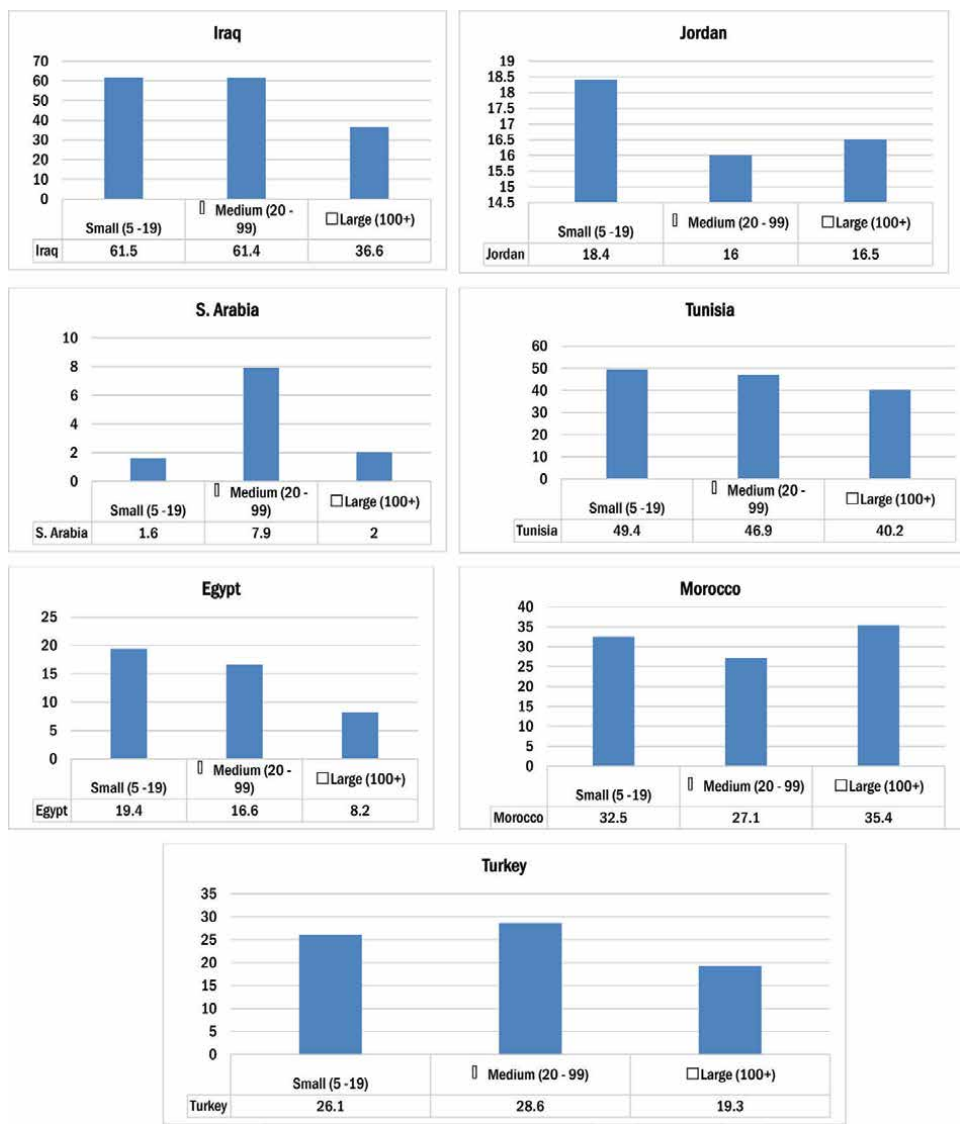


Figure 5.
Access to Finance as a Major Constraint by Different Firm Sizes in Select MENA Countries. Source: World Bank Enterprise Survey [13].

Additionally, country-level data also indicate that access to finance is identified as the major constraint by many of small and medium-sized firms in Iraq, Tunisia, Morocco, Egypt, and Jordan, while in Saudi Arabia, medium-sized firms' access to finance problems are more pronounced than small firms (Figure 5). As for Turkey, the biggest obstacles for SMEs are the tax rates, practices of the informal sector for firms, and cost of electricity, rather than access to finance. However, still, a significant percent of firms domiciled in Turkey also find it hard in accessing to finance.

4. An assessment of innovation landscape for MENA countries and Turkey

In this section, we focus on innovation landscape that could support the Fintech revolution in MENA countries and Turkey. In an attempt to assess the broader innovation landscape, we analyzed the Global Innovation Index (GII), [14] and its subheadings. The lower rankings of GII Index and related sub-indices reveal that innovation is in good stake and supported. Based on the data, Turkey's rankings of GII Index, Innovation Efficiency Ratio, Innovation Input Sub-Index, and Innovation Output Sub-Index are around 50ths and better than the average rankings for the MENA region, which are around 75ths to 80ths (Figure 6).

Checking the details that constitute the GII Index, we conclude that MENA region's rankings are better than those of Turkey in terms of the rule of law, regulatory environment, the availability of venture capital financing, as well as joint venture and strategic alliance deals. In addition, in terms of the criteria under the R&D endeavor such as university-industry collaboration and innovation linkages, MENA's rankings are better than Turkey (Figure 7).

With this said, Turkey is doing better in terms of innovativeness indicators. For instance, the number of patent applications by origin and the percentage of high-tech exports in trade seem more promising in Turkey. High-tech exports offer

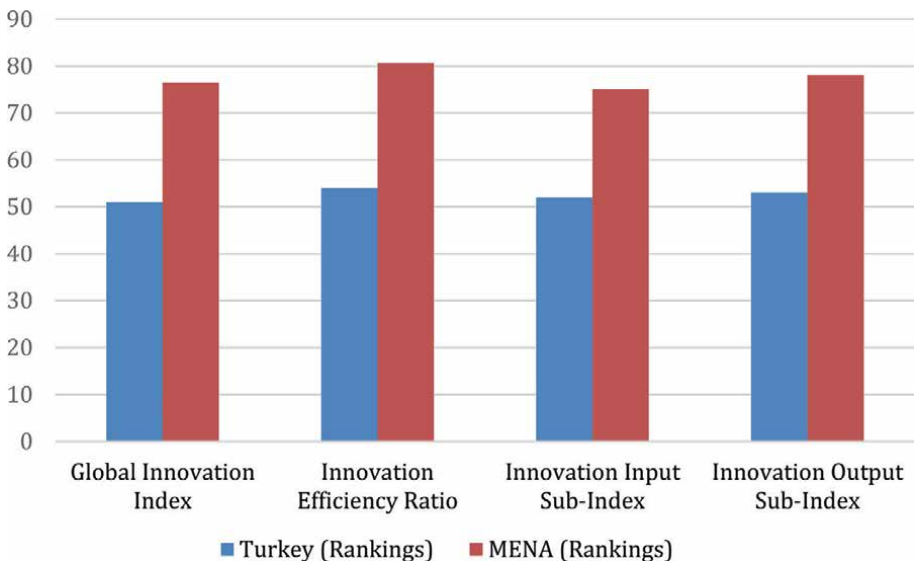


Figure 6.
Average GII Index and Sub-Indices Rankings in MENA Countries and Turkey. Source: Author's own calculations from GII Innovation Index [14].

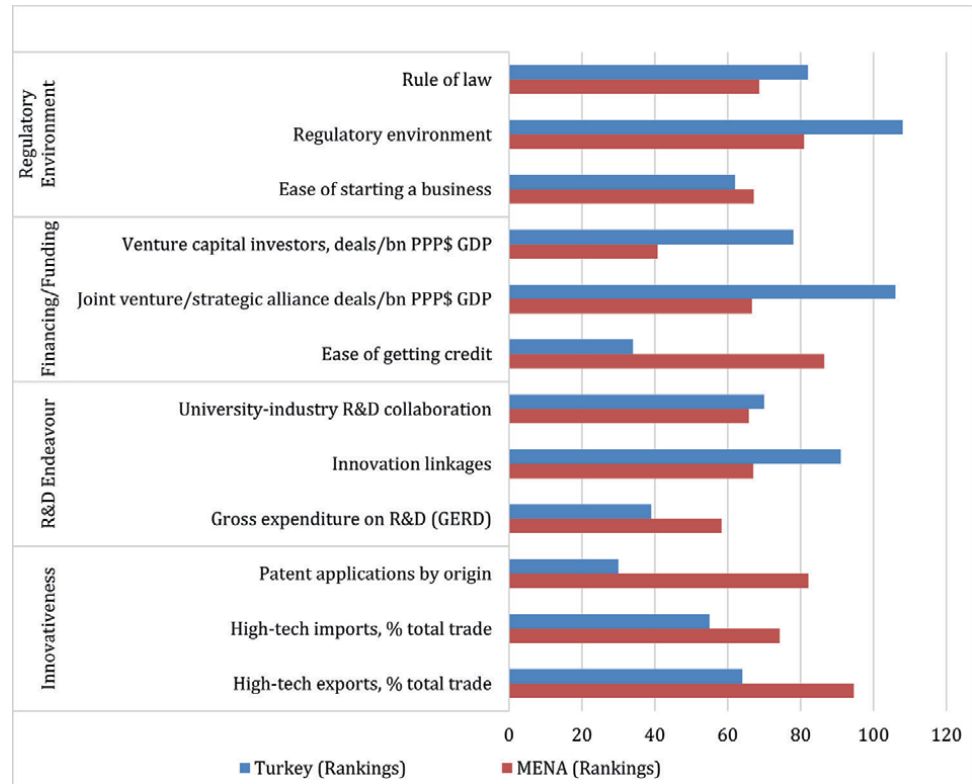


Figure 7.
Average Rankings for Sub-Content of the GII Index. Source: Author's own calculations from GII Innovation Index [14].

great potential thanks to the higher profit margins associated with them. As for the rankings of MENA and Turkey in terms of gross expenditures on R&D, it seems that Turkey is spending more on R&D. Also, businesses find it easier to start a business in Turkey rather than in MENA and have relatively easier access to credit through traditional financiers. However, Turkey needs more improvement regarding the alternative finance channels (such as angel investors, venture capitalists, and PEs) for Fintechs. Fintechs are usually established as start-ups and mostly try to get financing from these alternative channels. To enhance Fintech development, both MENA and Turkey must strengthen alternative financing channels such as venture capital and angel investment networks, which are crucial for supporting digital financial startups.

5. Green transition in MENA countries and Turkey

The energy sector is the largest emitter of greenhouse gases in the MENA region. Despite having vast solar energy potential, renewable energy accounts for only 2% of total consumption in MENA, compared to the global average of 19%. Turkey's renewable energy consumption as a percentage of total final energy consumption is slightly better with 13%, but still lags behind global benchmarks. In terms of accessing to basic needs such as electricity, clean fuels, and technologies for cooking, both MENA and Turkey are doing better than world averages (**Figure 8**).

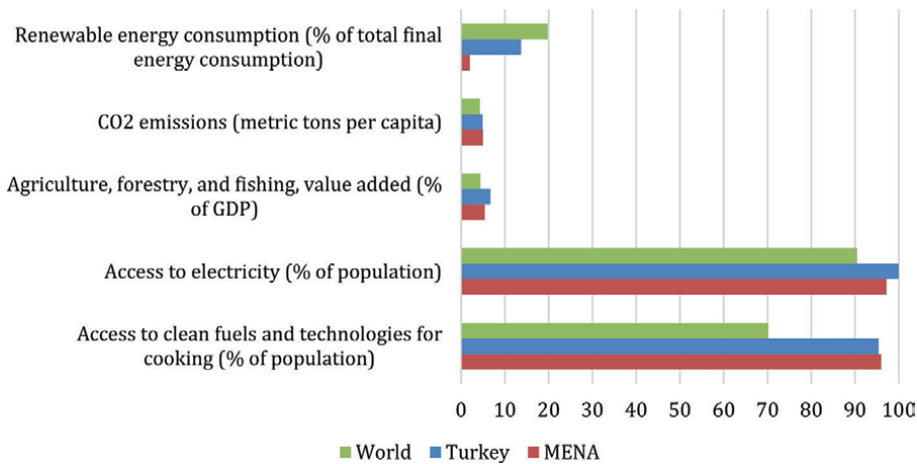


Figure 8.
Various Climate-Related Metrics for MENA, Turkey, and the World. Source: World Bank Sovereign ESG Data Portal [15].

It is also questionable whether or not MENA businesses are ready for green transition. Leveraging on the green economy data of World Bank Enterprise Survey, we find that on average, only 16% of firms domiciled in MENA region have adopted energy management measures to reduce emissions over the last 3 years. This is almost half of the global average figures. Despite that 9% of firms experienced damage of their physical assets due to extreme weather, climate-related monitoring activities are not sufficient enough. For instance, a big chunk of firms (82%) in the region do not yet monitor their CO₂ emissions. The most striking finding is that 60% of the region's population is living in highly water-stressed areas and 19% of firms are experiencing water insufficiencies (**Figure 9**). Thus, water management is another area that needs to be urgently addressed by policymakers.

MENA region, which hosted UN COP28 in UAE in 2023, is also faced with unique challenges and financial barriers in its transition to low-carbon energy. Finance

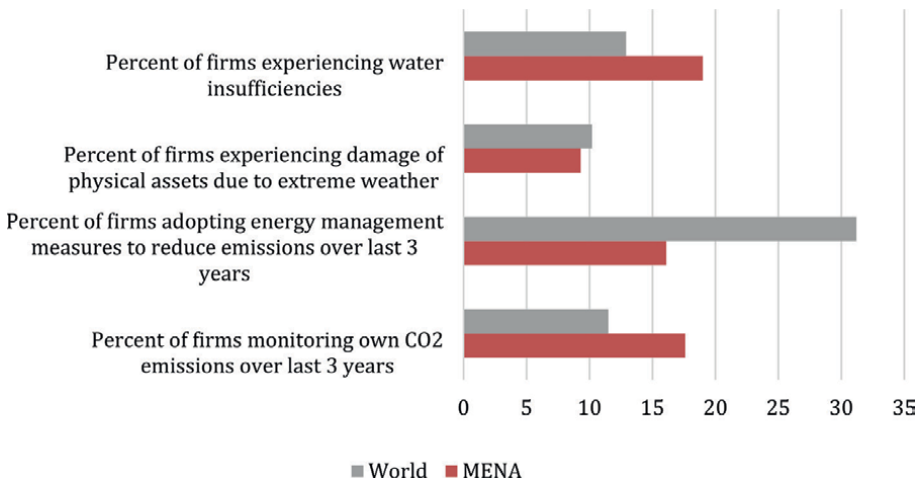


Figure 9.
Climate-Related Monitoring Activities and Adoption of Energy Efficiency Measures in MENA and the World. Source: World Bank Enterprise Survey [13].

remains an obstacle to MENA's green transition. There is a substantial funding gap for the effective implementation of adaptation and mitigation measures, in MENA countries including Egypt, Iraq, Jordan, Mauritania, Morocco, Palestine, Sudan, and Tunisia. Furthermore, there are additional challenges posed to SMEs, by the green transition. For instance, in a recently published study focusing on the risks, opportunities, and expectations in relation to green transition of the SMEs domiciled in Turkey, 40% of SMEs report that they need consultancy, while 39% determine lack of information and advice about financing opportunities as their biggest constraint. Another factor that will provide assistance to SMEs in their green transition is reported to be government incentives and grants, with a 24% response [16].

As a final word, financial inclusion and digitalization might definitely play a pivotal role in advancing sustainable development, by enabling access to green finance, promoting investment in clean technologies, and fostering climate resilience. Fintech platforms facilitate access to green credit, allowing especially small businesses to invest in renewable energy and other sustainable practices. Microfinance services also support climate adaptation by helping farmers adopt climate-resilient agricultural techniques.

6. Policy recommendations for an inclusive and sustainable future

Encouraging green investments requires tax incentives, an expanded green bond market, and increased sustainable sukuk issuance. Additionally, public-private partnerships can play a crucial role in financing climate adaptation projects. Governments should also introduce sustainability-linked lending schemes that encourage businesses to adopt environmentally friendly practices by offering reduced interest rates and providing long-term funds for green projects.

Economic policies in Turkey and Middle Eastern countries should be formulated to foster sustainability by encouraging enterprises to embrace environmentally friendly practices. Tax incentives for environmentally sustainable investments, financial support for renewable energy initiatives, and carbon pricing strategies with free allowances should be employed to motivate enterprises to reduce their carbon emissions. These policies foster a more favorable environment for attaining the Sustainable Development Goals, especially in areas such as climate action (mitigation or adaptation efforts) and sustainable urban development. By incorporating green finance into broader economic policies, these nations should ensure that their economic growth is both inclusive and sustainable.

Moreover, the implementation of inclusive economic policies that facilitate access to credit, financial services, and sustainable technologies for vulnerable communities mitigates inequality while fostering a transition to a green economy. This is especially crucial for underprivileged populations in Turkey and the Middle East, including women and small and medium companies (SMEs), who frequently encounter obstacles in obtaining financial services. Improving financial literacy through targeted programs for women and youth, promoting digital skills training, and facilitating mobile money adoption with regulatory support and incentives are key measures to enhance financial inclusion and digital transformation. Financial institutions should collaborate with educational institutions and NGOs to integrate financial literacy into school curricula and community outreach programs to ensure that financial education reaches all segments of society.

This integrated approach, combining regulatory support and economic incentives, is critical for creating a circular economy in Turkey and Middle Eastern countries,

where resources are reused, waste is minimized, and sustainability is achieved. Through green finance, these nations are building a financial bridge that supports both financial inclusion and long-term sustainability, ensuring that future economic growth is both inclusive and environmentally conscious.

7. Conclusion

In this study, we assessed financial inclusion indicators for MENA countries and Turkey. We also evaluated the supportiveness of innovation landscape for Fintech developments in these countries. We rely on data from open data repositories, namely, the World Bank Global Findex Database, World Bank Enterprise Survey, and Global Innovation Index (GII).

We find that 48% of adults in MENA countries have an account at a financial institution or with a mobile money provider, while 46% of them have an account at a financial institution. This figure implies that traditional providers of financial services are preferred to alternative providers in MENA region. We might also argue that the region has still a long way to achieve digital inclusion as only 6% of adults have an account with a mobile money service provider. This fact reveals the need for support from policymakers to focus more on the digital inclusion agenda, in an attempt to improve the figures. We argue that digital financial services and Fintech revolution persuasively expand access to and use of financial services, specifically in developing regions of the world.

As for Turkey, account ownership levels are totally in line with world average, with a 74% overall account ownership and 73% financial account ownership. It is striking that 18% of adults in Turkey have a mobile money account. Significantly high level of mobile money account ownership in Turkey proposes a promising potential for the future of Fintech companies in the country. We attribute this high mobile money account penetration to the young demographics of Turkey.

In an attempt to assess the broader innovation landscape in MENA countries, and Turkey, we also analyzed the Global Innovation Index (GII) and the subheadings of GII. Based on the data, Turkey's rankings of GII Index, Innovation Efficiency Ratio, Innovation Input Sub-Index, and Innovation Output Sub-Index are better than the average rankings for the MENA region. In addition, Turkey is doing better in terms of innovativeness indicators. For instance, the number of patent applications by origin and the percentage of high-tech exports in trade seem more promising in Turkey. Also, businesses find it easier to start a business in Turkey rather than in MENA and have relatively easier access to credit through traditional financiers. On the other hand, we also find that MENA region's rankings are better than those of Turkey in terms of rule of law, regulatory environment, the availability of venture capital financing, as well as joint venture and strategic alliance deals.

Leveraging green economy data of World Bank Enterprise Survey, we also assessed the readiness of MENA region and its firms to green transition. Despite the great potential of solar energy, the region is not fully utilizing renewables in its total final consumption. The figures indicate that renewables only account for 2% of total final consumption of overall MENA region, highlighting the need for policy interventions. In fact, we have recently witnessed significant efforts from the governments of high-income MENA countries, such as UAE and Saudi Arabia, to support the solar energy generation. However, the governments of middle-income countries in the region also need to create a more enabling environment, specifically for climate mitigation projects.

Turkey, although doing better in terms of renewable energy consumption, still has missing potential considering the high number of sunny days in the country. Fortunately, in line with its recent “More Domestic, More Renewable” energy strategy, Turkey’s energy policy has given top priority to utilizing renewable energy sources to the maximum extent while decreasing energy import dependency and improving supply security [17].

We also find that only 16% of firms domiciled in MENA region have adopted energy management measures to reduce emissions over the last 3 years. Moreover, a big chunk of firms (82%) in the region do not yet monitor their CO₂ emissions. Thus, climate-related monitoring activities need to be improved to avoid from potential risks and implications of climate change.

To sum up, the twin transition presents both challenges and opportunities for financial inclusion in both MENA and Turkey. While Fintech-driven innovations offer promising solutions to expand access to financial services, structural and regulatory barriers remain. Moreover, financial inclusion can play a crucial role in sustainability by enabling access to green finance and promoting environmentally friendly investments. Policymakers must adopt a multifaceted approach that enhances digital financial infrastructure, fosters green investment, and ensures inclusive economic growth. By implementing targeted policies, MENA and Turkey can effectively leverage the twin transition to drive inclusive and sustainable development.

Notes

The views expressed within are those of the authors and do not reflect the official view of institutions they are affiliated with.

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Unlocking Economic Growth: Digital Customer Experience in Grocery Retail – From Traditional via Unmanned to Humanized Unmanned Supermarkets

*Simon Georg Fauser, Marco Schmäh, Svend Hollensen,
Anna Marie Dyhr Ulrich and Susanne Gretzinger*

Abstract

As grocery retail sales in Europe in 2023 were still below the 2019 (adjusted for inflation) value, many retailers are experimenting with innovative shopping concepts in their search for growth. Among the offline concepts, unmanned stores are increasingly popular. We compare the customer experience of traditional, manned supermarkets with unmanned, digitalized supermarkets. A questionnaire was created for manned and unmanned stores. Participants acted as silent shoppers and answered the questionnaire after their purchase. They evaluated their perceived shopping experience, especially efficiency and repurchase intention. The framework was tested on a sample of consumers living in Germany. Data from 157 silent shoppers were analyzed using majority distribution. The main findings are that unmanned stores are perceived as more efficient than manned stores. Manned stores, however, are associated with a higher repurchase intention. Hence, leveraging both the efficiency of unmanned stores as well as integrating “humanness” has the potential to increase repurchase intention and, finally, to unlock growth in humanized unmanned supermarkets.

Keywords: customer experience, digitalization, services marketing, retailing, Germany

1. Introduction

For the European grocery industry, 2023 was a challenging year. Inflation led consumers to tighten their belts, leading to a drop in volume and significant down trading. As a result, industry growth was significantly below food price inflation. Food price inflation in Europe was 12.8 percent in 2023, while grocery sales grew at a rate of only 8.6 percent. Discounters and private labels benefited from this market

environment and were yet again the winners of the year. While inflation eased significantly over the course of 2023, it was still the dominant factor affecting the industry (Figure 1) [1].

1.1 Economic fundamentals

All outputs of every industry are fundamentally determined by the interplay between the demand side and supply side. While the study on manned and unmanned supermarkets especially targets the demand side (the first part of the chapter), the case study on the Schwarz Group with its different shop formats targets the supply side (the second part of the chapter).

1.1.1 The demand side

The theoretical framework for the demand side is provided in Chapter 2.

1.1.2 The supply side

An economy’s output of goods and services—its GDP—depends on (1) its quantity of inputs, called the factors of production, and (2) its ability to turn inputs into outputs, as represented by the production function [2]. The Cobb-Douglas production

Exhibit 1

Europe’s grocery retail market improved during 2023 as inflation slowed.
EU-5¹ retail sales vs previous year, by quarter, %



¹France, Germany, Italy, Spain, and United Kingdom.
²Changes in prices for food and beverages as collected by national statistics offices. Note that Europanel calculates “prices paid” instead of using official food inflation; thus value growth displayed does not match value growth collected by Europanel.
³Volume change is defined as the change in number of units sold.
⁴Downtrading refers to customers switching to lower-value items.
Source: Europanel (volume and up- and downtrading); Eurostat (inflation)

Figure 1.
Europe’s grocery retail market improved during 2023 [1].

function is very useful in discussing, i.e., the role of technology; hence we use this production function.

$$Y = F(K, L) = AK^\alpha L^{1-\alpha} \tag{1}$$

Where Y is income/output, K is capital input, L is labor input, α measures capital's share of income, and $\alpha - 1$ measures labor's share of income, A measures the productivity of the available technology [2].

We use the Cobb-Douglas production function to illustrate the effects of economic development in chapter two, especially on economic efficiency and implications for the labor market.

1.2 Trends

European CEOs are less pessimistic about market conditions in 2024 compared with 2023. They see eight trends characterizing the retail market of European groceries in 2024 [1]. We indicate the main impact on either supply or demand (**Table 1**).

As we can see from the previous table, trends impact supply and demand, with the supply side being more often affected. Hence, more and more grocery retailers alter and experiment with their business models.

Description of trends	Main impact (supply or demand side)
Cost and margin pressure: #1 concern 70% of surveyed CEOs named addressing cost and margin pressure as a top priority	Supply side
Return of polarization: 1 in 5 consumers in Europe intend to splurge on groceries over the next 3 months, while 45% continue to look for ways to save money	Demand side
Food to go: A wrestling match for a share of the stomach ×2.5 faster growth expected in away-from-home food (~8%) vs. overall grocery (~3%)	Demand side
Sustainability: Progress made, but still a long way to go. Twenty-nine percent of the top 10 retailers have achieved Scope 1 and 2 targets for 2025; however, none of them report progress on Scope 3 targets	Supply side
Online: Liberation from offline: 37% of online shoppers in the UK go to different stores online than offline	Demand side
Retail media: Click here to boost the bottom line. Twenty out of the top thirty European grocers already have an established retail media business	Supply side
Conversational commerce: The next wave of analytics: 6 promising generative artificial intelligence (AI) use cases can unlock 10–20% of the value of advanced analytics and AI	Supply side
Talent: Making retail a career again: 29.4% increase in retail vacancies, up from 1.7% in 2019 to 2.2% in 2023	Supply side

Table 1.
Trends in the European grocery retail market in 2024 and their main impact on supply or demand (own illustration, based on [1]).

1.3 New business models

The mentioned trends and the lack of growth in grocery retail call for what Euromonitor labels “retail reinvention” [3]. Since the mass production of goods became possible during the first industrial revolution, the wholesale business model has been the main way that shoppers bought goods. Retailers became the center of the shopping experience, with the physical store serving as the backdrop. However, the retail sector is not as straightforward anymore. Digitalization caused structural industry shifts and disrupted the buying journey. New ways of selling emerged. In addition, shoppers set higher expectations for personalized interactions and engaging experiences ([3], p. 2). The reality: retail gets reinvented. A clear outcome of this transformation has been the rise of e-commerce, which Euromonitor International expects to drive 56% of global retail sales growth in the next five years [3]. New business models, channel expansion, and shopper expectations continue to change the landscape. These three areas redefine industry rules and relationships—transforming the path to purchase in the process [3]. It is undisputed that the role of new digital technologies in services may fundamentally change the interplay between customers and service firms [4] in general and dramatically change service industries [5].

Digitization and rapid technological progress, also driven by the global Covid-19 pandemic, are leading to rapid and sustained innovation of business models, also in the food and retail industry. New approaches, such as contactless or unmanned grocery stores [6], are emerging all over the world [7].

The spectrum of the shopping experience is shifting from offline to online, and virtuality is merging with reality [8].

The omnichannel presence of many retailers has brought about the question of whether store personnel, especially salespeople, are still of importance nowadays. Due to the increased availability of product information, the assumption is being created that store personnel is becoming redundant [9]. In addition, unmanned grocery stores not only have the potential to improve the efficiency of shopping processes but also to create a special customer experience [10]. The following two hypotheses emerge:

H01: The shopping experience in unmanned grocery stores is NOT comparatively more efficient than in traditional supermarkets.

Studies found that staff service is an important aspect influencing customer satisfaction offline, but also for online distribution channels [11]. Product knowledge as well as communication plays a crucial role in creating customer satisfaction while shopping [12]. While the store staff is interacting with the customer as expected, positive emotions are being created that directly influence customer satisfaction [13]. Besides the importance of the staff, other studies found that products and brands play a pivotal role in retail customers’ repurchase intention and loyalty [14].

H02: The shopping experience in traditional (manned) grocery stores DOES NOT imply a comparatively higher likelihood for customers to come back.

In total, this study aims at researching customer experience of traditional and unmanned supermarkets while taking into account a variety of factors.

2. Theoretical framework

The study involves the development of a theoretical framework that bridges the gap between the key concepts of customer satisfaction and digital shopping

experience. Explorative methods are used to gain a comprehensive understanding of retail practices related to the traditional and digital shopping experience. Based on a synthesis of the findings, an integrated model is presented that relates theoretical and practical concepts.

2.1 Customer experience and technology

Customer experience is dynamic and multidisciplinary and requires multiple methods in its exploration [15]. The subjective feeling that occurs after the purchase of a product or service is the customer experience. It implies the individual processes that lead to customer satisfaction. Sensory, emotional, cognitive, pragmatic, and different lifestyles cause the customer experience to be perceived differently by consumers. It is more important than ever to provide a seamless experience to build a long-term, profitable, and emotional relationship with customers [16]. Innovation in technology is creating new business models, such as unmanned grocery stores, that increase productivity and customer experience while creating a more efficient process of the shopping experience [17].

2.2 A model for customer satisfaction

The suggested model has customer satisfaction at its core, which in retail is called shopping satisfaction. This in turn is based on a variety of factors, impacted by the customer experience. Shopping satisfaction, the perceived value, and the shoppers' attitude ultimately determine the repurchase intention (**Figure 2**).

In a supermarket environment, price and price-related primes are typically ubiquitous [19]. The model therefore includes perceived price fairness, taking the ubiquity and subjectivity of price valuation into account. Efficiency is also a crucial factor in the context of unmanned supermarkets [20]. Product excellence is another factor. Studies such as [21] found that a rather restricted selection of products is not necessarily satisfying the precise needs of the customer. Service excellence, primarily based on service quality, is a widely accepted factor (see the GAP model [22]).

Also, sustainability consciousness as well as health consciousness play an increasing role for many consumers. Recent years witnessed a growing interest in ethical consumption—"consumption activities that are consistent with conscience, values,

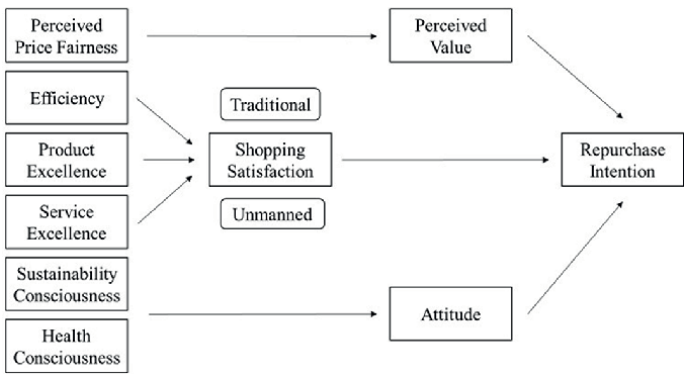


Figure 2.
Influencing factors that motivate repurchasing (adapted from Ref. [18]).

and morals” [23]. Here, also, regional images play a role in purchase probability [24]. Greater numbers of consumers, particularly young adults, identify that they value ethical and socially responsible perspectives in their buying decisions [25].

3. Methodology

The main idea of the present study is to compare the traditional way of shopping and unmanned grocery shopping, capturing the individual experience of a customer. An explorative research design has been used, with silent shoppers as a specific approach. An advantage of this method is the closeness to reality, as the shoppers are real customers. A disadvantage of the silent shopper method is its high subjectivity. Thus, we first used predefined objective evaluation criteria [26]. We used a questionnaire based on a subset of the SERVQUAL [27] approach—that uses a Likert 5 scale—and added further questions. Second, we conducted a relatively high number of silent shoppers. Third, we set a budget of five EUR for shoppers. Fourth, regarding the product, shoppers had to choose a typical snack combination of one sandwich and one drink.

For the traditional shopping experience, 86 participants were asked to enter a supermarket store of their choice and rate their overall shopping experience. Seventy-one participants were randomly assigned to make a first-time user purchase at the unmanned supermarket at Bildungscampus, Heilbronn University, Germany. Immediately after the purchase, the participants were asked to rate their shopping experience with the online survey. The shopping was conducted from the end of October to the middle of November 2022. The two datasets were then analyzed.

4. Major results

Given the explorative nature of the study, we analyzed the datasets by majority distribution in order to get an idea about the satisfaction of the factors in tendency. **Table 2** includes all questions rated on the Likert 5 scale—not including open questions—and indicates where the shoppers perceive differences.

The table shows differences in six out of twelve questions regarding customer satisfaction with manned and unmanned supermarkets. We focus on the questions where differences are found:

Question three shows that in the unmanned supermarket, a large majority were at least satisfied with the duration of the shopping experience. Likewise, in question four, a large majority were at least satisfied with the efficiency of the shopping experience in the unmanned supermarket.

Question five shows that in the manned supermarket, a large majority were at least satisfied with the purchased products. Question seven shows that in the unmanned supermarket, a majority were at least satisfied with the product-price ratio. Question twelve shows that in the manned supermarket, a large majority were at least likely to come back. Question 15 shows that in the unmanned supermarket, a large majority found the tangibles at least supportive.

In total, the shoppers rated the unmanned supermarket in four questions better than the manned supermarket, namely regarding the duration and efficiency of the process, as well as the product-price ratio and the supportiveness of the tangibles.

Question	Manned	Unmanned
Q1	++	++
Q2	++	++
Q3	+	++
Q4	+	++
Q5	++	+
Q6	-	-
Q7	-	±
Q8	+	+
Q9	-	-
Q12	++	+
Q13	+	+
Q15	+	++

++ = a large majority (> = 75%) is very satisfied or satisfied.
+ = a majority (> = 50% and < 75%) is very satisfied or satisfied.
- = a minority (<50%) is very satisfied or satisfied.

Table 2.
Customer satisfaction in manned vs. unmanned stores (own illustration).

In two questions the shoppers rated the manned supermarket better than the unmanned supermarket, namely regarding the purchased products and the likelihood to come back (repurchase intention).

5. Implications and outlook

Question one, “overall satisfaction,” and question two, “ease of purchase,” indicate that the consumers are generally satisfied with both store formats. All other replies, however, indicate a necessity for improvement for either the manned or the unmanned or both store formats.

More specifically, we found some evidence that H01, “The shopping experience in unmanned grocery stores is NOT comparatively more efficient than in traditional supermarkets,” can be rejected. This implies that most clients of the unmanned store appreciate the convenience and efficiency of the shopping procedure overall. According to a previous study [28], convenience and comfort combined can be considered as an aspect that is highly capable of contributing to the acceptance of artificial intelligence (AI) products by means of enabling the adopter of AI to possess a more convenient and comfortable daily life. These aspects are also of paramount importance for younger generations such as Generations Y and Z, as they in particular strive to be as time-efficient as possible. The former is responsible for balancing work and life simultaneously, which can take its toll if not conducted properly. The importance of a smooth, intuitive, and efficient process is also found when looking at a previously not displayed open question about “what was surprising.” More than half of the shoppers who answered this question pointed to the ease of the process, the smoothness of the check-in and check-out, the ease of payment, the door entry and exit, etc. This implies that even though customers are satisfied, there should

be further investments made in order to improve this stronghold of an unmanned supermarket. Surprisingly, the higher efficiency does not lead, however, to a higher likelihood of coming back, as H02 shows.

Also, H02: “The shopping experience in traditional (manned) grocery stores DOES NOT imply for the customers a comparatively higher likelihood to come back” can in tendency be rejected. This implies that the traditional supermarket offers something that has a high value for the customers to come back. The only comparatively better result in our study is with the purchased products as well as the previously not displayed questions about the staff, where a majority found the staff at least satisfying. The relevance of product types for repurchase intention has also been found in other studies [29]. Hence, products and staff play a pivotal role for customers to come back. Furthermore, there are rather general factors that explain the higher likelihood of coming back: There has been some concern about what would happen with the cashier- and staff-employment opportunities, as they are being replaced by automated processes [30]. Unmanned stores should at least be able to lessen the concern of the public by showing what new job opportunities can arise by implementing these new jobs [31] throughout marketing.

Going forward, first, the “customer journey” can be transformed from a normal customer experience into a digital customer experience thanks to digital technology. In the digital customer experience, touchpoints are supported by digital technologies [32]. Second, a positivity bias has materialized in consumer settings in such a way that the mere presence of a human employee in a store environment can boost customers’ positive emotions [33].

Taking this together, retailers must engage more with customers’ emotions in order to turn digital, rather than transactional, shopping experiences into emotional ones [34]. This calls for new service strategies [35], combining technology and humanness. This necessity, together with authenticity, also holds true for influencer marketing when comparing human and virtual influencers [36]. A promising approach could be hologram technology, also for retailers [37]. Considering the methodology, the questionnaire could benefit from taking the answers to the open questions into account. In addition, an increased sample size would allow for a quantitative approach. Considering online shopping with e-grocery and thus confronting all three shopping options could lead to further insights. In addition, a cross-country study would allow considering cultural aspects of customer satisfaction in manned and unmanned stores. This could be especially valuable when thinking about the particular shape a “digital humanness” should take.

6. Case study: The Schwarz group - evolution of stationary retail outlets

Based in South Germany (Neckarsulm), the Schwarz Group is the largest retailer in Europe and among the top three worldwide [38]. The organization strategically extends its operations along the vertical scope, with its cornerstone entities comprising Lidl and Kaufland in grocery retailing. In addition, Schwarz Production and PreZero engage in food production and environmental services. Schwarz Dienstleistungen assumes a central role in the corporate services division, managing and supporting the different business units of Schwarz Group (**Figure 3**) [40].

6.1 Retail history in a nutshell

In the nineteenth century, the first retail formats developed, starting with small, family-owned general stores. Over time, these evolved into larger general stores and



Figure 3.
Lidl discounter [39].

department stores, with supermarkets and shopping malls arising in the early twentieth century. The first discount retailer was established with the inauguration of Walmart in 1962. As technology increased, new formats started to evolve outside of brick-and-mortar retailing. In 1995, Amazon sold its first book online. Online retailing pressures classical formats, forcing them to rethink and differentiate again. Big players are developing omnichannel retailing, combining offline and online formats [41].

6.2 History of Schwarz group

In the year 1930, Josef Schwarz, the father of the current owner of the Schwarz Group, Dieter Schwarz, founded his first retail store in Heilbronn. Unfortunately, this store was damaged during World War II but was reconstructed in the late 1940s. Following this, the company opened its first cash & carry market in Heilbronn in 1960 and launched the first Lidl store in 1973 in Ludwigshafen. In 1984, the first self-service store was established in Neckarsulm. Five years later, the Schwarz Group began its international expansion. In 1999, the consolidation of administrative and financial services of Schwarz units resulted in the creation of Schwarz Dienstleistungen as an independent company, evolving into the central corporate services provider for Lidl and Kaufland since 2014. Three years later, Lidl started its expansion of Lidl into the U.S. markets. In May 2019, the synergy between Lidl IT and Kaufland IT resulted in the formation of Schwarz IT (**Figure 4**) [43].

The Schwarz Group currently employs 575,000 individuals and operates 13,700 stores in 32 countries across the world (October 2023). In 2022, with Lidl and Kaufland as its flagship companies, the group reported an annual sales revenue of 154.1 billion euros [44]. Lidl alone achieved 114.8 billion euros, witnessing a 13.8% increase from the previous year, while Kaufland reached 31.8 billion euros, reflecting a growth rate of 16.1%. Furthermore, the organization's online retail revenue reached approximately 1.9 billion euros.



Figure 4.
First retail [42].

With the acquisition of Schwarz Produktion and PreZero, the group aims to extend its operations along the supply chain. So far, this extension seems to be a success: Schwarz's waste disposal and recycling business, PreZero, contributed approximately 3.9 billion euros in revenue [45]. Schwarz Produktion owns bakery manufacturers, chocolate, ice cream, dried fruits, coffee, and beverage producers [46]. These in-house companies that produce goods for Lidl and Kaufland achieved about 3.4 billion euros. In 2022, Schwarz Production acquired Germany's largest pasta manufacturer, "Erfurter Teigwaren." Among the 1.7 billion euros in other revenues were income streams from new IT services, including their proprietary cloud platform STACKIT [47].

Schwarz has further increased its digital sovereignty and named the unit Schwarz Digits. Schwarz Digits provides the IT infrastructure and solutions for the vast ecosystem of the companies of Schwarz Group, continually developing it further for the future. Schwarz Digits creates optimum conditions for the development of groundbreaking innovations for end customers, companies, and public sector organizations. Schwarz Digits encompasses 7500 employees and the brands Schwarz IT, Schwarz Digital, STACKIT, XM Cyber, Kaufland e-commerce, Lidl e-commerce, Schwarz Media, and mmmake [48].

Hence, its units are:

- a. Producing: Schwarz Produktion
- b. Retailing: Lidl, Kaufland
- c. Recovery and Recycling: PreZero
- d. Digitalizing: Schwarz Digits [49].

6.3 Classic retail

Classical retail, also known as brick-and-mortar retail, refers to the tangible presence of businesses with warehouses and/or physical storefronts for the sale of their products or services. It is characterized by attributes such as physical accessibility, operating hours, face-to-face interaction, and localized customer support. The term has gained prominence since the rise of e-commerce, which contrasts with classical retail by distributing exclusively over the internet. While online retail must deal with functioning and user-friendly platforms, traditional retail faces distinct challenges, including attracting customers to their physical location, creating a positive customer experience, and creating a good shop atmosphere. Additionally, they must face customer streams during peak hours in their aisles and at the checkout counters, as well as handle operational expenses related to logistics, maintenance, rent, and electricity [50].

6.4 The supply side of classic retail (manned supermarkets)

Classic retail is capital-intensive; however, labor also plays an important part. The Cobb-Douglas function applies [51].

$$Y = F(K, L) = AK^{\alpha} L^{1-\alpha} \quad (2)$$

Growth, or more specifically an increase in output, is typically generated by an increase in the efficiency of capital and labor, sometimes with offsetting effects. Examples are classical employee training that improves labor productivity (increasing $1 - \alpha$), requires, however, an initial investment, for example, for training personnel or a new payment system, and hence, reducing capital productivity (or α , at least in the short run). More recently, growth has also been achieved by inducing an increase in A , for example, by introducing self-checkout cashiers. And hence, substituting labor (L) input with capital input (K).

6.5 New retail

The rising prominence of e-commerce has created a competitive environment for traditional retail. To remain competitive and to attract customers, classical retailers are compelled to embrace the internet and technology in their operations as well. Both brick-and-mortar businesses (e.g., Kaufland) and online retailers (e.g., Amazon) are developing new strategies to transform into omnichannel entities, which means combining online and physical presence [48]. Although physical stores still hold appeal, the current transformation of the retail industry forces them to adapt from just existing as conventional transaction points to becoming modern hubs that enhance an extensive customer experience to continue differentiation and gather customer data to enhance personalization [49]. All this in an attempt to meet shoppers' higher expectations for personalized interactions and engaging experiences [1].

Recently, the Schwarz Group has taken significant steps toward digitalization. They have introduced a new cloud platform named Stackit, which serves not only their own IT needs but is also offered to numerous mid-sized businesses. It positions them as a European alternative to prominent US companies like Amazon or Microsoft. Additionally, in 2021, they acquired the Israeli company XM Cyber to upgrade their

IT security [50]. Furthermore, the Schwarz Group has commenced research and development efforts aimed at innovating classical brick-and-mortar retail formats. Examples of this are the concepts of Shop Box & Collect Box, which will be discussed in the following section.

6.5.1 An example of new retail: Shop box & collect box

In 2021, Schwarz IT launched a pilot project by opening two smart stores on the University of Heilbronn campus. The first, known as the collect box, facilitates an automated delivery of pre-reserved items via the app. Students can compile their purchases through the app to assemble their desired purchases, which can then be collected at the terminal. Alternatively, they can select items directly through a touch screen. Once selected, the items then arrive from a fully automated high-rack warehouse with a capacity of between 2000 and 3000 items via an output chute.

Right next to it is the shop box, a 35 m² traditional walk-in retail. It displays approximately 250 items displayed on shelves and refrigerators. Access through the store is granted via app and QR code. The selected goods are recorded via various sensors in the store, and due to the automated payment process via the app, the conventional checkout procedure upon leaving the store becomes unnecessary. Both stores are accessible 24/7, presenting an alternative concept to the traditional brick-and-mortar retail model. Project Manager of Schwarz IT, Andreas Laube, emphasizes that these initiatives are merely intended for R&D. Nonetheless, this innovative example indicates a growing trend, with approximately 26 smart store concepts (operating 24/7) in Europe, 18 of which are in Germany alone (**Figure 5**) [52].

6.6 The supply side of new retail (unmanned supermarkets)

New retail is even more capital-intensive than classic retail, aiming at the point of full automation where no labor is anymore used, at least in the sales process. Growth, or more specifically an increase in output, is typically generated by a big increase in capital through fully substituting labor with capital. Examples are fully autonomous



Figure 5.
Shop box & collect box [52].

supermarkets like the shop box with no sales personnel. Unlike classic supermarkets, these concepts predominantly aim at driving labor inputs (L) to zero. Hence the production function would change to

$$Y = F(K) = AK^{\alpha} \quad (3)$$

Where L is eventually eliminated. Even in cases where L is marginalized, the productivity gains from increasing labor productivity would become marginal, and hence, investments in capital will become the focus.

Even as this development increases economic efficiency on the supply side, it does not imply the demand side. It remains open whether demand, or more specifically retail customers, “accept” unmanned stores. Also, as seen, repurchase intention is lower than for classic retail. Hence, other solutions, especially personalized solutions, could be a way to fill the gap between efficiency (supply side) and customer experience driving repurchase intention (demand side).

6.7 A future solution for new retail

While the collect box and shop box concepts represent ongoing initiatives by the Schwarz Group, there exist numerous other opportunities and possibilities for the future transformation of brick-and-mortar stores into modern hubs that deliver comprehensive, personalized shopping experiences. One such development is a recent hologram concept by a company called Proto Inc. Although the firm is currently not cooperating with the Schwarz Group, its emergence leads to consideration of whether its products could contribute to the Schwarz Group’s efforts to develop new formats for enhancing their customer experiences in their local retail stores, Lidl & Kaufland.

Proto Inc. was established in 2018 and is headquartered in Los Angeles, USA. Their new product, “The epic,” is a 2.1-meter-tall, life-sized holographic device that can simulate the presence of an actual person or object within it, also with AI [53]. This groundbreaking technology allows spectators to interact with live or scheduled individuals “beamed in” from anywhere in the world. It is the first and only holographic communications device that integrates both hardware and software, complemented by its own app system. On their website, they articulate their vision: “We want to become a solution so incorporated into our daily lives that life before proto becomes hard to imagine. We want to be the leaders of the technology that changed the way we do business, keep in touch and conceive entertainment” (**Figure 6**) [54].

This lifelike holographic technology opens a new kind of opportunity for enhancing customer experience and attracting attention, with potential applications spanning advertising, retail, communications, digital humans, transportation, hospitality, travel, training, education, and healthcare [54]. The company is collaborating with over 120 customers, including companies like H&M, Netflix, DHL, and T-Mobile, along with collaborations with celebrities such as Ellen DeGeneres, Usain Bolt, and Lewis Hamilton [54]. Their pioneering efforts in holographic technology were validated when they secured a patent from the Department of Innovation, Science, and Economic Development at the Canadian Intellectual Property Office in 2022 [55].

Could Porto’s holographic technology be the next solution for the Schwarz Group to transform their classical retail by offering a unique sensation and memorable shopping experience? Could this approach attract customers to their stores, enhance personalized shopping by evoking emotions, and unlock AI-data-driven shopping potentials to build and maintain a loyal customer base?



Figure 6.
Proto Inc. products [54].

6.8 The supply and demand side of future retail (humanized unmanned supermarkets)

Classic retail is labor-intensive, and new retail is capital-intensive. In the metaverse [56], we could come to a point where the immersive experience is so strong that differentiating between capital and labor from a customer (demand) perspective is less and less possible. The impact of the proto hologram on customers could be very much the same, irrespective of whether the hologram is a real person (i.e., situated 1000 km away) or a perfect avatar (no human). In the first case, it would be labor input (L), and in the second, mere capital input (K) with regard to the sales process.

Mirroring this effect on the production function would change it to the following:

$$Y = F(K, L) = A(KL)^\alpha \quad (4)$$

Growth, or more specifically an increase in output, is then generated by either an increase in the efficiency of capital and/or labor. Thus, they become one factor, “labor capital” or “lapital” or “cabor,” with no more offsetting effects.

6.8.1 Impact on efficiency

As a consequence, capital could fully replace labor while still being associated with a high—in the traditional view, the human-based—repurchase intention. It increases efficiency, and including AI in the proto hologram, solution would also increase A, which measures the productivity of the available technology [57].

6.8.2 Impact on the labor market

In the short run, automation will thus lead to job losses of sales personnel or diminish retail vacancies (see **Table 1**). This holds especially true for rather unskilled personnel. The general consensus among labor and macroeconomists is that technical change has been skill-biased over the past 60 years [long run], and most probably throughout the twentieth century. Technical change has been favoring skilled workers over unskilled workers. [58] Skilled workers are especially required, as they are the ones to design, implement, and run the humanized unmanned stores.

7. Conclusions

Having pointed out that retailers—grocery and nongrocery—must engage more with customers' emotions in order to turn digital, rather transactional shopping experiences into emotional ones [34], there is a necessity for new service strategies [35]. These strategies must combine technology and humanness. A promising approach is hologram technology. It has the power to transform rather transactional into highly personalized, emotional shopping experiences, even without human sales staff. Together with its comprehensiveness and quality perception, it has the potential for truly enabling a metaverse [56]—at a much higher level than any online solution as of today. It increases efficiency (supply side) and humanness (demand side). It can become the crystallization point enabling many—if not all—of the six suggested strategies for growth [59]:

1. Winning the value proposition [it adds outstanding value]
2. next-generation engagement [it specifically addresses high-value target customer segments]
3. omnichannel commerce [it is an entry point for third-party marketplaces]
4. beyond retail: from products to service platform [additional service can easily be integrated]
5. end-to-end cost optimization [it enables inventory savings by an advanced customer profile] and
6. Accelerating AI deployment [AI is already implemented!].

These strategies impact the demand and supply side and are promising options for growth by addressing the industry trends (see **Table 1**).

Are we on the way from traditional to unmanned to humanized unmanned supermarkets? The future will show it. It could well be the case ...

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Section 5

Regional and Sectoral Perspectives

Critical Factors Influencing Economic Growth: A Case Study of Vietnam

Lu Phi Nga and Phan Thanh Tam

Abstract

Vietnam's economy during 2022–2023 occurred against the backdrop of significant fluctuations in the global economy. The conflict between Russia and Ukraine is volatile, heightening dangers to the financial market, currency stability, energy security, and international food supply. The study aims to identify the principal factors influencing economic growth and offer policy recommendations for short-term and long-term economic growth. Moreover, the authors employed formal study methodologies in prominent cities, including Ho Chi Minh City, Can Tho, Da Nang, Hai Phong, and Hanoi. The participants of the survey for data collection are economic specialists. The data collection strategy involves direct interviews via a structured questionnaire with a sample size of 450 economic experts. For analysis, the authors use SPSS version 20.0 and Amos software. The study's result identifies five critical factors influencing economic growth at a significance level of 0.01 and five accepted hypotheses. The unique contributions based on the novelty highlight the significant influence of fiscal and monetary policy on economic growth in Vietnam. Finally, the authors propose policy deliberation to implement and facilitate a swift economic reaction to foster growth.

Keywords: fiscal, monetary, policy, economic, growth

1. Introduction

Economic growth is crucial for a nation's progress and the well-being of its citizens. A constant growth rate in a nation's economy yields the following advantages: (1) Enhance individuals' income, guarantee social welfare, and foster a healthy community environment. Subsequently, education, healthcare, tourism, and nursing facilities will be strengthened and enhanced. Conditions such as severe illness and malnutrition will diminish, enabling children to attend school. (2) Generate additional employment and entrepreneurial prospects for individuals in the future [1, 2]. Decreasing the unemployment rate among younger generations will ensure stable pay for workers. This element aids society in mitigating societal ills such as theft, substance abuse, gambling, and others. (3) The government will implement policies and strategies to train and enhance human resources for national security and defense. (4) Utilize and implement cutting-edge scientific innovations in research, technology,

education, and healthcare. Fortify relations with developing nations globally to augment the country's standing [3–7].

Economic growth refers to a nation's income rise over a specified duration, typically 1 year. The augmentation is evident in both magnitude and velocity. The magnitude of growth indicates a significant or slight increase, whereas the growth rate serves a comparative function, denoting the swift or gradual increase across time intervals [5, 6]. The economy's income can be represented as an object or a value. Income is represented by value as indicated by gross national product (GNP) and gross national income (GNI) metrics, measured for the entire economy or per capita.

Consequently, the essence of expansion signifies quantitative alterations inside the economy. Economic growth is necessary to enhance sustainability or guarantee development quality. In this regard, the constant and effective enhancement of the per capita income index and its growth rate is further highlighted. Furthermore, that process must be established by the critical elements of science, technology, and human capital within a rational economic framework [7].

In 2023, the global economy persisted in encountering numerous obstacles and hurdles. Global economies are experiencing growth rates below expectations due to diminishing aggregate demand; inflation has abated yet persists at elevated levels; monetary policy remains restrictive; global public debt has surged to unprecedented heights; the military conflict between Russia and Ukraine has become more intricate; and factors such as geopolitical instability, food security concerns, natural disasters, and climate change are on the rise. In 2023, international organizations had revised their global economic growth projections in various directions; however, most of these forecasts were below the growth rate observed in 2022.

To attain economic growth, it is essential to accomplish substantial growth by synchronous coordination between macromanagement and microcontrol, integrating objective and subjective factors, using economic principles, and utilizing leverage instruments such as taxation, currency, interest rates, and employment. Economic growth is a pivotal factor influencing the prosperity and collapse of a nation's economy [8]. Addressing the challenge of economic growth to generate new income enables the resolution of various other difficulties, including budgetary balance, substantial investment, social welfare, job creation, crime prevention, and securing money for military and security. If economic growth is not attained at the requisite level, society will undoubtedly encounter complex issues. Furthermore, fiscal and monetary policies are crucial for sustained growth. Countries that uphold sound macroeconomic policies will foster sustained and stable growth. Therefore, the chapter determines critical factors affecting economic growth and provides policy implications for short- and long-term economic growth.

2. Literature empirical review

2.1 Economic growth (EG)

Economic growth refers to the augmentation of value inside an economy. Economic growth is evidenced by various indices, with the most prevalent being gross domestic product (GDP), GNP, GNI, capital accumulation, labor expansion, and an enhancement of market capacity [8–10]. The interplay of GDP components, including domestic consumption, investment, government expenditure, and the trade balance, will alter the economic growth rate. The growth process demonstrates the optimal exploitation and utilization of resources, including natural resources, capital, labor,

technology, management, relationships, and markets. Economic growth includes expansion in breadth and depth, quantity and quality, and short-term and long-term dimensions. Numerous domestic and foreign companies have quantified the effects of enhanced resource expansion on quality and growth dynamics [11].

Conversely, economic growth refers to the augmentation in GDP, GNP, or per capita income over a specified duration. Economic development signifies a quantitative transformation inside the economy. Nonetheless, economic disparity is considerably pronounced in many nations, resulting in numerous individuals enduring poverty despite elevated per capita income [1, 12, 13]. After analyzing the economic growth of developed and developing nations, economists have identified five critical factors that jointly propel economic growth in the contemporary era and facilitate international integration: fiscal policy, monetary policy, quality of public services, digital transformation, and political environment. The five elements vary by country, and their combinations yield distinct outcomes for economic growth [14].

2.2 Fiscal policy (FP)

Fiscal policy is a macroeconomic strategy that influences the magnitude of economic activity by alterations in government expenditure and/or taxation. Keynes contended that the government should augment expenditure and be prepared to incur budget deficits to transition the economy from pervasive unemployment to a condition approaching full employment. A strategy of augmenting expenditure or reducing taxes theoretically enhances aggregate demand via the debt label effect, resulting in job creation to satisfy demand and elevating national income [15–17]. When economic activity is excessively high, the government may reduce spending or increase taxes to diminish aggregate demand. The principal aim of fiscal policy is to mitigate production volatility over the business cycle. This objective necessitates the perspective that the government must oversee the functioning of the economy. Numerous economists contend that fiscal policy is not a universal remedy for all economic ailments [18]. They claimed it was suitable solely for the recession during which Keynes composed his general theory of employment, interest, and money, but not for an inflationary economy. During periods of inflation and recession, fiscal policy lost favor. Individuals started to have confidence in the efficacy of monetary policy in attaining macroeconomic objectives [19]. Thus, the authors gave hypothesis H1 below:

Hypothesis H1: Fiscal policy affects economic growth.

2.3 Monetary policy (MP)

Monetary policy involves utilizing credit and foreign exchange instruments to stabilize the currency, thus ensuring economic stability and fostering growth and development. The central bank is the entity responsible for orchestrating the execution of monetary policy. Monetary policy objectives include price stability, GDP growth, and decreased unemployment [20, 21]. Monetary policy influences the money market, thus impacting aggregate demand and output and serving as an effective economic stabilization instrument for the government. Monetary policy presents numerous challenges. We can reduce the growth rate of the money supply and constrain inflation to a single digit, yet the existing monetary policy possesses numerous deficiencies [22–24]. It still entails significant administrative intervention. Numerous administrative tools are employed in the monetary and financial markets. In addition, monetary

policy aimed at sustaining the currency's value does not imply that the inflation rate is zero, hindering economic development. In periods of economic stagnation, maintaining inflation at a moderate level (often in single digits) will reinvigorate economic growth [24]. Thus, the authors gave hypothesis H2 below.

Hypothesis H2: Monetary policy affects economic growth.

2.4 Quality of public service (QPS)

Public services are vital services the state gives, ultimately accountable for benefiting society and the community. Public services are crucial in socioeconomic life and represent the objective of any organization to enhance living standards and welfare, providing equity and holistic development for all societal members [25, 26]. The state is crucial in delivering public services to enhance quantity and quality. The role and status of the state in contemporary society have undergone significant transformation [27]. The state not only oversees the management process but also undertakes the provision of public services.

Consequently, the quality of public service is a critical indicator of the efficacy of state administrative agencies [2–6, 28]. The evaluation of online public services' quality facilitates the identification of the system's deficiencies, advantages, and constraints that require resolution, therefore providing solutions to enhance public service delivery [29]. Methods for evaluating the quality of online public services must be empirical and applicable to both theoretical and practical contexts to improve service quality. Thus, the authors gave the following hypothesis H3:

Hypothesis H3: Quality of public service affects economic growth.

2.5 Digital transformation (DT)

Digital transformation entails the incorporation of digital technologies across all facets of an organization, utilizing these technologies to fundamentally alter operational processes and business models, thereby generating new value for both the organization and its customers, as well as accelerating business activities or service delivery [30–33]. Digital transformation entails a cultural shift within firms, necessitating continuous adaptation, innovation experimentation, and an open acceptance of failures. The primary advantages of digital transformation for organizations include decreased operating expenses, enhanced long-term customer access, and expedited, precise decision-making facilitated by an efficient reporting system, optimizing employee productivity [17, 34–36]. These factors enhance the operational efficiency and competitiveness of the business, hence contributing to economic growth. Thus, the authors proposed the final hypothesis H4 as follows:

Hypothesis H4: Digital transformation affects economic growth.

2.6 Political environment (PE)

The political landscape encompasses the legal framework, governmental institutions, and the influence of social advocacy groups. The evolution of these aspects significantly and immediately impacts businesses' investment decisions. The political environment comprises the variables that influence the system, shaping its existence

and condition [4, 17, 36, 37]. The domestic political environment refers to the internal framework of a nation, often comprising three elements: political parties, the state, and social organizations. An essential component of the domestic political landscape is the institutional framework composed of normative documents delineating the duties, positions, responsibilities, and authorities of the political party, the state, and social groups. The domestic political environment encompasses traditional practices, political culture, and civic consciousness, which are challenging to delineate yet significantly influence economic growth [6, 12, 38, 39]. The political factor is highly intricate. This element will impact economic development on a national or international scale, contingent upon certain conditions [40]. Strategic managers aiming to expand the market must be attuned to the political landscape in each geographic region and anticipate political events at national, regional, and global levels to formulate timely and suitable strategic decisions. Thus, the authors gave the following hypothesis H5:

Hypothesis H5: The political environment affects economic growth.

Based on the abovementioned things, economic expansion enhances a nation's production and output of goods. It plays a crucial role in the economy, facilitating access to significant initiatives and research, producing high-quality consumer services and goods, and enhancing productivity and facilitating numerous options for international collaboration. The authors utilize the theory of economic growth and incorporate local and foreign studies as a basis for developing a research model on economic growth within the framework of economic expansion. Recent advancements present numerous opportunities and difficulties for the innovation of Vietnam's growth

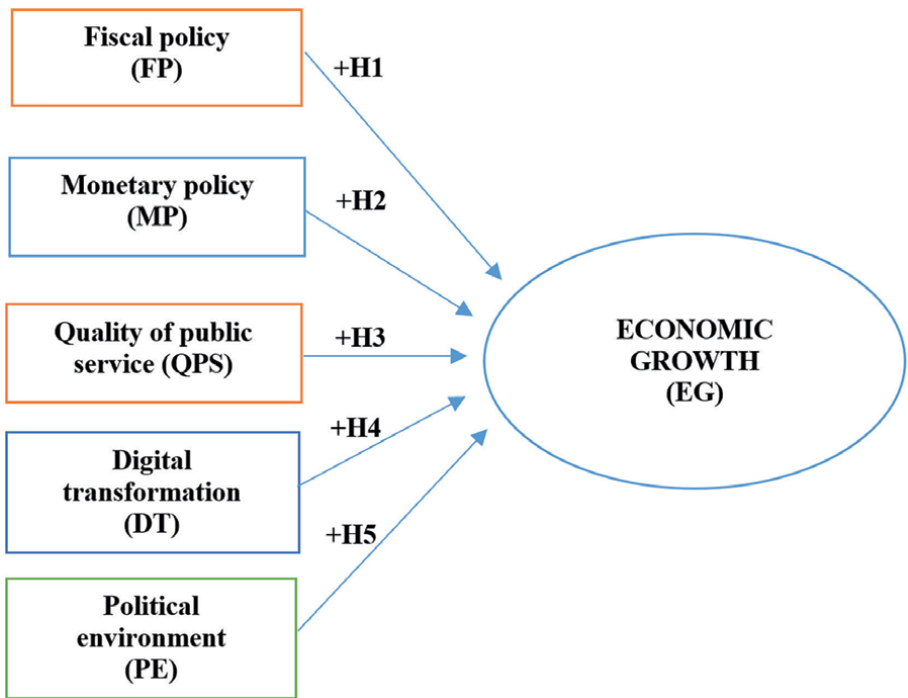


Figure 1.
A research model for critical factors affecting economic growth. Source: The authors proposed.

model. The authors focused on the following five factors: fiscal policy, monetary policy, quality of public services, digital transformation, and political environment.

Figure 1 shows five independent factors influencing economic growth in Vietnam: (1) fiscal policy (FP), (2) monetary policy (MP), (3) quality of public services (QPS), (4) digital transformation (DT), and (5) political environment (PE). **Figure 1** also shows that the dependent factor is economic growth (EG).

3. Methodology and data

This research consists of three steps: (1) conducting qualitative research, (2) quantitative (preliminary) research, and (3) formal quantitative research. Qualitative research is conducted through an in-depth interview to establish the scales and research hypotheses below (**Figure 2**).

Preliminary quantitative research is conducted as a descriptive study utilizing direct interview techniques to evaluate the measuring scales of research concepts and refine the questionnaire. Formal quantitative analysis is employed to assess the validity and reliability of the scale for evaluating the theoretical model and the assumptions in Model 1 above [41]. The article delineated the research and development process of the ranking executed through the subsequent steps:

Step 1: The writers identified the study problem and conceptual framework grounded in a theory of economic growth. In Step 1, the study conducted three analyses: (1) provide a theoretical framework for examining concepts associated with economic growth; (2) analyze the interconnections among the concepts within the research model; (3) develop a preliminary scale for the research concepts, precisely the scale of factors influencing economic growth.

Step 2: The authors developed conceptual measurements via empirical research and group discussions with nine corporate managers from various cities and provinces in Vietnam pertinent to economic growth, including Ho Chi Minh City, Can Tho, Hai Phong, Da Nang, and Hanoi. Simultaneously, the authors conducted interviews and group discussions with nine economic experts to obtain recommendations regarding the magnitude of economic growth [41].

This phase has two distinct tasks: (1) modify and enhance the scale of scaled notions and (2) develop a collection of variables on a new scale for inclusion in the model. The initial study modified and enhanced the original scales via focus group discussions. Focus group interviews were performed. Multiple groups were established and interviewed. The outcome of this stage was the modification of the absolute scale, referred to as the changeable scale [41].

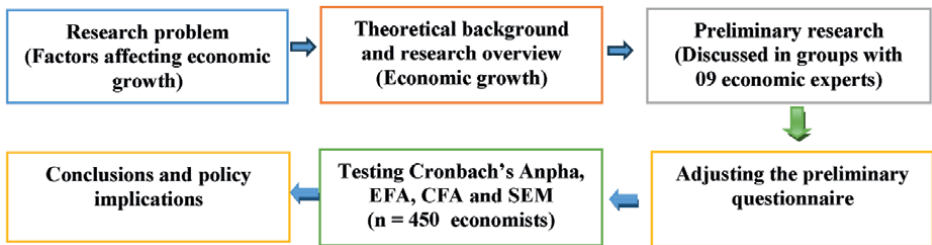


Figure 2.
A research process for critical factors affecting economic growth. Source: The authors proposed.

Step 3: Data Collection: The authors performed initial quantitative research via direct interviews with 31 Vietnamese economic specialists. The survey for economic specialists in this study is suitable since economic growth is evaluated through the questionnaire developed after Step 2. The sample size comprised $n = 31$ experts. Economists interviewed Vietnamese cities and provinces, particularly in major urban centers such as Ho Chi Minh City, Can Tho, Hai Phong, Da Nang, and Hanoi.

Step 4: Conduct a preliminary scale assessment utilizing the reliability coefficient of Cronbach's alpha and exploratory factor analysis (EFA) based on data gathered in Step 3. The modified scale was assessed by initial quantitative research with a sample size of $n = 450$ economists (with only 413 votes processed) and employing a random, nonprobability sampling technique. The scales were calibrated using two primary methods: (1) Cronbach's alpha for reliability assessment and (2) exploratory factor analysis (EFA). The Cronbach Alpha coefficient analysis was employed to assess the scale's reliability. The scale was deemed credible when its coefficient exceeded 0.6. The primary variable was the correlation coefficient with the average of other variables on the same scale. A higher coefficient indicated a stronger correlation of the variable with other variables in the group. The correlation between the variable and the sum must exceed 0.3. The factors with a total correlation coefficient below 0.3 were deemed inconsequential and omitted from the scale [41].

The authors employed exploratory factor analysis (EFA) to assess the validity of the conceptual scale. Following the identification of EFA, the authors proceeded with CFA and SEM analyses; thus, it is imperative to consider the scale structure and the distinctions among factors. Consequently, the authors performed an exploratory factor analysis; the performance criteria are as follows.

Promax rotation is used using the principal axis factoring method.

- Criterion 2: Coefficient load factor maximum of each variable 0.4.
- Criteria: At each variable, factor loading is most significant.
- The load factor must be ≥ 0.3 to ensure factor difference [41].
- Total variance extracted 50% [41].
- $KMO \geq 0.5$, the Bartlett test has statistical significance ($Sig < 0.05$).

Step 5: Persist in data collection: In this phase, the writers formally studied significant urban centers, specifically HCMC. Can Tho, Ho Chi Minh City, Da Nang, Hai Phong, and Hanoi. The survey participants are economic experts. The data collection strategy involves direct interviews via a structured questionnaire, with a sample size of $n = 450$ economic experts. The sampling method employed is probability sampling, specifically utilizing random sampling techniques for assessment. Following data collection, the information was subjected to coding, data entry, cleaning, and analysis using SPSS version 20.0 and Amos software. Moreover, the authors selected to survey economic experts from Ho Chi Minh City, Can Tho, Da Nang, Hai Phong, and Hanoi, as these areas epitomize significant economic regions in Vietnam, featuring a variety of industries, trade centers, and financial hubs, thereby offering a comprehensive perspective on the determinants of economic growth in urban and regional settings.

Step 6: Assess the reliability of the scales using Cronbach's alpha, utilizing the data gathered in Step 5. In this phase, the writers reassessed the trustworthiness of

the ranks by analyzing the system's quantity. Cronbach's alpha is derived from data obtained through formal research.

Step 7: The authors assessed the scale value through the examination of the exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) of the structural equation modeling (SEM) framework.

EFA analysis is based on a scale reliably assessed through Cronbach's alpha coefficient performed in Step 6 and data collected in formal research in Step 5. The CFA methodology is employed to evaluate the validity of the scales. The authors integrated EFA and CFA into the SEM framework to substitute Step 7 in the suggested methodology [41].

Step 8: The authors established the standard scale and analyzed the SEM structure to evaluate the model and research hypotheses. SEM evaluates the adaptability of theoretical frameworks and proven research ideas.

Step 9: The authors suggested governance implications derived from the outcomes of model testing.

The authors conducted the research, synthesized the theoretical foundation and pertinent domestic and international studies, and developed a research model. Following establishing the research model, the authors developed the anticipated scale, evaluated the model and the scale, and gathered preliminary data from 31 economic experts to examine the scale's reliability and validity. After the first phase, the writers gathered official data to evaluate the study model and hypothesis. The authors presented results and proposed policy implications to enhance economic growth.

4. Empirical results

4.1 Analysis of the situation for Vietnam's economy during 2021–2023

Vietnam's economic growth during the previous two decades has attained a notably strong growth rate since implementing doi moi. Vietnam's GDP experienced an average increase of approximately 6.57%; however, this growth rate has declined over the past decade to around 5.6%. By 2021, the economy was projected to attain a size of over 363 billion USD, positioning it among the Top 40 largest economies globally, while GDP per capita is expected to approach 3700 USD, representing an increase of roughly 2.4 times compared to 2011. However, the measurement of Vietnam's GDP is a contentious issue.

In 2021, Vietnam's GDP growth rate decelerated due to several variables, encompassing both internal conditions and the external objective environment. It is universally acknowledged that the era of capital-driven expansion is concluding. Consequently, Vietnam must identify new growth sources and seek distinctive elements for sustained long-term growth. According to the World Economic Outlook Database 2021, Vietnam's per capita income based on buying power parity in 2021 was merely 17% of that of the United States and 24–26% of that of Japan and South Korea, which is approximately 17% behind. 33 years), 40% of Malaysia (about 30 years later), and equivalent to 61% of Thailand and China. Vietnam can only attain parity with higher-income nations if it sustains a prolonged high growth rate; otherwise, its capacity to catch up will diminish, increasing the risk of being left behind.

In 2022, the GDP at current prices was estimated at VND 9513 trillion, equivalent to USD 409 billion. In 2022, the predicted GDP per capita at current prices was 95.6 million VND per person, equivalent to 4110 USD, reflecting an increase of 393 USD from 2021. The labor productivity of the entire economy in 2022 was estimated at

current prices. Estimated at 188.1 million VND per employee (equal to 8083 USD per employee, reflecting an increase of 622 USD compared to 2021). In 2022, labor productivity at constant prices was projected to rise by 4.8% due to enhanced worker qualifications, with the percentage of trained workers holding diplomas and certificates expected to reach 26.2%, an increase of 0.1 percentage points from 2021. Despite the obstacles facing Vietnam's economy, the government and the prime minister have demonstrated proactivity, adaptability, and resolve to guide ministries, sectors, and localities. In conjunction with the solidarity, trust, and support of the public and the business sector, many initiatives have been taken to overcome challenges, foster growth, and maintain macroeconomic stability and necessary economic balances. As a result, the nation's economy has achieved favorable results, demonstrating a continuous recovery trend, with quarterly growth rates exceeding those of prior quarters.

In 2023, economic growth was anticipated to be 5.05%, with quarterly increments of 3.41, 4.25, 5.47, and 6.72%. The agriculture, forestry, and fishery sector expanded by 3.83%, contributing 0.46 percentage points; the industry and construction sector increased by 3.74%, contributing 1.51 percentage points (with industry alone rising by 3.02%); and the services sector exhibited the highest growth at 6.82%, contributing 3.25 percentage points. Furthermore, after accounting for product subsidies, the net effect of product taxes rose by 3.33%.

Achievements and challenges:

Vietnam has attained accomplishments and faces numerous problems. Vietnam's inflation rate has remained in single digits from 2021 to 2023. Before it, Vietnam's economy consistently underwent phases of double-digit inflation. Since 2016, the trade balance has consistently exhibited a surplus, contrasting sharply with the substantial trade deficit observed from 2009 to 2011, accompanied by a fiscal deficit and the devaluation of the local currency. However, in the past 5 years, we have rectified the trade imbalance due to the prospective export market facilitated by free trade agreements (FTAs). Foreign investment remains relatively stable. Foreign direct investment (FDI) capital alone amounted to over 20 billion USD distributed, resulting in a substantial increase in Vietnam's foreign exchange reserves, which had grown nearly tenfold compared to a decade before. Nonetheless, we continue to face specific issues, particularly with monetary and fiscal matters, such as the following:

The public debt burden escalates swiftly and is anticipated to induce instability in the forthcoming decade. If Vietnam implements extensive investment initiatives and projects, such as the North-South railway expressway or other essential endeavors that deplete national resources, it will fail to attain fiscal equilibrium. Despite the reduction in state debt to GDP, this was attributable to the "confusing manner" in which Vietnam's GDP was adjusted. This indicates that Vietnam's statistical capabilities are inadequate, as not all economic activity has been monitored, resulting in a relatively imprecise GDP measurement. During this era, the absolute value of public debt has escalated by about 3.2 times, with a growth rate in the past decade nearing double digits.

Furthermore, relative to the magnitude of budget income, the ratio of public debt to budget revenue experienced a minor decline in 2015–2016, followed by a recent U-shaped growth. The increasing scale of public debt significantly escalates the burden of yearly principal and interest payment obligations, which formerly constituted approximately 12–13% of budget revenue and has risen by about 12–13% during the past 2–3 years. 21–22% of budgetary revenue. Consequently, each year, Vietnam allocates around one-fifth of its budget resources to fulfill debt obligations.

Secondly, there are numerous issues concerning monetary policy. We can reduce the growth rate of the money supply and constrain inflation to a single digit, but the

existing monetary policy exhibits numerous deficiencies. It still exhibits significant administrative intervention. Numerous administrative tools are employed in the financial and capital markets. Vietnam lacks a sustainable growth foundation, as the quality of its human resources struggles to align with emerging technology advancements, hindering its potential to transition into a middle-income nation globally in the following decades. The Vietnamese economy has relied on exports and substantial foreign investment over the previous decade. Over the last two decades, Vietnam's exports of products and services have climbed by approximately 55%; in recent years, this figure has escalated to 105% of GDP, indicating that the volume of exports has surpassed 100%. Imports are analogous; exports and imports exceed twice the GDP.

Economic development in 2023 was bolstered by several advantageous factors:

The stable macroeconomic environment and effective integration of fiscal and monetary policies have enabled the maintenance of inflation within a manageable range, while the gradual reduction of operating interest rates underpinned the decrease in lending interest rates to enhance output. Maintaining economic assistance, actively promoting the restructuring process, and ensuring food supply and security have resulted in countless excellent outcomes and fostered sustained growth in recent years. The service sector is steadily recovering, with tourism being a significant aspect. Tourism has increased, boosting consumer demand and markedly affecting production in several service sectors, including transportation, housing, food and beverage, travel, arts, and entertainment, contributing favorably to economic growth. Industrial activity has consistently recovered, the industrial output index has seen a slight upward trend, and the government has taken measures to enhance the allocation of public investment resources.

Effective inflation management will enhance cash flow stability, a vital component of economic growth. Alongside beneficial factors, some obstacles and problems have hindered progress in 2023, as detailed: geopolitical uncertainties, global economic difficulties, slow recovery in aggregate demand, high inflation in various countries, and unstable supply chains have affected the domestic economy. Notwithstanding positive advancements in industrial production, progress continued to be slow and did not exhibit substantial acceleration compared to the corresponding period of 2022. This standstill was chiefly due to a decrease in orders, high input prices, and a lack of export markets, negatively affecting all areas of industrial production, especially the processing and manufacturing industries. Import and export activities underwent a sluggish recovery attributed to reduced global demand, rigorous monetary policy, and heightened inflation. The real estate market is unfavorable, characterized by limited cash flow, primarily due to substantial pressure to fulfill and repay corporate obligations in 2023. In 2023, attracting foreign investment has been ineffectual, as investors have not expanded their investment scale in projects in Vietnam due to the significant issues confronting the world economy and the commercial sector.

4.2 Analysis of descriptive statistics and Cronbach's alpha for factors affecting economic growth

Table 1 tests the reliability of the scale, including five independent factors: (1) FP, (2) MP, (3) QPS, (4) DT, and (5) PE. Besides, the dependent factor shows EG. **Table 1** shows that Cronbach's alpha for critical factors affecting EG is higher than 0.7. **Table 1** displays the descriptive statistics and Cronbach's alpha coefficients for factors associated with economic growth. Each construct has multiple items, with Cronbach's alpha reflecting internal consistency, while the mean and standard deviation characterize the distribution of responses. Below is a summary:

Code	Items	Cronbach's alpha	Mean	Std. deviation
	Fiscal policy (FP)	0.926	—	—
FP1	Government spending activities expenditure on goods	0.899	3.065	0.961
FP2	Government spending activities expenditure on services	0.912	3.075	0.986
FP3	Direct taxes are taxes levied directly on the wealth and/or income of the people	0.887	3.130	0.930
FP4	Indirect taxes are taxes levied on the value of goods and services	0.916	3.058	0.961
	Monetary policy (MP)	0.836	—	—
MP1	Suitable credit interest rates	0.783	3.530	0.840
MP2	Use a suitable and flexible credit limit tool	0.776	3.583	0.879
MP3	Flexible exchange rate	0.827	3.401	0.923
MP4	Use the required reserve ratio tool	0.782	3.479	0.868
	Quality of public service (QPS)	0.806	—	—
QPS1	Improve the professional qualifications, skills, and IT application of public servants	0.772	2.341	0.708
QPS2	Continue to propagate widely about public services to people and businesses	0.722	2.414	0.619
QPS3	Increase investment in the synchronous technical infrastructure system	0.793	2.411	0.682
QPS4	Regularly upgrade, maintain, and supplement computer systems to ensure network safety and security at all levels	0.737	2.464	0.708
	Digital transformation (DT)	0.923	—	—
DT1	Improve people's connectivity to high-speed internet	0.892	3.084	1.000
DT2	Strengthen digital education, promote high-quality workforce training	0.898	3.099	0.981
DT3	Continue to improve the logistics system, especially in linking industry and interdisciplinary infrastructure	0.892	3.138	0.936
DT4	Promote online payment method	0.915	3.024	1.009
	Political environment (PE)	0.940	—	—
PE1	Political stability	0.914	3.021	0.961
PE2	The system of legal documents is complete	0.925	2.995	0.992
PE3	Stable and competitive tax policies	0.931	3.089	0.929
PE4	Regulations on safety, consumer protection, environmental protection	0.916	3.019	1.019
	Economic growth (EG)	0.751	—	—
EG1	Annual GDP growth rate	0.597	3.486	0.931
EG2	GDP per capita growth rate	0.656	3.249	1.018
EG3	The service sector/GDP ratio increases year by year	0.751	3.113	1.069

Source: Authors collected and processed from SPSS 20.0.

Table 1.
Testing descriptive statistics and Cronbach's alpha for economic growth.

The total Cronbach's alpha for FP is 0.926, indicating substantial dependability. The mean values of various items span from 3.0654 to 3.1308, reflecting moderate agreement, while the standard deviations (SD) indicate diversity in replies. FP1 to FP4 delineate governmental expenditures and tax-related initiatives.

MP possesses an alpha of 0.836, indicating dependability. The average scores have increased from 3.4019 to 3.5835, signifying a greater consensus about comments on credit interest rates, currency rates, and reserve ratios. MP1 to MP4 concentrate on credit interest rates, adaptable credit limits, currency rates, and reserve ratios.

QPS exhibits a lower alpha of 0.806, signifying acceptable reliability. The average scores are below 3, ranging from 2.3414 to 2.4649, indicating a diminished perception of public service quality. QPS1 to QPS4 denote enhancements in public servants' competencies, public service engagement, technological infrastructure, and system advancements.

DT exhibits a high-reliability score of 0.923. The mean values span from 3.0242 to 3.1380, reflecting an overall favorable assessment of digital transformation initiatives. DT1 to DT4 encompass high-speed internet access, digital education, enhancement of logistical systems, and online payment solutions.

PE demonstrates substantial reliability, with a Cronbach's alpha of 0.940. The average values oscillate about 3, signifying judgments of modest political stability and legal structures. PE1 to PE4 emphasize political stability, the integrity of legal systems, fiscal policies, and safety laws.

EG, exhibiting the lowest alpha of 0.751, demonstrates moderate internal consistency. The mean values span from 3.1138 to 3.4867, indicating moderate perceptions of GDP growth and contributions from the service sector. EG1 to EG3 concentrate on GDP growth rates and the service sector's impact on GDP.

This summary conveys the dependability and perceptions associated with several elements influencing economic growth, offering a balanced perspective on critical economic indicators.

Table 2 shows five factors affecting economic growth, with a significance level of 0.01. The article's novelty is finding out the fiscal and monetary policy's most substantial impact on economic growth in Vietnam, with a standardized estimate of 0.487 and 0.156.

Table 2 displays the standardized estimates and significant levels of the key elements influencing EG. The correlations between economic growth and several factors such as FP, MP, DT, PE, and QPS are examined through a structural model. The findings indicate the subsequent outcomes: (1) FP exerts the most significant favorable

Relationships			Standardized estimate	S.E	C.R	P-value	Result
EG	<---	FP	0.487	0.045	7.616	***	Accepted H1
EG	<---	MP	0.156	0.042	3.162	0.002	Accepted H2
EG	<---	DT	0.113	0.022	2.656	0.008	Accepted H4
EG	<---	PE	0.111	0.032	3.107	0.002	Accepted H5
EG	<---	QPS	0.090	0.066	3.485	***	Accepted H3

Source: Authors collected and processed from SPSS 20.0, Amos, *** with 1%.

Table 2.
Testing critical factors affecting EG.

influence on economic growth, with a normalized estimate of 0.487. The critical ratio (C.R) is 7.616, and the p-value is highly significant (***), signifying a strong association. Consequently, FP is an essential determinant in fostering economic progress. (2) MP substantially affects economic growth, with a normalized estimate of 0.156 and a critical ratio of 3.162. The p-value is 0.002, indicating that this link is statistically significant. (3) DT exhibits a modest yet notable influence on economic growth, evidenced by a normalized estimate of 0.113, a C.R. of 2.656, and a p-value of 0.008. (4) PE benefits economic growth, evidenced by a normalized estimate of 0.111. The C.R. is 3.107, and the p-value is 0.002, indicating its importance. (5) QPS positively influences economic growth, with a normalized estimate of 0.090. The correlation coefficient is 3.485, with a significant p-value (***) indicating a substantial association.

In conclusion, all five components are essential and profoundly influence economic growth, with FP exerting the most substantial impact, succeeded by MP, DT, PE, and QPS.

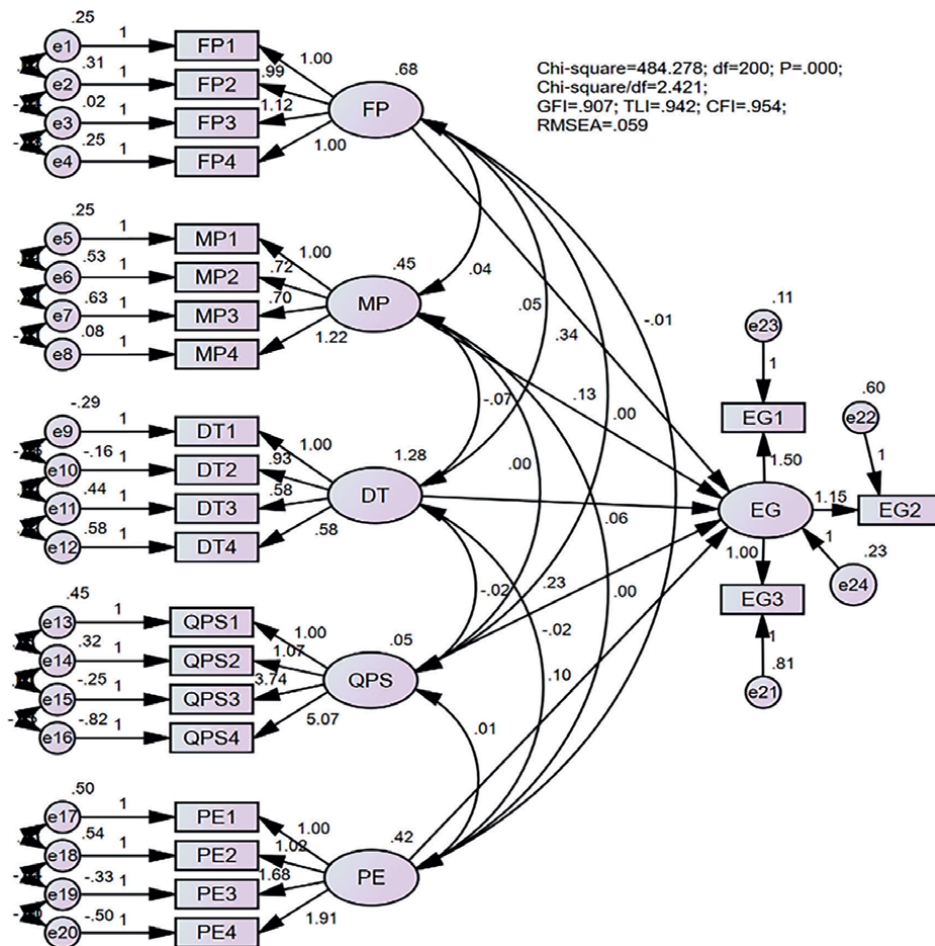


Figure 3. Testing for various factors affecting economic growth (ED). Source: Authors collected and processed from SPSS 20.0, Amos.

Parameter			SE	SE-SE	Mean	Bias	SE-bias	Result
EG	<---	FP	0.061	0.001	0.339	0.001	0.002	0.50
EG	<---	MP	0.062	0.001	0.137	0.003	0.002	1.50
EG	<---	DT	0.024	0.001	0.062	0.004	0.003	1.33
EG	<---	PE	0.044	0.001	0.108	0.001	0.001	1.00
EG	<---	QPS	0.083	0.002	0.207	0.002	0.003	0.67

Source: Authors collected and processed from SPSS 20.0, Amos.

Table 3.
Testing bootstrap 30.000 samples for factors affecting economic growth.

Figure 3 showed that the assessment of the key factors affecting economic growth: CMIN/DF = 2.421 (<5.0), GFI = 0.907 (>0.800), TLI = 0.942 (>0.900), CFI = 0.954 (> 0.900), and RMSEA = 0.059 (<0.08). The article aims to determine the five factors affecting economic growth in Vietnam, especially FP's most substantial impact on economic growth in Vietnam, with a standardized estimate of 0.487, which is the most important.

Table 3 illustrates the application of bootstrap testing with 30,000 samples to examine factors influencing economic growth at a significance level of 0.01. This outcome is wholly aligned with the principles of applied economic theory and practice in Vietnam. This outcome is scientific evidence for policymakers to consult and formulate accurate predictions.

4.3 Result discussion

The research findings indicate that Vietnam's growth rate is, in fact, declining, accompanied by numerous fiscal and monetary issues. In this environment, will fiscal and monetary policy contribute to future economic trends, and what obstacles are you encountering? We wish to underscore the significance of fiscal and monetary policy in the long-term growth. Countries that uphold effective macroeconomic policies will foster high and stable growth, resulting in enhanced budget revenues and a robust fiscal foundation. Consequently, they will ensure the sustainability of public debt and budget income while securing resources for developmental investment to uphold a low monetary growth rate. During that period, monetary policy is not misused to stimulate economic growth. To achieve the long-term growth objectives of the Vietnamese economy, it is essential to focus on the following matters:

1. The standardized value of 0.487 indicates that fiscal policy exerts the most significant impact on economic growth. The notably elevated C.R. of 7.616 and a p-value of *** (showing $p < 0.001$) signify that this link is very significant [3, 17, 40, 42]. The significant positive impact of fiscal policy on economic growth is due to its function in managing government expenditure and taxation. Fiscal policy influences aggregate demand and supply via public investment in infrastructure, social services, and productive industries, promoting economic development. Moreover, efficient taxation and government expenditures can foster a conducive climate for enterprises, enhance consumer consumption, and attract international investment. The findings indicate that policymakers should prioritize strategic budgetary measures to improve economic growth by concentrating on public investment that increases productivity and ensures

long-term economic stability. Moreover, the initial aspect is fiscal policy, which must guarantee the sustainability of public debt, encompassing two criteria: stabilizing the magnitude of public debt concerning state budget income and regulating debt obligations based on budget revenue. Enhancing the budget expenditure framework to diminish consumption and augment investment and developmental expenditures is essential. The state budget revenue should be reduced following unsustainable revenue sources while refraining from implementing new fees and charges. Fiscal policy should be countercyclical, particularly during periods of robust economic growth; a budget surplus is essential to amass resources and prepare for adverse conditions, such as the Covid-19 pandemic.

2. The correlation between monetary policy and economic growth, with a normalized estimate of 0.156, is significant despite being weaker than fiscal policy, as indicated by a p-value of 0.002. The C.R. of 3.162 substantiates the dependability of this estimate [6, 17, 31]. The beneficial impact of monetary policy on economic growth underscores the significance of suitable interest rates, adaptable exchange rate management, and the application of monetary instruments, like credit limitations and reserve ratios, to affect liquidity and credit conditions within the economy. Through the management of inflation, stabilization of the currency, and encouragement of lending, monetary policy can enhance investment, production, and consumption, thus fostering economic growth. These findings highlight the necessity for a balanced and flexible monetary policy framework that adapts to domestic and international economic circumstances. Moreover, the second aspect is monetary policy, which emphasizes regulating inflation by managing the expansion of the money supply and preventing excessive increases, as observed in the past decade. Monetary policy, particularly in Vietnam, must adhere to transparency regulations and provide clear explanations, which remains a notable deficiency. An erratic, opaque policy will astonish the economy and induce a detrimental shock. Monetary policy must adhere to defined principles; adjustments to interest rates should be justified, for instance, modifying interest rates to stabilize inflation, maintain the exchange rate, or decrease unemployment. During that period, the market, enterprises, and individuals will be able to predict.
3. With a standardized estimate of 0.113 and a C.R. of 2.656, digital transformation exerts a moderate but significant impact on economic growth, as confirmed by the p-value of 0.008 [9, 17, 32]. Digital transformation encompasses integrating digital technologies into various aspects of the economy, including finance, industry, and public services. It can drive productivity improvements, reduce transaction costs, and create new business models that spur innovation. The results suggest that further investment in digital infrastructure, such as expanding access to high-speed internet and promoting digital literacy, could enhance the productivity and competitiveness of the economy. This factor is becoming increasingly critical as economies shift toward more technology-driven growth models. Moreover, Vietnam is enhancing consumer access to inexpensive, high-speed internet by fostering equitable competition within the private sector. The transmission speed and quality of mobile and fixed bands in Vietnam are relatively stable; however, governmental support is necessary to enhance and expand the coverage of more diversified frequency bands. Vietnam persists in improving digital education and advancing high-quality worker training. Education in

the digital economy aims to foster knowledge of its benefits and problems while necessitating the comprehensive preparation of a trained workforce capable of adaptation and seizing chances. Enhance user trust by guaranteeing transparency regarding data privacy, network security, and legal issues within the company system.

4. The political context, with a normalized estimate of 0.111 and a p-value of 0.002, significantly influences economic growth. The C.R. of 3.107 signifies that this link is statistically significant [15, 17, 32]. A stable political environment is essential for sustaining investor trust, upholding the rule of law, and establishing a predictable regulatory framework. Political stability diminishes uncertainty, promoting both domestic and foreign investments. An established framework of legal documentation, competitive taxation policies, and safety and consumer protection regulations cultivates a business-friendly atmosphere that supports economic growth. Consequently, sustaining political stability and enhancing governance can profoundly influence the long-term economic growth. Moreover, stabilizing the political environment is essential for achieving sustained economic growth. Stability is both a foundation and an outcome of exceptional economic growth achievements. Stability constitutes an appropriate atmosphere for economic progress. Guaranteeing individuals' well-being fosters trust and cultivates peace and prosperity as the economy advances. The party committee, government, populace, and enterprises consistently maintain confidence in the established basis, the stability of political security, the safety of the social environment, and the collective will and aspiration for advancement. Vietnam will persist in advancing swiftly, decisively, comprehensively, and sustainably in promoting online payment. Consequently, digital payments are a fundamental component and a primary focus of the digital economy. Vietnam encounters significant hurdles as cash constitutes over 90% of the market. The Global Findex may serve as an essential metric for assessing this index soon. Accelerated advancement of electronic governance. The government must spearhead digital transformation.
5. The standardized estimate of 0.090, while the lowest among the components, indicates a statistically significant association between the quality of public services and economic growth, evidenced by a C.R. of 3.485 and a p-value of *** ($p < 0.001$) [17, 26, 31–33]. This suggests that, despite its lesser extent, the quality of public services has a favorable impact on economic outcomes. Practical and dependable public services, including education, healthcare, and infrastructure, foster human capital development and augment total economic production. Furthermore, enhanced public service delivery might elevate citizen happiness and faith in governmental institutions, which is crucial for maintaining social and economic advancement. Investments in public service quality should prioritize enhancing accessibility, optimizing service delivery efficiency, and utilizing technology to meet residents' requirements. Moreover, information technology is essential for socioeconomic growth. Information technology to streamline administrative processes and deliver public services enhances document-processing efficiency, minimizes expenses, augments transparency within governmental operations, and facilitates advantages for individuals and enterprises. Consequently, it is imperative to persist in innovating and enhancing the quality and efficiency of online public services across all tiers, particularly

online ones; advocate for the reform of administrative procedures; improve the business investment climate; streamline and standardize investment and construction processes for execution in an electronic framework; persist in refining bidding and auction protocols; bolster the utilization of science and technology; cultivate high-quality human resources; advance digital transformation; foster a green, circular, and sharing economy; and enhance the production capacity of enterprises, industries, regions, and the overall economy.

These findings are significant because fiscal and monetary policies are essential for stable currency, controlling inflation, and fostering sustainable investment in Vietnam's swiftly evolving economy. Strategic policy modifications can significantly enhance Vietnam's capacity to withstand global economic disruptions, promoting consistent growth and enabling the economy to adjust to fluctuating circumstances, as evidenced in 2022–2023.

In summary, the five identified elements, particularly fiscal and monetary policies, are fundamental foundations propelling Vietnam's economic growth, highlighting their vital role in fostering a resilient and adaptable economy capable of addressing both internal and global issues.

5. Conclusions

In 2022, the world economy faced many challenges, and leading economies will face many difficulties, adversely affecting all countries with sizeable economic openness. However, Vietnam is still considered a “Bright spot” in the world's “dark economic picture” with “Record” numbers compared to many years ago. The study has an in-depth identification and assessment of the factors that made up Vietnam's economic growth in 2022 and discovers the barriers to implementing development breakthroughs as a basis for arguments for some orientations and solutions for economic growth in 2023. The chapter finds five factors affecting economic growth with a significance level of 0.01, and five hypotheses are accepted. The article's value has the fiscal and monetary policy's most substantial impact on economic growth in Vietnam. Based on the above results, the Vietnamese Government needs to clarify the nature of fiscal and monetary policies and the effects of these two policies on economic growth and inflation goals, thereby explaining the interactive relationship between the two policies toward sustainable development and what needs to be done to ensure effective interaction. This issue needs attention in the process of operating the monetary policy of Vietnam, whereby it is necessary to be based on a scientific basis to choose which policies are mainstream and determine the impact dose of each tool. In each period, consistency, synchronization, support, and information-sharing principles should be ensured based on selecting implementation techniques to provide scientific and practicality toward the highest efficiency in coordination between two policies, especially in public debt management.

6. Policy recommendations

The findings indicate that fiscal policy, monetary policy, digital transformation, the political environment, and the quality of public services substantially affect economic development, but to differing extents. Fiscal policy emerges as the most

significant determinant, highlighting the necessity of precisely directed government spending and taxation strategies. Although less impactful, monetary policy is essential for economic stabilization and growth promotion via interest rate regulation and other monetary instruments. Digital transformation is increasingly vital in the contemporary economy, providing potential for innovation and enhanced efficiency. A stable political environment and the quality of public services, albeit less influential, are essential factors in sustainable economic growth. This comprehensive approach indicates that policymakers should implement a cohesive plan reconciling these diverse elements to attain sustainable economic development. In light of the prevailing global difficulties and uncertainties, coupled with a nation characterized by significant openness yet limited competitiveness and resilience to external shocks, unforeseen factors pose potential risks that are challenging to anticipate. To attain the ambitious growth target sanctioned by the National Assembly, it is imperative to concentrate on the execution of specific policies aimed at capitalizing on opportunities and addressing challenges as outlined below:

1. Vietnam should continue to implement monetary policy with caution, proactivity, flexibility, and efficacy and in tight alignment with fiscal, trade, and other policies. Meticulously observe market trends and local and international conditions to effectively implement and harmonize monetary policy instruments, stabilizing the monetary and foreign exchange markets and ensuring liquidity. Adjust interest and exchange rates to align with macroeconomic equilibrium, inflation, and monetary policy objectives. Stringently regulate inflation and meticulously observe trends, economic conditions, pricing, global inflation, and policy actions of principal economies. Prudent credit expansion, satisfying the monetary demand for credit capital, fostering growth, allocating credit to production and business sectors, priority areas, and economic growth drivers, rigorously regulating credit for sectors with inherent risks. Facilitating advantageous conditions for enterprises and individuals to obtain credit capital; instructing commercial banks to execute the 120 trillion VND credit package efficiently. Proactively executing the policy of revising debt payback conditions and sustaining debt groups to assist distressed firms.
2. Vietnam should continue to execute a judicious, targeted, and essential expansionary fiscal strategy. Enhance the administration of state budget income to guarantee accurate, adequate, and prompt collection; rigorously curtail spending, particularly recurrent expenses, while promoting efficiency and combating wastefulness. Stringently regulate the budget deficit; guarantee that governmental debt remains within secure thresholds. In 2024, it is anticipated that while monetary policy may be relaxed due to the US Federal Reserve indicating potential interest rate cuts, the decrease will be modest owing to persistent inflation, rendering domestic monetary policy sensitive. Furthermore, prevailing interest rates are relatively low and will likely be challenging to decrease until mid or late 2024. Thus, fiscal policy that enhances public investment and utilizes taxes and fees to bolster aggregate demand, consequently increasing the economy's aggregate supply, remains the primary option in 2024. Public investment has consistently served as a crucial catalyst for economic growth; thus, it is imperative to sustain the promotion of public investment, prioritize near-completion projects, and expedite the implementation of significant national initiatives and critical breakthrough endeavors that facilitate GDP growth, generate employment,

enhance consumption, improve logistical efficiency, foster regional connectivity, bolster competitiveness, and minimize the time and costs associated with the movement of goods and services.

3. Vietnam should continue to enhance the distribution of goods via digital platforms and e-commerce to augment domestic consumption and encourage Vietnamese citizens to prioritize utilizing domestically produced goods. Concentrate on updating the distribution system in rural and mountainous regions to facilitate the delivery of Vietnamese goods to these areas and to enhance domestic consumption initiatives in locales with distinctive products and advantages. Maximize opportunities and market recovery trends to enhance exports, effectively utilize and persist in promoting bilateral and multilateral trade agreements to broaden the market reach for Vietnamese products. Encourage and draw international tourists to Vietnam. This extensive sector generates spillover effects, fostering the development of interconnected industries such as accommodation, food and beverage, transportation, trade, and various services while augmenting foreign currency inflow and addressing local labor resource challenges to engage in the domestic service export production chain.
4. Vietnam persists in achieving stabilization, and the political regime is a distinct type of social movement characterized by order and discipline, which ensures the preservation of the structures and functions inherent to its nature. Stable and fortifying do not result in chaos or instability. Political stability is an essential element of a country's sustainable development. Implement a strategy to attract foreign investment capital into Vietnam, transitioning from indiscriminate attraction to selective engagement aimed at enhancing national production capacity and fostering synergies between the foreign direct investment sector and the domestic economy, particularly in emerging fields such as renewable energy, semiconductor manufacturing, and other industries that support socioeconomic development, sustainable economic growth, and a green economy. The agriculture, forestry, and fishery sectors have consistently exhibited stable growth rates over the years, reinforcing their status as a cornerstone of the economy. Achieving breakthrough growth is challenging because the industry relies on fixed elements such as land, climate, and growth duration.
5. Vietnam delivers public services that guarantee equity and equality among various groups and areas within society. Individuals residing in metropolitan and delta regions have convenient access to public services, whereas those in remote and mountainous locations frequently encounter challenges in access due to geographical obstacles. Geographic location, developmental status, or service supply network are not assured. Enhance decentralization in the administration of online public service delivery for local governments; reinforce discipline and administrative rigor; and foster initiative adaptability, local potential, and advantages in management and policy formulation. Simultaneously, it is essential to enhance socialization in developing and delivering online public services, particularly in environment, transportation infrastructure, culture, education, health, and information and communication.

Limitations and future research: The study tackles five essential factors: fiscal and monetary policy, digital revolution, public service quality, and political environment.

Foreign direct investment, labor market dynamics, international trade, and technical innovation essential for economic growth were ignored. A detailed analysis may be limited. Future studies should widen the analysis area, include longitudinal data, and examine component relationships. This will help you understand economic growth dynamics. Qualitative and comparative methods may yield more detailed and accurate understandings, improving policymaking and economic planning.

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Author contributions

Lu Phi Nga and Phan Thanh Tam did everything equally, such as the conception and design, data analysis, critical revision of intellectual content, and final approval of the version to be published.

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The Impact of Trade Openness on Economic Growth in Rwanda: An Empirical Analysis

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Abstract

This study examines the influence of trade openness on Rwandan economic growth from 1996 to 2022. Openness to trade and economic growth are positively correlated, according to a number of “scientific studies and economic theories”. According to the Unit Root Augmented Dickey-Fuller (ADF) test, the sequence’s order was integrated at the same level. Both the long-run and short-run connections were evaluated using the cointegration approach and the error correction model (ECM) technique. The results of the long-run relationship estimation indicate a strong and positive correlation between trade openness and gross domestic product (GDP) that correlated with exchange rates, interest rates, inflation, and foreign direct investment. The results of the short-run relationship estimation indicate that the GDP and exchange rate have a positive and statistically significant relationship, whereas the relationships between trade openness, interest rates, inflation, and foreign direct investment were found to be statistically insignificant. The aforementioned findings indicate that trade openness and economic growth are positively correlated. All things considered, the results emphasize how important trade openness is to Rwanda’s economic development and how important it is to implement laws supporting global commerce to fulfill the nation’s economic goals.

Keywords: trade openness, economic growth, exchange rate, interest rate, FDI, inflation

1. Introduction

International trade has grown in importance to measure the high and sustained economic growth that the world economy is striving for claims [1]. International trade has played a crucial part in the growth processes of both developed and emerging nations, as observed by Ijirshar [2]. Since the dawn of civilization, trade has been essential to human advancement and wealth. Experience has shown that increased trade activity improves a nation’s economic standing.

These days, trading is easy and international because of scientific and technological advancements [3]. International financial organizations such as the World Bank, and International Monetary Fund (IMF), and the World Trade Organization (WTO) have advised nations vigorously to pursue trade liberalization, ensure macroeconomic stability, and give other drivers of economic growth careful consideration [4]. Participation in international trade, according to Padhyay [3], is a good indicator of a nation's total economic output. These nations fared well because of their free markets and faster trade growth.

Trade openness, according to Mugun [5], is the degree to which the economy of a particular nation is oriented both inward and outside. According to George [6] economies that exhibit an outward orientation are those that make significant use of the chances, they have to trade with other nations, while economies that exhibit an inward orientation fail to seize or are unable to seize such possibilities. Trade openness is defined by other researchers as the degree to which a country participates in international economic operations that allow goods and services to pass through its borders with minimal restrictions [7]. According to Keho [8], trade openness is calculated as the ratio of imports to GDP minus exports. Furthermore, studies by scholars [2, 4, 9] demonstrate the beneficial effects of trade openness on economic growth. According to Ozturk and Radouai [10], trade openness can undoubtedly increase economic growth by expanding effective resource allocation and enhancing total factor productivity through technological advancement and knowledge circulation. Therefore, trade is viewed as a way to raise living standards and income levels in a particular country [9]. Trade openness is one of the policy tools used by nations. An open trade policy is one that is neutral toward trade activity [3].

Trade openness and international trade are essentially connected. The degree to which a nation participates in international trade by removing trade restrictions like tariffs and quotas is known as trade openness [11]. Increased trade openness encourages cross-border interchange of products and services and grants more access to foreign markets, which in turn promotes international trade. Increased specialization, economies of scale, and access to a wider variety of goods are all benefits of this interaction that can lead to economic growth [12]. International commerce, in accordance with Ntihemuka [1], strongly supports the theory that increased trade openness might favorably stimulate economic growth [4]. The majority of nations opened up their economies after joining the WTO to maximize the benefits of global commerce. However, since increasing exports and expanding the manufacturing base with enough infrastructure was a challenging challenge for them, none of them succeeded in achieving the goal of achieving exorbitant interests. While there are many benefits to free trade, other policies that affect trade should also be given the appropriate weight because they have a significant economic influence [3].

In this regard, Rwanda has been aggressively negotiating trade deals and opening up its economy in recent years. With support from the World Bank and the International Monetary Fund (IMF), Rwanda has effectively completed important structural and economic reforms while maintaining steady growth rates. To expand markets, Rwandan trade must travel outside of our boundaries more frequently, according to Ntihemuka [1]. Making a significant contribution to international trade is a fantastic way to boost economic expansion and help the economy transition to a sustainable growth path [13]. This research analyzes the impact of trade openness on Rwanda's economic growth and provides valuable insights for Rwandan policymakers aiming to promote long-term economic development and poverty alleviation through trade liberalization and reform.

Due to its landlocked status, Rwanda has among the highest import and export shipping prices worldwide. Ntihemuka [1] states that the government of Rwanda has made economic growth one of its top priorities in its major initiatives to raise living conditions and create a self-sustaining Rwandan economy. According to Esperance [14], the rate of economic output for the 2017–2018 fiscal year was 8.9%, 3.4% higher than the previous fiscal year. This significant gain is mostly due to the service sector, where commerce grew by 15% and taxes by 8%. Based on these results, we can also draw the conclusion that Rwanda's GDP is significantly influenced by trade.

Rwanda is the only low-income country (LIC) in the top 30 and is regarded as the 29th easiest place in the world to do business [15]. This is because the Single Customs Territory has shortened the time release needed for import and export and made it simpler for people to establish businesses and obtain loans. Despite its 9.5% annual economic growth, Rwanda imports more goods than it exports [16], which results in a trade deficit despite the country's still modest trade participation. In order to achieve its goals of becoming an upper-middle-income nation by 2035 and a high-income economy by 2050, Rwanda must find specific answers to these problems in order to achieve double-digit average annual growth rates. One way to do this is by encouraging foreign trade to become one of the primary drivers of economic growth. It will take a medium to lengthy time to increase Rwanda's involvement in global trade. Although Rwanda has recently experienced considerable economic changes and liberalization, including opening its markets to foreign commerce, the specific influence of the openness to trade on Rwanda's economic development outlook remains unclear. The data provided will be used to analyze the relationship between Rwanda's openness to trade and its economic growth. This study provides valuable insights for Rwandan policymakers aiming to promote long-term economic development and poverty alleviation through trade liberalization and reform. Studying the link between openness for trade and Rwandan economic growth allows us to understand the consequences of trade openness in order to formulate strategies and policies that foster economic growth while reducing negative effects on certain sectors and decreasing inequality.

2. Objective

This research aims to investigate the impact of trade openness on the economic growth of Rwanda for the period of 1996 to 2022. It is crucial to examine the effect of the openness to trade on the economic growth and determine whether there is a cause-and-effect link between these two factors for Rwanda.

3. Research hypotheses

In this study, the researcher is going to test the relationship between trade openness and economic growth, based on the following hypothesizes:

Null Hypothesis (H₀): There is non-positive relationship between GDP and trade openness in Rwanda Alternative.

Alternative Hypothesis (H₁): There is a positive relationship between GDP and trade openness in Rwanda.

4. Literature review

4.1 Theoretical review

Regarding the amount of international trade between countries in their separate models, the two well-known economists in the field of international trade held different opinions. According to the Ricardian model, international trade depends only on how productive labor is produced in various countries. Conversely, the Heckscher-Ohlin-Samuelson model deduced that the degree of global commerce is determined by the disparity in the factor endowment of various countries [12].

A country's best interest, according to Ntihemuka [1] highlighted that a trade surplus occurs when the exports of goods are more than the imports, increases government intervention to achieve a trade balance surplus, and views trade as a zero-sum game in which the profit of one country results in the loss of another. These arguments date back to the sixteenth century, according to mercantilists. The primary objective of mercantilism was to increase the power of the nation's state wealth, which is defined by its gold holdings in the treasury [17]. Since mercantilism is essential to economic expansion, high tariffs on domestic industries are necessary to discourage imports and encourage exports.

In 1776, Adam Smith created a hypothesis explaining how national specialization led to gains from international trade. This implies that a nation has a clear edge in the manufacturing of goods when it outperforms all other nations and raises overall productivity by participating in a free trade agreement. If two countries have similar resources and one can manufacture a commodity more effectively at a lower input cost than the other, then that nation has an absolute advantage over the other in producing that commodity. Countries would therefore be restricted to the commodities and services produced inside their borders in the absence of foreign commerce. Consequently, greater productivity and benefits from international commerce followed by enhanced efficiency production runs offer more incentives for the development of more productive work processes. Additionally, Smith demonstrated that workers may double their proficiency six times by performing the same tasks again and can save time by switching from one type of product manufacturer to another [17].

The classical theory of comparative advantage was developed in 1817 by David Ricardo, who also developed the concept of comparative advantage and the classical theory of international commerce. Ricardo was the first to demonstrate that variations in comparative advantage, as opposed to variations in absolute advantage, are what drive international commerce. The ability of a country to produce a good at a lower opportunity cost than another is known as comparative advantage. Thus, the necessity to reduce production costs gives rise to international commerce. What is meant by "competitive advantage" is "comparative advantage." Therefore, even if one country produced both commodities more efficiently than the other in a scenario involving two countries and two commodities, trade would still occur [18]. Therefore, a country would engage in international trade if it discovered that consuming goods and services from elsewhere was less expensive than consuming those produced domestically. To maximize the benefits of international trade and advance the nation's economic progress, a nation ought to focus on manufacturing more productive items.

Bertil Ohlin and Eli Heckscher put out this notion. By adding components of evolutionary trade theory, neo-classical economics sought to alter several features of classical economic theories. Their hypothesis adds capital as a second development

driver, providing a more compelling explanation for comparative cost differences between countries. DeBate et al. [19] assume that “there are two countries, two commodities, and two production variables”. The potential obstacle arises from the fact that, although countries utilize the same technology, the product is made domestically using rather labor-intensive methods. It might be made using relatively capital-intensive methods elsewhere. Because of its fatal weakness, the Heckscher-Ohlin theorem asserts that every nation exports the product produced in that nation, which allows for the relatively intensive use of the factor that is present in that nation’s relative abundance. This suggests that a country that produces a product that requires a lot of effort must do so in exchange for a product that is produced using labor-intensive methods with comparatively abundant resources in another nation. The addition of a second production element appears noteworthy to all of them. Because of this, the approach of neo-classical theory differs fundamentally from that of classical theory in some key areas, particularly in how it addresses the relationship between income distribution, factor allocation, and international commerce [18].

A key figure in the development of the new trade theory was Paul Krugman. The idea served as the basis for industrial policy and concentrated on leveraging market flaws like imperfect competition and externalities as trade drivers in order to achieve economies of scale or decrease unit production costs linked to a wide output scale. Consequently, industrial policy can increase national revenue by encouraging the growth of industries with positive externalities and helping local businesses achieve market domination overseas [17].

The export-led growth hypothesis, according to Solomon and Tukur [20], is predicated on the fundamental idea that the expansion of exports primarily facilitates an economy’s ability to grow. This demonstrates that an economy’s performance and its amount of exports are strongly correlated. According to this theory, the expansion of exports is a significant factor in determining the overall growth of differences, in addition to the availability of labor and capital. This theory is based, among other things, on the assertion made by Feder [21] that increasing exports has the potential to benefit non-export sectors by improving their resource management and production techniques and making these sectors more efficient. Furthermore, Krugman [12] claimed that increasing exports will lead to higher productivity as well as easier access to overseas markets and foreign exchange, providing further evidence in favor of the export-led growth argument.

Whereas numerous earlier studies have emphasized the role that trade plays in promoting long-term economic growth, according to macro-econometric studies, nations with open economies typically experience faster economic growth than those with closed economies. Similarly, micro-econometric results indicate that export-oriented businesses typically grow more quickly.

According to David Ricardo’s Comparative Advantage Model, a country should focus on producing and exporting goods in which it has a comparative advantage to gain from international trade. This is because, under trade liberalization, countries can freely trade by exporting what they are best at producing and importing what they are less efficient at. If all countries adhere to this model, international trade would expand, leading to more efficient and effective use of resources.

This study seeks to examine how trade openness impact economic growth. Trade openness facilitates access to international investors, which can stimulate market growth and strengthen market position. Frankel and Romer [22] have presented convincing evidence supporting the beneficial impact of transparency on economic growth, as suggested by new growth theories. They contend that countries that are

more open to foreign trade have increased potential to adopt advanced technology from developed countries, thus enhancing economic growth in developing nations.

Furthermore, there is a belief that a country's progress is linked to how much it engages in international trade. According to Wagner [23], being more involved in exporting to global markets leads to increased competition and development within the country. Mora and Torres [24] provide evidence that supports the theoretical relationship between the real exchange rate and Costa Rica's exports and imports from 1991 to 2006. They discovered that deliberately keeping the currency undervalued to stimulate economic growth could result in what is known as a "beggar my neighbor impact." This term refers to a situation where competitive devaluations occur between countries, ultimately harming all economies involved. This phenomenon was notably exacerbated during the spread of the Great Depression in the 1930s [25]. This argument also underpins concerns regarding China's policy of undervaluing its currency [26].

When a country seeks to protect its local industries by implementing extra tariffs or quotas on imported goods, it initiates a trade conflict. This approach may initially benefit domestic producers and create jobs, but in the long term, it leads to job losses and obstructs trade and development for all participating nations. Such tariffs ultimately hinder economic growth.

In conclusion, we anticipate that trade openness will positively impact economic growth. Consequently, examining these macroeconomic factors and suggesting appropriate trade policies to promote economic growth is essential.

4.2 Empirical review

Globally, many scholarly investigations have examined the impact of trade liberalization on economic expansion. The results and conclusions of these investigations have been varied. A strong, long-term association was discovered when 158 nations analyzed the correlation between openness and growth [27]. Then, he examined the short-run relationship using the error correction model, arrived at a negative short-run adjustment, and proposed that transparency may harm the economy during short-run adjustment.

While maintaining a largely optimistic and significant outlook has a beneficial long-term influence, a positive short-term adjustment results from positive income. As a result, the findings suggest that high-income and low-income nations use distinct trade arrangements. To conduct an empirical study on the association between openness and growth using a panel fixed effects estimate process, Tahir and Lodhi [4] used data from two samples of nine industrialized nations from 1990 to 2009. The major conclusions demonstrate a favorable and statistically significant association between trade liberalization and growth in the economy. Additionally, labor, education, democracy, and domestic investment all have a substantial and statistically significant impact on economic progress. The findings also suggest that policies that are erratic, like market price volatility, are detrimental to long-term economic growth. Lastly, they advise developed nations to liberalize trade with other countries, preserve macroeconomic stability, and give other factors that influence economic development for favorable attention to grow economically more quickly in the long run.

A study on how foreign commerce affects economic growth has been conducted in South Africa. In this study, the Vector Autoregressive was employed, and the variables under examination were GDP, exports, openness to trade, and the exchange rate. The results demonstrate the cointegration of the variables. The study discovered

numerous unidirectional relationships between the pairs of variables included in the model using Granger-causality analysis. The study's findings and recommendations may be used by policymakers in the development and formulation of economic policies for South Africa. The study's conclusions might improve South Africa's economic policies and those of other developing nations traveling in the same direction [28].

Yusuf and Omar [29] looked at Tanzania's trade openness and the impact it had on economic growth from 1981 to 2017. The association between trade openness and economic growth was tested using cointegration and the vector error-correction mechanism (VECM) technique, and the casual relationship between the variables was investigated using the Granger causality test. The variables were integrated after taking the first difference, according to unit root tests, and the Johansen cointegration result confirmed this. Tanzania's economic growth during the study period was positively correlated with trade openness, as indicated by the VECM estimate. This positive correlation may have resulted from Tanzania opening its borders to foreign traders. Furthermore, the Granger causality test showed that trade openness and economic growth in Tanzania are not causally related. The study's conclusions suggested that the government support the development of additional local businesses and draw in more capital to boost the nation's export-oriented manufacturing sector.

As stated by Ntihemuka [1], the impact of international commerce on economic growth is a topic of continuous debate and investigation, spurred by the rise in global trade volumes and the reduction of trade barriers. The speed of adjustment term (ECM) was also discovered to be significant. The impact of short-term causality, which follows from variables related to the gross domestic product, shows that there is short-term causality between exports, domestic investment, and the currency rate. Regretfully, as mentioned in this report's abstract, there was no variable that indicated how significant the trade barrier was. As a result, the conclusions drawn from this discussion are false.

Using empirical analysis and the Wald test, import, export, domestic spending, and exchange rates are examined in connection to GDP. The results show that the series are cointegrated. A significant and positive correlation has been found between GDP and exports with domestic investment, according to the results of the short- and long-term relationship calculations. It has been discovered that imports and exchange rates have a negative relationship and are statistically significant for GDP. Countries all across the world are liberalizing trade because they see it as one of the most important tools for advancing economic progress. The paper does an empirical analysis of how trade openness has affected Kenya's economic growth between 1970 and 2014.

In secondary and postsecondary institutions that are used to generate human capital, the enrollment coefficient as a proportion of the whole population was negative and statistically significant. The inflation used as a measure of macroeconomic stability was statistically significant and negative. Ultimately, they observed that in order to boost economic growth and the general public's standard of living, Kenya has to quicken the trade liberalization procedure [30]. It is clear from the non-linear link between trade openness and economic growth that trade gains are not always guaranteed. The impact of trade openness may vary depending on the level of trade openness. Sub-Saharan African nations must so increase their economic growth through foreign commerce while effectively regulating trade openness, particularly with regard to imports of consumer products. According to our research, trade liberalization should be accompanied by complementary measures that increase institutional effectiveness, attract new investment capital, and help people acquire new skills and adapt to changing circumstances. As a result, it is impossible to view

trade globalization in a vacuum. More policies and tactics are required to enhance its impact on economic growth. Sub-Saharan nations should implement appropriate policy changes to encourage investment, facilitate efficient governance, and foster the accumulation of human capital [31].

According to Frankel and Romer [22] a cross-country analysis found that trade openness has a significant positive effect on per capita income. Similarly, Dollar and Kraay [32] examined data from developing countries and concluded that greater trade openness is associated with faster economic growth, higher investment levels, and poverty reduction. However, Rodrik [33] warns that while trade can stimulate growth, its effectiveness largely depends on complementary factors such as institutional quality, governance, and human capital.

In Africa, research indicates that the trade-growth relationship is influenced by infrastructure quality, governance, and regional trade agreements. Sachs et al. [34] found that open economies in Africa tend to grow faster than closed ones, but policy inconsistencies and weak institutions often limit the benefits of trade liberalization. Similarly, Yeats [35] analyzed intra-African trade and highlighted that regional integration efforts, such as the African Continental Free Trade Agreement (AfCFTA), can enhance economic growth through increased market access and trade efficiency. However, Balamoune-Lutz and Ndikumana [36] argue that trade openness alone is insufficient for growth in sub-Saharan Africa unless supported by strong institutions and infrastructure investments.

Rwanda has actively pursued trade liberalization through policies such as membership in the East African Community (EAC) and participation in the AfCFTA that facilitate regional trade. Empirical research on Rwanda suggests that trade openness has positively influenced economic growth but also presents challenges. Nsengiyumva and Uwitonze [37] found that Rwanda's trade liberalization efforts have contributed to GDP growth, although the volatility of export earnings remains a concern. Similarly, a report by MINECOFIN noted that while trade openness has increased foreign exchange reserves, Rwanda still faces a trade deficit due to high import dependency.

5. Trade and economic growth in Rwanda

5.1 Trade performance of Rwanda

As per the 2019 study from World Bank, Rwanda is undergoing robust economic growth, with an average of annual growth rate of more than 7% during the past two decades. The nation's economy expanded by more than 8% in 2018 as a result of greater agricultural productivity, increased international prices for some conventional exports, increased travel and tourism, and a rebound in building activity. These factors helped the nation recover from a 2016 cyclical slump and drought. Inflation in Rwanda in 2018 was less than 5%, the country's "debt-to-GDP ratio is relatively low and rising steadily at 47.1%, the share of foreign assistance (external grants and loans) in the national budget has dropped from over 80% to 32.4%" over the past 10 years, and there are a number of other positive economic indicators. In the 2019 poll, Mauritius was ranked second best in sub-Saharan Africa, while Rwanda was ranked 29th out of 190 economies in the World Bank's Ease of Doing Business Index. Rwanda is ranked highly in this index. Africa [38] states that an economy's growth spikes are usually associated with export expansion. Consequently, it was advised that Rwanda

needs better export performance in order to accomplish the objective of reaching middle-income status and subsequent objectives. Exports frequently result in complex lama productivity increases through the use of economies of scale, integration of foreign technology, management, and business processes.

Product exports have increased in value by 37%, from USD 840.7 million reported in 16/17 to USD 1152.0 million, according to Onesphore [39]. This growth was specifically ascribed to the production of minerals (59.7%) and other common commodities (53.4%). Furthermore, there was a 17.8% and 18.5% growth in tea and coffee exports, respectively, which can be attributed to a 10.0% and 10.5% increase in export value. Re-exports rose by 26.9 13%, primarily as a result of the strong demand from the DRC and Burundi, two nearby countries. This led to a 30.1% increase in volume. Rwanda's primary exports include minerals, tea, and coffee. Agricultural goods like fruit and nuts, vegetable textile fibers, vegetable fats, grains, spices, beans, and so on are probably going to be shipped to Rwanda in the near future. In the medium term, Rwanda could focus on promoting more advanced export goods such as refined food and beverage items (such as cereals, honey, milk, juices, and confectionery), wood products (such as sawn wood, wood, and charcoal), building materials (such as marble or other stone-based building materials, rebar, and pneumatic inner tubes), rubber products such as natural rubber and pneumatic inner tubes, and tire essence extraction. Africa [38] states that during the fiscal year 2017–2018, imports of goods climbed by 6.6%. This increase was attributed to increases in energy products and intermediate goods of 14.2% and 14.0%, respectively, over the previous fiscal year. As a result, the corresponding volume increases were 17.7% and 15.2%. Following a decrease in the preceding fiscal year, capital goods experienced a growth of 1.9%. Consumer items have increased by 5.8% as a result of a 15.3% growth in volume over the 16/17 fiscal year. One advantage of imports for a developing nation like Rwanda is that it gives them access to higher-quality commodities and/or higher technology. It has been demonstrated that high-quality production inputs are necessary to produce high-quality goods that are successful in the export market. Even while it might still be worthwhile to use imported production elements to produce high-quality items for export markets, we need at least to be aware of the job impact. According to Africa [38] "From US\$ -1,155.2 million in the previous fiscal year" 2016–2017 to US\$ -1058.4 million in the current fiscal year 2019, there was an 8.4% improvement in the trade balance. This, the study indicates, was brought about by a 37.0% rise in export value in 2017–2018 as contrasted to a 6.6% increase in import value in the same year (2016–2017).

Based on the export coverage of imports, it went from 45.3% in the previous year to 58.3% in 2017/2018. The service sector underperformed, with a 66.1% increase in its deficit as service debit (import) climbed by 11.5%, while service credit (export) decreased by 2.8%. This was mostly because travel debit (import) increased by 14.6%, while travel credit (export) decreased by 10.3%.

5.2 Economic growth performance in Rwanda

The World Bank (2024) reports that Rwanda's GDP increased by 7.6% in the first three quarters of 2023, despite a challenging global environment and the recent floods that destroyed infrastructure and agricultural commodities in April and May of 2023. This assertion is made in the 22nd edition of Rwanda Economic Update (REU), titled Mobilizing Domestic Savings to Boost the Private Sector in Rwanda.

The report continues by stating that the services sector, ongoing domestic demand, and the revival of the industrial sector were primarily responsible for the

robust growth and the better economic trajectory. The REU notes that through balancing inflation control, keeping fiscal constraints, and skillfully managing foreign deficits, Rwanda has proven to have a strong banking industry. Despite rising external deficits and the depreciation of the Rwandan franc, fiscal discipline was preserved thanks to prudent fiscal management strategies. The economy was bolstered by the banking sector's sustained stability and prosperity.

In 2023, Rwanda's economy demonstrated resilience and adaptation by achieving a high growth rate despite a number of difficult external and internal variables. The World Bank advises the nation to continue its careful fiscal management by cutting back on discretionary spending and giving human capital investment first priority.

The REU projects that GDP growth will pick back up speed in 2024–2026, averaging 7.2% growth. The expected rebound in international tourism, new building initiatives, and a rise in manufacturing activity are the main sources of optimism. The goal of fiscal consolidation will remain to be cutting subsidies, managing state-owned businesses, and enacting tax reforms to increase the revenue base.

However, there are a number of serious dangers associated with this prognosis, such as interruptions to commerce, the global economy, and the availability of concessional resources. On the home front, recurrent weather-related shocks may lead to lower food production and higher food costs, which would be detrimental to low-income households. The study, which focuses primarily on the private sector, emphasizes the vital connection between the expansion of private sector investment and the currently low level of domestic savings capacity. Rwanda's savings rates are lower than those of other East African nations, despite noteworthy progress in savings mobilization. This has an effect on the availability of capital for businesses, particularly small- and medium-sized ones.

The adoption of incentives and subsidies, educational initiatives that highlight the advantages of saving, and a thorough policy approach are just a few of the tactics the REU recommends to increase domestic savings. Key interventions for successful savings mobilization include promoting customer-centric product development, utilizing digital financial literacy initiatives, and interacting with the Rwandan diaspora.

6. Research methodology

In this study, we have collected annual time series data from the World Bank.

6.1 Data analysis techniques

For the purpose of better understanding the relationship between Rwanda's economic development and trade openness, the researcher has developed an econometric model in this study. Techniques for time series econometrics like the "Augmented Dickey-Fuller (ADF)" stationary test, "the cointegration test to examine the long-run relationship between trade openness and economic growth, and the error correction model (ECM)" model were utilized to determine the rate of adjustment and the intricate relationship between foreign direct investment and trade openness. (ECM) Error collection.

6.2 Model specification

The model utilized in the study can be stated in its functional forms as follows:

$$GDP = TO, FDI, EXR, IR, INFL \quad (1)$$

where:

GDP : Gross domestic product is the dependent variable

TO : Trade openness

IR : Interest rate

INFL : Inflation

EXR : Exchange rate

FDI : Foreign direct investment

$$GDP_t = \beta_0 + \beta_1 TO + \beta_2 FDI + \beta_3 IR + \beta_4 EXR + \beta_5 INFL + \varepsilon_t \quad (2)$$

7. Discussion and results

7.1 Effect of trade openness on GDP

The coefficients in the regression analysis in **Table 1** shed light on how different factors affect GDP. Positive coefficients for “Trade Openness (LTO), Exchange Rate (LEXR), and Foreign Direct Investment (FDI GDP) indicate that increases in these variables are positively correlated with GDP, most likely at a significance level of

Dependent variable: LGDP				
Method: Least squares				
Date: 06/11/24; Time: 10:08				
Sample: 1996 2022				
Included observations: 27				
Variable	Coefficient	Std. error	t-Statistic	Prob.
C	20.98588	2.199453	9.541406	0.0000
LTO	1.143129	0.342528	3.337332	0.0031
LEXR	0.578509	0.229303	2.522899	0.0198
IR	−0.100194	0.062074	−1.614094	0.1214
INFL	−0.104126	0.063662	−1.635596	0.1168
FDI_GDP	0.194291	0.042707	4.549338	0.0002
R-squared	0.947393	Mean dependent var.		22.26219
Adjusted R-squared	0.934868	S.D. dependent var.		0.711662
S.E. of regression	0.181623	Akaike info criterion		−0.380638
Sum squared resid.	0.692725	Schwarz criterion		−0.092674
Log-likelihood	11.13862	Hannan-Quinn criter.		−0.295011
F-statistic	75.63795	Durbin-Watson stat.		1.701890
Prob. (F-statistic)	0.000000			
Source: (Author's computation using EViews, 2025).				

Table 1.
Effect of trade openness on GDP.

less than 5%. To be more precise, a one-unit increase in LEXR is correlated with a 0.578509 increase in GDP and other explanatory variables holding constant, a one-unit increase in FDI GDP is linked to a 0.194291 increase in GDP and other explanatory variables holding constant, and a one-unit increase in LTO is linked to a 1.143129 increase in GDP. Conversely, the coefficient for inflation (INFL) has a probability of 0.1168, which is more than the 5% significance level. In contrast, the coefficient for interest rate (IR) has a probability of 0.1214, which is not statistically significant. Thus, it does not affect GDP. The overall significance of the regression model is indicated by the high F-statistic of 75.63795 and the corresponding probability around zero, implying that at least one of the independent variables significantly affects GDP. Furthermore, the high adjusted R-square value of 0.934868 suggests that the independent variables in the model have a good explanatory power, explaining around 93.4%” of the variation in GD.

7.2 Cointegration test

H0: $\delta = 0$ there is no cointegration.
H1: $\delta < 1$ there is cointegration.
Based on the results in **Table 2**, as the |ADF| test statistic equals -4.449592 , which is greater than the |ADF| test critical, which is -2.981038 at 5% of statistic

Null hypothesis: U has a unit root				
Exogenous: Constant				
Lag length: 0 (Automatic—based on SIC, max lag = 6)				
			t-Statistic	Prob. [*]
Augmented Dickey-Fuller test statistic			-4.449592	0.0017
Test critical values:	1% level		-3.711457	
	5% level		-2.981038	
Augmented Dickey-Fuller test equation				
Dependent variable: D(U); Method: least squares				
Date: 06/11/24; Time: 10:10				
Sample (adjusted): 1997 2022; Included observations: 26 after adjustments				
Variable	Coefficient	Std. error	t-Statistic	Prob.
U (-1)	-0.876596	0.197006	-4.449592	0.0002
C	0.007293	0.032156	0.226790	0.8225
R-squared	0.452041	Mean dependent var.		0.007542
Adjusted R-squared	0.429209	S.D. dependent var.		0.217022
S.E. of regression	0.163962	Akaike info criterion		-0.704566
Sum-squared resid.	0.645201	Schwarz criterion		-0.607789
Log-likelihood	11.15936	Hannan-Quinn criter.		-0.676698
F-statistic	19.79887	Durbin-Watson stat.		2.016671
Prob. (F-statistic)	0.000168			
[*] One-sided p-values.				
Source: (Author's computation using EViews, 2025).				

Table 2.
Cointegration test.

level of significance, as well as the p-value 0.0017, which is less than 5%, shows that the error term (U_t) is stationary at level, according to the above E-views results for the stationarity test in residuals (error term). Consequently, the H_0 is disproved. The residuals are hence stationary. We would like to conclude that U is stationary and rejects the null hypothesis that there is a unit root in U based on the data. This suggests the dependent variable, GDP, and the independent factors, including trade openness (LTO). The exchange rate (LEXR), interest rate (IR), inflation (INFL), and foreign direct investment (FDI_GDP) have a long-term relationship.

7.3 Short-run relationship between trade openness and economic growth

Table 3 shows that the preceding results demonstrate the coefficient of the explanatory variables. The independent variables, such as trade openness, foreign direct investment, interest rate, currency rate, and inflation, may be examined by analyzing the coefficients. Then, with a probability higher than the 5% level of significance, the coefficient for the first difference of independent variables, such as DIR (p-value: 0.1922), DLTO (p-value: 0.2155), DINFL (p-value: 0.2570), and DFDI_GDP (p-value: 0.3039), demonstrates that the coefficient is statistically insignificant.

Dependent variable: D(LGDP)				
Method: Least squares				
Date: 06/11/24; Time: 10:23				
Sample "(adjusted)": 1997 2022				
Included observations: 26 after adjustments				
Variable	Coefficient	Std. error.	t-Statistic	Prob.
C	0.145093	0.016042	9.044759	0.0000
D (LTO)	0.223232	0.174208	1.281410	0.2155
D (LEXR)	-1.425044	0.258927	-5.503651	0.0000
D (IR)	-0.021395	0.015825	-1.352011	0.1922
D (INFL)	-0.018685	0.015988	-1.168711	0.2570
D (FDI_GDP)	0.013707	0.012971	1.056726	0.3039
U (-1)	-0.045353	0.082450	-0.550067	0.5887
R-squared	0.761470	Mean dependent var.		0.087114
Adjusted R-squared	0.686145	S.D. dependent var.		0.084341
S.E. of regression	0.047250	Akaike info criterion		-3.041927
Sum squared resid.	0.042419	Schwarz criterion		-2.703209
Log-likelihood	46.54506	Hannan-Quinn criter."		-2.944389
F-statistic	10.10909	Durbin-Watson stat		1.210741
Prob. (F-statistic)	0.000045			

Source: (Author's computation using EViews, 2025).

Table 3.
Relationship between trade openness and economic growth.

Make the case that there is no immediate relationship between trade liberalization and economic growth. Conversely, an exchange rate (DEXR) exhibits a statistically significant coefficient (t-statistic of -5.503651 and p-value of 0.0000) that indicates its impact on LGDP.

In conclusion, the model suggests that exchange rate fluctuations (LEXR) have a large short-run impact on gross domestic product (GDP). In contrast, other factors could not have significant short-term effects (ECM findings).

H0: There is a normal distribution.

H1: Based on **Figure 1** there is no normal distribution.

Given that the p-value of 0.789020 is greater than the 5% significance level, the null hypothesis will not be rejected. This means that, at a 95% confidence level, the error term follows a normal distribution.

7.4 Heteroskedasticity

H0: There is no heteroskedasticity.

H1: There is heteroskedasticity.

Table 4 shows that as the “p-value of the F-statistic (0.6822), is greater than the significance level of 0.05 (95% confidence interval), we do not reject the null hypothesis of constant variance. Indicating the presence of homoscedasticity in the regression model.”

H0: There is no serial correlation.

H1: There is a serial correlation.

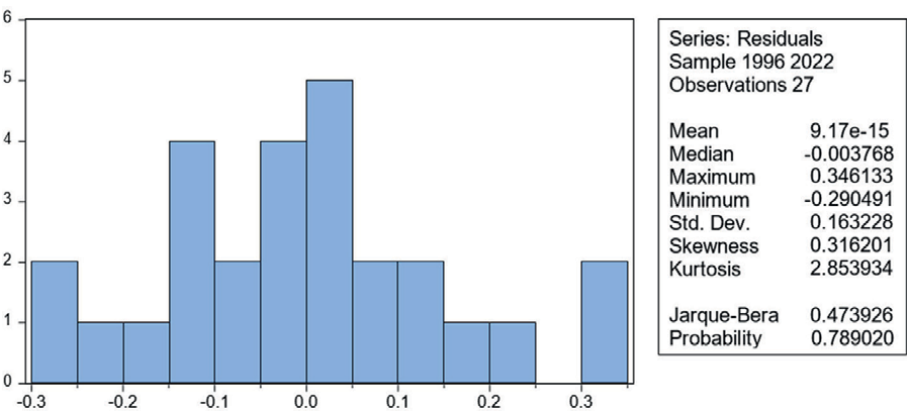


Figure 1.
Normal distribution. Source: (Author's computation using EViews, 2025).

Breusch-Godfrey serial correlation LM test:			
F-statistic	0.390197	Prob. F (2, 19)	0.6822
Obs*R-squared	1.065229	Prob. Chi-square (2)	0.5871

Source: (Author's computation using EViews, 2025).

Table 4.
Heteroskedasticity.

According to the result in **Table 5**, a p-value of the F-statistic equals to 0.6822 exceeds the 5% significance level, indicating that there is no statistical significance, and thus no autocorrelation.

Table 6 and **Figure 2** show the roots of the characteristic polynomial indicate that no root lies outside the unit circle. This confirms that the estimated VAR model satisfies the stability condition, meaning that the model is dynamically stable and can be used for forecasting and policy analysis.

The results in **Table 7** highlights the selection criteria, including Akaike information criterion (AIC) and Schwarz criterion (SC), suggest that a *two-lag VAR model* is optimal for capturing the dynamics of the dataset.

“Breusch-Godfrey serial correlation LM Test”:			
F-statistic	0.390197	Prob. F (2, 19)	0.6822
Obs*R-squared	1.065229	Prob. Chi-square (2)	0.5871

Source: (Author’s computation using EViews, 2025).

Table 5.
Serial correlation.

Roots of characteristic polynomial	
Endogenous variables: LGDP LTO	
FDI_GDP LEXR INFL	
Exogenous variables: C	
Lag specification: 1 2	
Date: 03/05/25; Time: 20:06	
Root	Modulus
0.986793	0.986793
0.804977 – 0.392498i	0.895568
0.804977 + 0.392498i	0.895568
0.706855	0.706855
0.062563 – 0.598965i	0.602224
0.062563 + 0.598965i	0.602224
–0.097549 – 0.590715i	0.598715
–0.097549 + 0.590715i	0.598715
–0.587847	0.587847
–0.362765	0.362765
No root lies outside the unit circle.	
VAR satisfies the stability condition.	

Sources: (Author’s computation using EViews, 2025).

Table 6.
Roots of characteristic polynomial.

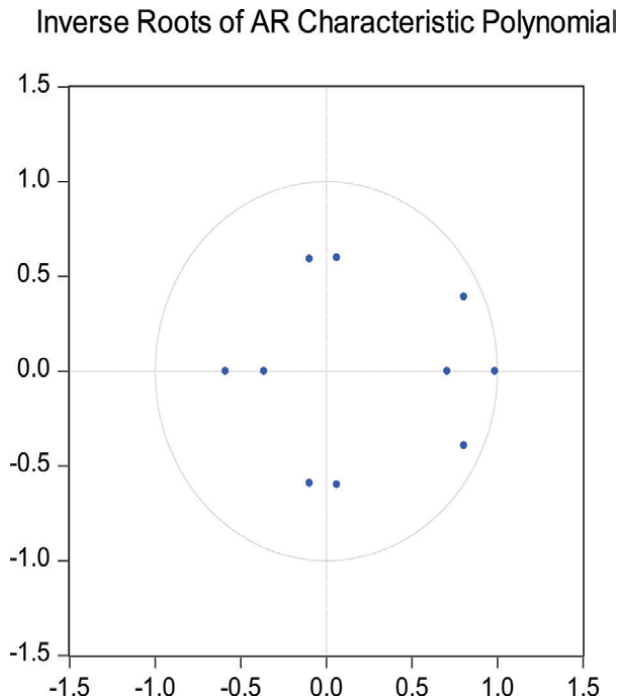


Figure 2.
Stability of the VAR model.

VAR Lag order selection criteria						
Endogenous variables: LGDP LEXR LTO INFL FDI_GDP						
Exogenous variables: C						
Date: 03/05/25; Time: 20:18						
Sample: 1996 2022						
Included observations: 25						
Lag	LogL	LR	FPE	AIC	SC	HQ
0	-77.33607	NA	0.000499	6.586886	6.830661	6.654499
1	63.72594	214.4143 [*]	4.86e – 08	-2.698075	-1.235424 [*]	-2.292398
2	96.62308	36.84480	3.40e – 08 [*]	-3.329847 [*]	-0.648320	-2.586105 [*]

^{*}Indicates lag order selected by the criterion.
LR: sequential modified LR test statistic (each test at 5% level); FPE: final prediction error; AIC: Akaike information criterion; SC: Schwarz information criterion; HQ: Hannan-Quinn information criterion. Sources: (Author's computation using EViews, 2025).

Table 7.
Lag order selection.

8. Conclusion and recommendations

This study examined the impact of trade openness on economic growth in Rwanda, focusing on the relationship between trade liberalization and GDP

dynamics. The primary objective was to assess the effects of trade openness on Rwanda's economic performance and determine whether a significant relationship exists between trade openness and GDP growth. The research incorporated both theoretical and empirical literature to provide insights into the advantages and challenges associated with trade openness. Using econometric techniques, data from the World Bank (1996–2022) was analyzed through stationarity tests (ADF test), cointegration analysis, and an Error Correction Model (ECM).

The findings indicated that Trade Openness (LTO), Exchange Rate (LEXR), and Foreign Direct Investment (FDI_GDP) had a significant positive impact on GDP growth, while Interest Rate (IR) and Inflation (INFL) were not statistically significant. Cointegration tests confirmed the presence of a long-run relationship between GDP and these independent variables, while short-run analysis revealed that only the exchange rate had an immediate impact on GDP growth. The stability of the model was verified through normality, heteroscedasticity, and serial correlation tests, confirming the reliability of the regression results.

Despite the positive correlation between trade openness and economic growth, trade liberalization also presents several risks, particularly in Rwanda. One of the main concerns is the risk of trade imbalances, as increased trade openness often results in higher imports than exports. Rwanda's heavy reliance on imported goods, including industrial machinery, consumer products, and raw materials, has contributed to persistent trade deficits. If exports fail to grow at the same pace, the country may face increasing external debt and currency depreciation, which can negatively impact economic stability. Addressing this challenge requires strategies to enhance the competitiveness of Rwandan exports and reduce dependency on foreign goods.

Another potential downside of trade openness is excessive dependence on imports, which can stifle domestic industrial growth. While access to foreign products benefits consumers by providing a variety of goods at competitive prices, it may also weaken local production capacity. Rwandan businesses, particularly in the manufacturing sector, may struggle to compete with cheaper imports, leading to job losses and decreased investment in domestic industries. Over time, this can result in deindustrialization, where the economy becomes overly reliant on imports rather than developing its own productive base. Without adequate support for local industries, trade openness may exacerbate structural economic weaknesses rather than promote sustainable growth.

Furthermore, trade openness increases Rwanda's vulnerability to external shocks and global economic fluctuations. Since Rwanda depends on international markets for exports and imports, any disruption in the global economy such as financial crises, trade wars, or supply chain disruptions can have severe consequences. For instance, the COVID-19 pandemic highlighted the risks of over-reliance on global supply chains, as Rwanda experienced delays in importing essential goods and materials. Additionally, fluctuations in global commodity prices can affect Rwanda's export earnings, especially in key sectors like agriculture and minerals. If global demand for Rwandan exports declines, the economy may face reduced foreign exchange earnings, leading to economic instability.

8.1 Policy recommendations

To maximize the benefits of trade openness while minimizing its risks, Rwanda must adopt targeted policy interventions. One crucial strategy is export

diversification and value addition. Instead of relying on a limited range of exports such as coffee and tea, Rwanda should promote industrialization by processing raw materials locally to increase their value. Expanding export-oriented industries and developing new markets can help reduce trade deficits and create a more resilient economy. Government incentives, infrastructure development, and investment in technology should be prioritized to enhance Rwanda's competitiveness in global markets.

Additionally, trade policy and exchange rate stability should be carefully managed to prevent economic distortions. The study found that exchange rate fluctuations significantly impact GDP growth, highlighting the need for stable currency management. Strengthening foreign exchange reserves, improving trade policies, and implementing measures to control inflation will help mitigate the negative effects of trade imbalances. Rwanda must also negotiate favorable trade agreements that protect its economic interests while ensuring compliance with regional and international trade regulations.

Another key policy recommendation is investing in infrastructure and trade facilitation to improve Rwanda's trade efficiency. High trade costs, due to inadequate transport and logistics infrastructure, can offset the benefits of trade openness. Enhancing road networks, ports, and digital trade platforms will reduce transaction costs and improve Rwanda's ability to compete in international markets. Additionally, simplifying customs procedures and reducing bureaucratic barriers will enhance trade efficiency and attract foreign investors.

To prevent the negative effects of excessive import dependence, Rwanda should implement strategic industrial policies that support domestic businesses. Encouraging import substitution in key sectors, such as manufacturing and agriculture, can help reduce reliance on foreign goods. Providing financial incentives, tax relief, and capacity-building programs for local enterprises will promote domestic production and create employment opportunities. By fostering local industries, Rwanda can achieve a more self-sufficient and diversified economy, reducing the risks associated with global economic uncertainties.

Regional trade integration is another important strategy that Rwanda can leverage to mitigate external vulnerabilities. Participation in regional economic blocs such as the East African Community (EAC) and the African Continental Free Trade Area (AfCFTA) can provide access to larger markets and reduce dependency on external trade partners. Strengthening regional value chains and improving trade relations within Africa will enhance economic resilience and create opportunities for sustainable growth. Finally, social protection measures should be implemented to safeguard workers in industries that may be negatively affected by trade openness. As global competition increases, some sectors may experience job losses, requiring retraining and support programs for displaced workers. Investing in education, vocational training, and skill development will enable Rwanda's workforce to adapt to changing economic demands and take advantage of new employment opportunities in growing industries.

Appendix

See **Table 8**

Vector autoregression estimates					
Date: 03/05/25; Time: 20:18					
Sample (adjusted): 1998 2022					
Included observations: 25 after adjustments					
Standard errors in () and t-statistics in []					
	LGDP	LEXR	LTO	INFL	FDI_GDP
LGDP (–1)	0.913756	0.339649	0.402930	95.28912	1.721004
	(0.53356)	(0.21616)	(0.40009)	(50.4240)	(6.58874)
	[1.71257]	[1.57128]	[1.00709]	[1.88976]	[0.26120]
LGDP (–2)	0.076327	–0.301082	–0.275639	–97.13810	2.850356
	(0.53615)	(0.21721)	(0.40204)	(50.6694)	(6.62081)
	[0.14236]	[–1.38611]	[–0.68560]	[–1.91710]	[0.43051]
LEXR (–1)	–0.851266	1.865089	0.865469	104.4659	–7.162800
	(0.83644)	(0.33887)	(0.62722)	(79.0481)	(10.3290)
	[–1.01772]	[5.50387]	[1.37986]	[1.32155]	[–0.69347]
LEXR (–2)	1.121773	–0.965170	–0.646419	–79.35006	5.201000
	(0.79041)	(0.32022)	(0.59270)	(74.6977)	(9.76052)
	[1.41923]	[–3.01409]	[–1.09064]	[–1.06228]	[0.53286]
LTO (–1)	–0.028756	–0.300674	0.468264	–71.87573	3.594530
	(0.38906)	(0.15762)	(0.29174)	(36.7682)	(4.80438)
	[–0.07391]	[–1.90759]	[1.60507]	[–1.95484]	[0.74818]
LTO (–2)	–0.191274	0.312606	0.075491	52.27659	–7.953671
	(0.36912)	(0.14954)	(0.27679)	(34.8836)	(4.55813)
	[–0.51819]	[2.09043]	[0.27274]	[1.49860]	[–1.74494]
INFL (–1)	0.001199	–0.002326	–0.001262	–0.569393	–0.008786
	(0.00394)	(0.00160)	(0.00295)	(0.37214)	(0.04863)
	[0.30449]	[–1.45786]	[–0.42724]	[–1.53004]	[–0.18068]
INFL (–2)	0.001633	–0.002848	–0.001396	–0.244128	0.018907
	(0.00236)	(0.00096)	(0.00177)	(0.22297)	(0.02914)
	[0.69195]	[–2.97980]	[–0.78918]	[–1.09487]	[0.64892]
FDI_GDP (–1)	–0.001995	–0.005124	0.002551	–0.104277	–0.394699
	(0.02229)	(0.00903)	(0.01671)	(2.10657)	(0.27526)
	[–0.08951]	[–0.56742]	[0.15264]	[–0.04950]	[–1.43392]
FDI_GDP (–2)	–0.025897	0.005077	–0.019583	–0.500287	–0.118344
	(0.02190)	(0.00887)	(0.01642)	(2.06950)	(0.27042)
	[–1.18262]	[0.57221]	[–1.19256]	[–0.24174]	[–0.43764]
C	–1.549376	–0.191919	–4.648495	–136.0506	–90.50990
	(2.02635)	(0.82094)	(1.51948)	(191.501)	(25.0228)
	[–0.76461]	[–0.23378]	[–3.05926]	[–0.71044]	[–3.61709]
R-squared	0.995699	0.996887	0.984078	0.499197	0.823212

Vector autoregression estimates					
Date: 03/05/25; Time: 20:18					
Sample (adjusted): 1998 2022					
Included observations: 25 after adjustments					
Standard errors in () and t-statistics in []					
	LGDP	LEXR	LTO	INFL	FDI_GDP
Adj. R-squared	0.992628	0.994663	0.972706	0.141480	0.696934
Sum sq. resids.	0.045831	0.007522	0.025770	409.3279	6.988795
S.E. equation	0.057216	0.023180	0.042904	5.407190	0.706541
F-statistic	324.1359	448.3288	86.53057	1.395508	6.519078
Log likelihood	43.29743	65.88602	50.49409	-70.41897	-19.54137
Akaike AIC	-2.583795	-4.390881	-3.159527	6.513518	2.443309
Schwarz SC	-2.047489	-3.854576	-2.623222	7.049823	2.979615
Mean dependent	22.34771	6.416395	-0.931416	6.077992	1.839262
S.D. dependent	0.666360	0.317308	0.259693	5.835746	1.283420
Determinant resid. covariance (dof adj.)		5.49E - 09			
Determinant resid. covariance		3.02E - 10			
Log likelihood		96.62308			
Akaike information criterion		-3.329847			
Schwarz criterion		-0.648320			
Number of coefficients		55			

Table 8.
Vector Autoregression Estimates.

The coefficient of LGDP (-1) is 0.9138, and it is statistically significant, suggesting strong persistence in economic growth, meaning past GDP levels substantially affect current GDP. The coefficient of LEXR (-1) is -0.8513 but is not statistically significant, indicating that the exchange rate might not have a strong immediate impact on GDP growth. LTO (-1) has a small negative coefficient, implying a weak short-term negative impact of trade openness on GDP, while FDI_GDP has an insignificant coefficient, showing that FDI inflows do not strongly influence economic growth in the short run. For the exchange rate, LEXR (-1) has a coefficient of 1.8651, which is statistically significant, indicating that the past exchange rate significantly determines its current level. LGDP (-1) has a positive but not highly significant coefficient, suggesting that GDP movements do not have a major immediate impact on exchange rate fluctuations. Additionally, INFL (-1) has a small but negative coefficient, implying that inflationary pressures may contribute to exchange rate depreciation over time. Regarding trade openness, the coefficient of LTO (-1) is 0.4683, suggesting a positive but statistically weak impact on its current value, while the coefficient of LEXR (-1) is positive, implying that exchange rate movements may influence trade openness, potentially through export and import dynamics. Inflation follows an autoregressive process, as indicated by the coefficients on past values of inflation, -0.5694 (INFL (-1)) and -0.2441 (INFL (-2)). The exchange rate coefficients suggest that currency depreciation might contribute to higher inflation, but

the impact is not statistically significant, and the coefficient of LGDP (−1) is positive, suggesting that economic growth might be associated with inflationary pressures. Finally, the coefficients of lagged FDI_GDP values are negative, indicating that past FDI levels might have a crowding-out effect on future FDI inflows. The impact of LGDP on FDI_GDP is positive but insignificant, showing that economic growth does not necessarily drive FDI inflows in the short run, while trade openness (LTO) has a negative but weak effect, suggesting that higher trade openness might not necessarily attract more FDI immediately.

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Impact of Climate Change on Agriculture in Sub-Saharan Africa: Quantification of Price Bias in Econometric Approaches

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Abstract

The present study aims to examine the impact of climate change on agriculture in sub-Saharan Africa by assessing the influence of rainfall on wheat and corn yields. Based on a panel covering 48 countries during the period 1960–2023, the analysis highlights a quadratic relationship between rainfall and yields, reflecting a positive effect up to a threshold, beyond which the effect reverses. Furthermore, the study reveals the existence of a significant price bias for both wheat and corn, which can reach around 5%. This observation highlights the urgent need to jointly integrate price and quantity dynamics in the assessment of the impacts of climate change, and calls for adaptation strategies specifically developed for the most vulnerable contexts.

Keywords: agricultural yield, agriculture, climate change, Price bias, sub-Saharan Africa

1. Introduction

In a context where a profound transformation of the Earth's climate is anticipated by the end of the twenty-first century [1], growing concerns are emerging at the national, regional, and international levels about the impacts of climate change on agriculture in the short, medium, and long term. These issues have stimulated a proliferation of empirical studies on the interactions between climate variability and agricultural systems, mobilizing disciplines such as geography, economics, and agronomy. This subject also receives sustained attention at international scientific conferences and symposia.

Pioneering work in this field has mainly been concentrated in the United States, while developing regions, particularly sub-Saharan Africa (SSA), are particularly vulnerable due to an economy that is essentially dependent on agriculture, a high rate of poverty, restrictions on access to credit, a deficit in adaptation technologies, and the predominance of rain-fed agricultural production [2]. Furthermore, Burke

et al. [3] argue that the economic losses caused by climate change in these regions are mainly the result of their initially warm climatic conditions.

In this context, it appears essential to precisely quantify the repercussions of climate change on these territories, with the aim of informing policy orientations. An in-depth understanding of the potential effects of climate variability would make it possible to guide the implementation of strategies aimed both at mitigating negative impacts and at strengthening the adaptive capacities of agricultural systems.

Furthermore, a review of the literature examining the link between climate change and agriculture reveals that a considerable number of recent studies have attempted to quantify the impact of this phenomenon on agricultural yields in various countries. To carry out this assessment, four alternative methodological approaches are generally recommended: (i) the production function approach, or agroeconomic approach; (ii) the Ricardian approach; (iii) the advanced Ricardian approach, using panel data; and (iv) the time series approach.

Among the studies that have carried out such an evaluation, it is worth highlighting that of Emediegwu et al. [4], who quantified the economic impact of variations in climatic parameters on the yield of pearl millet in SSA. Based on a panel data set covering the period 1970–2016, these authors incorporate spatial effects on all components of the exposure-response function into their model and introduce a time lag for the covariates, using spatio-temporal econometric techniques. Their results demonstrate that local climatic variables—namely the vapor pressure deficit, temperature, and frequency of rainy days—have significant contemporary impacts on millet yield, the effect of rainfall being amplified by spatial effects and attenuated by temporal effects. In addition, they emphasize that local crop production is also influenced by that of neighboring countries.

Similar studies, notably those of Barrios et al. [5], examined the impact of climate change on total agricultural production in SSA and extended their analysis to a sample that also included non-SSA developing countries (NSSA). By adopting an agroeconomic approach integrating agricultural production, these studies demonstrate that the climate, as indicated by variations in precipitation and temperature on a national scale, appears to be a major determinant of agricultural production in SSA. Conversely, non-SSA countries seem to be less sensitive to these meteorological fluctuations, thus suggesting a differentiated response to the vagaries of climate change.

In the same vein, Ogundari and Onyeaghala [6] analyze the impact of climate variations—particularly those of temperature and rainfall—on the growth dynamics of total factor productivity (TFP) in agriculture in Africa. Their study, enriched by the incorporation of additional exogenous variables, also examines the existence of a convergence of agricultural TFP levels within the region over the period 1981–2010, adopting a Ricardian approach. The empirical results highlight a trend toward the convergence of performances in terms of agricultural TFP, although this process remains relatively slow. Furthermore, rainfall has a significant positive effect on the growth of this productivity, while the influence of temperature appears negligible.

In the field of time series analysis, Warsame et al. [7] examine the influence of climate change—understood in terms of rainfall, temperature, and CO₂ emissions—on Somali agricultural production, based on data covering the period 1985–2016. To do this, they use bounds tests based on the AutoRegressive Distributed Lag (ARDL) model, as well as Granger causality analysis, to model long- and short-term cointegration relationships and discern causal relationships between variables. The empirical results highlight long-term cointegration between the various indicators, revealing that increased rainfall supports agricultural production in the long term while

constraining it in the short term, while rising temperatures have a negative influence on both time frames. Furthermore, CO₂ emissions do not appear to have a significant impact on agricultural production.

Among the recurring criticisms leveled at the Ricardian approach, the so-called “price bias” figures prominently. This method is limited to measuring the impact of climatic conditions on producers, without integrating the dimension of the well-being of consumers of agricultural goods. Thus, a lasting reduction in supply, induced by climate change, leads to an increase in prices and a reduction in the quantities consumed, which penalizes households. Paradoxically, the increased value of production resulting from this rise in prices can offset or even cancel out the initially negative effect of the climate on agricultural income. Furthermore, if such climate change is confirmed on a long-term basis, this bias also has an impact on the estimated value of land.

This issue, initially addressed by Ouchou and Quirion [8] in the context of Burkina Faso and based on a theoretical model presented in the appendix, is extended here by our study, which aims to quantify price bias in various SSA countries. The aim is to extend the analysis to a broader group, including countries with deepwater ports, whose direct access to international markets could affect price transmission and, consequently, the extent of the bias.

Greatly facilitated by the growth of data on agricultural prices, particularly through Food and Agriculture Organization of the United Nations (FAO) initiatives, it has been possible for us to expand the initial sample. The choice of SSA is justified by the high propensity to observe a price bias in economies with little integration into world markets. In these contexts, unfavorable climatic conditions and exacerbated vulnerability to climate change intensify the risks to food security, so that this bias is potentially more pronounced than in developed countries or those with “price taker” status.

The objective of this article is to quantify price bias in developing countries, particularly in sub-Saharan Africa. The second section outlines the econometric methodology used and the data employed, while the third section presents the empirical results obtained. The fourth section is devoted to simulations aimed at estimating the magnitude of this bias and discussing its socioeconomic implications. The fifth section offers a comparative discussion of the results obtained in light of existing work, before the sixth section concludes the study by summarizing the main lessons learned.

2. Methodology and data

The quantification of a possible price bias is part of a two-step approach, developed from a panel of 48 African countries over a period of 64 years (1960–2023).¹ The choice of this approach is based on several methodological considerations. First, the small number of countries—less than a hundred—makes purely cross-sectional analyses less relevant. Furthermore, as Vaitkevičiūtė et al. [9] points out, cross-sectional estimates, made using the ordinary least squares method, tend above all to isolate a long-term effect, requiring the endogenous variable to reflect land value—the discounted sum of future income—rather than

¹ Please note that the panel is not balanced, and that the number of observations used for econometric estimation varies according to data availability.

simple annual production or agricultural income for the year. However, in most low-income economies, and more particularly in SSA, the absence of developed land markets considerably limits access to reliable data on land values. Therefore, the adoption of a panel model appears to be the most appropriate approach, following a trend already well established in the literature, from the work of Deschênes and Greenstone [10] to that of Blanc and Reilly [11].

The method adopted is divided into two distinct stages. First, a set of regressions is used to estimate the sensitivity of agricultural yield (measured in production per hectare) to various climatic factors. This approach, which is like agro-meteorology, nevertheless falls within a historical economic tradition, illustrated by the pioneering analysis of Wright [12]—who perceived cotton yield as a “supply curve shifter” [13]. The second stage consists of evaluating the impact of the yield on the price of cereals, based on a new series of regressions. When these two empirical components demonstrate statistically significant relationships, they will then provide conclusive evidence in favor of the existence of a price bias.

In the body of this chapter, we present the results obtained from the random effects (RE) and fixed effects (FE) models, which prove to be relatively convergent. The different equations, formulated based on the concepts developed above, are as follows²:

$$Y_{it} = \beta R_{it} + \gamma R_{it}^2 + \delta_i + \varepsilon_{it} \quad (1)$$

$$Pr_{it} = \tau Y_{it-1} + \theta W_{it} + \omega I_{it} + \epsilon_{it} \quad (2)$$

In these expressions, i denotes the country, t the year, Y_{it} the yield, R_{it} the rainfall (expressed in millimeters accumulated over the course of a year). In addition, Pr_{it} represents the price of cereals, W_{it} the world market price, and I_{it} the consumer price index, with the latter two variables serving as controls. The terms ε_{it} and ϵ_{it} refer to random errors, while reflects δ_i the fixed effects specific to each country, present exclusively in the fixed effects model.

The introduction of the quadratic term in precipitation (R_{it}^2) aims to model a nonlinear relationship between precipitation and agricultural yield. We hypothesize that the linear coefficient associated with R_{it} is positive, while that associated with R_{it}^2 is negative, which would reflect a convex relationship and the existence of a water optimum for agricultural production.

In the second equation, the yield exerts an influence on the price with a one-year lag. This specification is justified by the start of the harvests during the agricultural campaign of the year and by the staggering of the marketing of cereals during the subsequent year. Consequently, the yield recorded in the year determines the price observed the following year.

Considering the work presented in the first section, which jointly integrates precipitation and temperature, it should be noted that we have omitted the temperature variable due to marked collinearity between these two parameters. In fact, in the context of the SSA, a very clear negative correlation between temperature and precipitation is apparent both in space and time, which complicates the identification of the specific effects of each of these variables.

² Variables are expressed in logarithmic form.

Variable	Unit	N	Mean	Standard-Deviation	Min	Max
Yield (Wheat)	Yield (t/ha)	1570	1.69	1.36	0.00	9.94
Yield (Corn)	Yield (t/ha)	2624	1.28	0.94	0.00	13.55
Precipitation	(mm) Cumulative	3024	1125.19	670.96	43.81	3538.99
Wheat prices	In dollars	221	366.36	182.47	97.40	1465.80
Corn prices	In dollars	689	307.73	327.47	52.50	3082.40
World cereal prices	In dollars	1632	88.39	30.98	51.42	154.67
Consumer price index	Index	1627	89.45	120.21	8.98	1179.03

Table 1.
Descriptive statistics for variables.

The data relating to the quantities harvested and the areas cultivated with corn and wheat are taken from the FAO database. The yield, defined as the ratio between the quantity of grain harvested (in tons) and the cultivated area, is estimated separately for each of these two cereals. In addition, the prices of cereals in SSA countries, as well as the world price of cereals, are also taken from the FAO database. To our knowledge, there is no global price specific to each type of cereal; we have therefore used an aggregate price index for all cereals. The consumer price index is taken from the World Bank database.

Table 1 presents the descriptive statistics for all these variables.

The climate data used in this study comes from the Climate Change Knowledge Portal. It is presented in the form of monthly grids at a spatial resolution of $0.5^\circ \times 0.5^\circ$ (i.e., approximately 50 km by 50 km at this latitude) and is based on measurements taken by rain gauges and ground-based weather stations.

Before presenting the results, it is worth outlining the various hypothesis tests that were carried out. Dickey-Fuller unit root tests (ADF) confirm that the explanatory variables (rainfall) and yields are stationary in levels. However, the price of cereals is stationary in first difference. Thus, for eq. (1), we can continue the estimation procedure without additional transformation. For eq. (2), no cointegration test is required since the explanatory variables—in this case, rainfall—are stationary in levels and the price of cereals in first difference. We therefore proceed with the estimation considering the first difference stationarity of the price index.

It also appears that the various equations present problems of heteroscedasticity. To remedy this, we use White's estimator for the variance-covariance matrix of the estimators. All the regressions were carried out using STATA 16 software.

3. Results

The econometric estimates presented in **Table 2**, significant at a threshold of 1% in both the fixed-effect and random-effect models, these findings highlight the complexity and nonlinear nature of the climate-economic interactions governing agricultural performance. This observation remains, despite the low coefficients of determination, indicative of the multiplicity of factors at play.

The results reveal that a moderate increase in rainfall significantly improves wheat and corn yields, highlighting the importance of optimal water supply for these crops. However, beyond a certain threshold, this effect becomes negative, reflecting a nonlinear relationship characterized by an estimated water optimum of approximately 1250 mm/

Model→	Wheat		Corn	
Variables↓	FE	RE	FE	RE
Rain	0.81** (2.00)	0.88** (2.21)	0.84** (2.28)	0.86** (2.40)
Rain ²	−0.06* (−1.92)	−0.07** (−2.19)	−0.05* (−1.92)	−0.05* (−1.63)
Constant	−1.68 (−1.34)	−1.81 (−1.49)	−3.52*** (−3.01)	−3.59*** (−3.15)
N	1570	1570	2624	2624
R ² (Overall)	0.02	0.04	0.12	0.12
F/Wald (p-value)	40.12 (0.00)	40.91 (0.00)	13.34 (0.00)	36.40 (0.00)

t-statistics are shown in parentheses. ****p* < 0.01, ***p* < 0.05, **p* < 0.10.

Table 2.
Yield estimation results for the two cereals.

year. This inflection point reflects excess water stress that can trigger unfavorable phenological or physiological responses, as also observed by Ochou and Quirion [8].

This nonlinear dynamic is consistent with the results obtained by Schlenker and Lobell [14], Sultan and Gaetani [15], and Blanc and Reilly [11], who identified a rainfall threshold beyond which yields decline due to soil saturation, root hypoxia, and the proliferation of pathogens induced by excessive moisture. The threshold observed here, which is lower than that estimated by Emediegwu et al. [4] for pearl millet (≈ 1400 mm), highlights the greater water sensitivity of temperate and tropical cereals in sub-Saharan agroecosystems.

Two main factors help to explain this difference. On the one hand, the nature of the soils: Pearl millet crops are generally planted on well-drained sandy soils, which delays the harmful effects of excess water [16], while wheat and maize are often grown on silty-clay or ferruginous soils, which are more prone to anoxia and nutrient leaching. Secondly, the phenology of the species: Pearl millet, harvested before the peak rainfall period, is partially spared from late rainfall, unlike corn and wheat, whose critical development stages (flowering, grain filling) coincide with the heaviest rains [17].

These findings call for targeted agrotechnical adaptation strategies. The introduction of early-maturing or water-tolerant varieties, combined with light drainage improvements (ditches, infiltration strips), would make it possible to raise the optimal water threshold and limit interannual yield variability. In addition, detailed soil mapping and spatial adjustment of crops to projected rainfall patterns are inexpensive but effective adaptation options. Finally, the integration of these agro-climatic thresholds into index insurance instruments and hydro-agricultural management policies appears essential to strengthen the productive resilience of cereal systems in the face of increasing climate hazards.

The simulated variations in rainfall, integrated into the econometric model presented above and illustrated in **Figure 1**, highlight a differentiated decrease in wheat and maize yields within our panel of African countries, correlated with the estimated elasticity values. The approach consists of introducing proportional changes—for example, a reduction ranging from 5 to 100%—in rainfall, to deduce the effects on

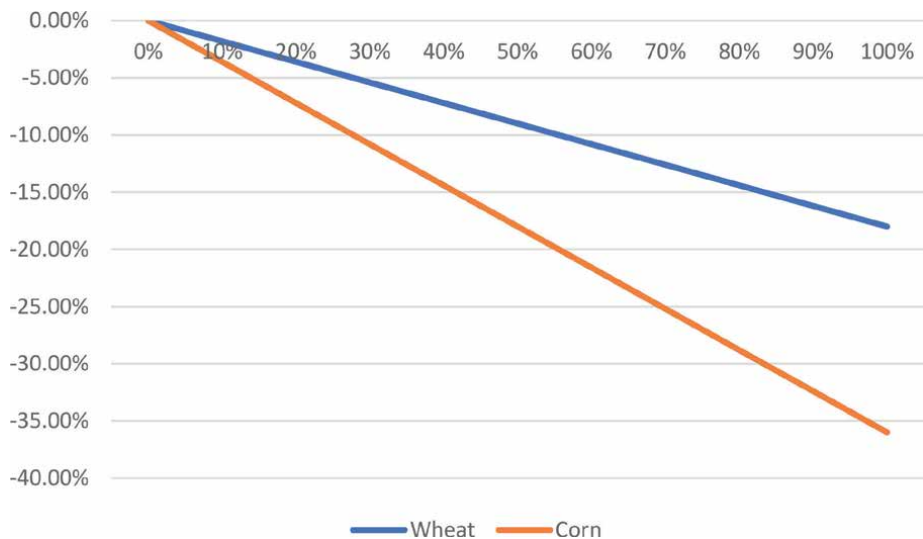


Figure 1.
Variation in the yield of two cereals according to climatic conditions.

the yields of the two cereals. In addition, the incorporation of a quadratic term, whose elasticity coefficient is positive, induces a compensatory marginal effect, attenuating the extent of the decline. The results indicate that corn suffers substantial losses. The significance of the effects, particularly those related to rainfall, highlights the urgency of implementing adaptation strategies—such as optimizing water and input management or agricultural diversification—to preserve the stability of cereal yields in an unfavorable climate context, particularly for corn.

Furthermore, the results presented in **Table 3** reveal a significant influence of the explanatory variables on wheat and corn prices once the lagged effects of yields and macroeconomic determinants are considered. These findings illustrate the complexity of the interactions underlying the price formation mechanisms in the cereals sector.

The results reveal that the coefficient of the yield variable for the previous period is negative and statistically significant, indicating that an improvement in agricultural productivity tends to lower prices. Moreover, international grain prices have a marked positive influence on all local prices, attesting to the predominance of the world market in the transmission of exogenous shocks. The coefficient for wheat (0.76) is slightly lower than that for corn (0.79), suggesting that the wheat market is less responsive to international fluctuations. In addition, the consumer price index has a positive impact on the price of wheat, demonstrating the effect of domestic inflation on food prices, whereas this effect is not significant for corn. Finally, the R^2 values indicate a better explanatory performance of the model for wheat (0.64) than for corn (0.27), highlighting a greater proportion of the variability of wheat prices explained by the selected variables.

Figure 2 summarizes the impact of shocks on yields by quantifying the magnitude and direction of price adjustments. The method consists of extracting yield declines from the simulations, weighting them by the coefficient associated with the yield in period $t-1$, and then measuring the price increases, thus highlighting distinct responses depending on the type of cereal and the strength of the yield-price relationship.

Model→	Wheat prices	Corn prices
Variables↓		
Yield in t-1	-0.45*** (-7.58)	-0.16*** (-5.73)
World cereal prices	0.76*** (9.48)	0.79*** (8.51)
Consumer price index	0.27*** (3.76)	0.14 (1.55)
Constant	1.73*** (5.44)	1.43*** (4.13)
N	173	514
R ² (Overall)	0.64	0.27
F (p-value)	98.07 (0.00)	63.61 (0.00)

t-statistics are shown in parentheses. ****p* < 0.01, ***p* < 0.05, **p* < 0.10.

Table 3.
Results of price estimates for the two cereals.

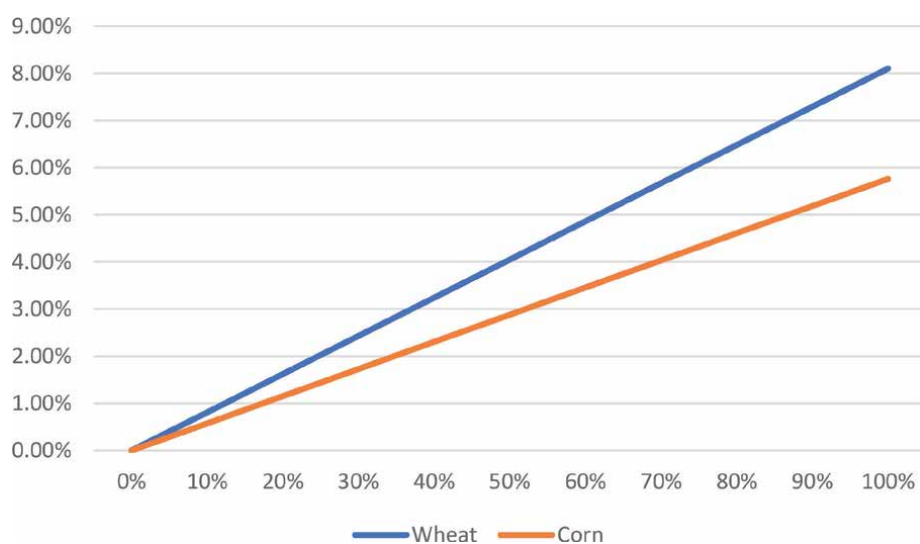


Figure 2.
Variation in the price of two cereals according to climatic conditions.

The results show that a marked deterioration in yield, attributable to drought, translates into a significant rise in prices, with extreme scenarios (100% drop in yield) leading to increases of more than 8% for wheat. This mechanism can be explained by the inverse relationship between yield and supply: The contraction in production reduces stocks, thus intensifying the pressure on prices. Although corn follows a similar trend, its attenuated coefficient moderates the magnitude of the effect. These

findings underscore the need to examine, beyond production alone, the impact of climate change on markets, food security, and agricultural incomes. In an African context, where stable access to food remains crucial, it seems imperative to strengthen information systems, storage capacities, crop diversification, and social protection mechanisms to mitigate the repercussions of climatic hazards.

4. Quantifying price bias and socioeconomic effects

The results presented in this section, illustrated in **Figure 3**, confirm and extend to the regional level the findings of Ochou and Quirion [8] in Burkina Faso, highlighting a price bias of up to 5.10% of agricultural income in severe climate shock scenarios. This magnitude, comparable to the estimates of Hertel and Lobell [18] for food crops in the least developed countries, contrast sharply with the $\approx 1\%$ observed by Mendelsohn et al. [19] for the United States. This divergence suggests increased structural vulnerability of agricultural markets in SSA, linked to several interdependent mechanisms.

First, weak market integration limits the interregional circulation of agricultural products. In SSA, trade fragmentation, exacerbated by high logistics costs and inadequate transport infrastructure, hinders the spatial adjustment of supply. Imbalances between production basins and consumption areas are only partially resolved, so that price adjustments occur locally, exacerbating the sensitivity of agricultural incomes to climate shocks. Conversely, in economies such as the United States, the density of the logistics network and the harmonization of standards facilitate the rapid reallocation of flows, mitigating short-term effects on domestic prices.

Second, transaction costs and information asymmetries, exacerbated by the predominance of informal trade and limited access to market information, reduce the efficiency of price formation mechanisms. This situation increases the margins between producers and consumers, limiting farmers' ability to benefit from higher

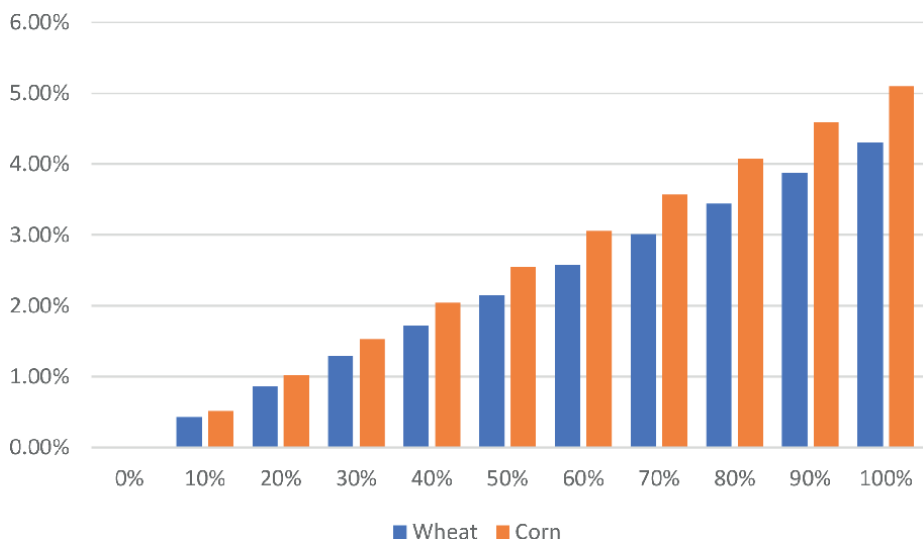


Figure 3.
Price bias as a percentage of agricultural income.

prices during periods of scarcity. Thus, a contraction in supply is reflected more strongly in higher consumer prices than in higher net farm income, accentuating the measured bias.

Third, stabilization capacity through stocks remains very limited. While OECD countries have reserves covering an average of 12 months of consumption, storage capacity in SSA generally does not exceed 3 months [20]. This inadequacy limits the possibilities for intertemporal mitigation in the face of production shocks, making markets more responsive and volatile. Moreover, the absence of functional futures markets and the low penetration of index-based insurance mechanisms increase producers' exposure to climate hazards.

In addition, the results confirm that crop responses to shocks are not homogeneous. Corn has a greater impact on price bias than other cereals, which can be explained by its increased sensitivity to climatic conditions and its predominance in regional consumption. These findings highlight the need to explicitly model the endogeneity of prices relative to yields to rigorously assess the economic effects of climate shocks.

Taken together, these findings call for structural reforms aimed at reducing the extent of price bias in cereal value chains. Strengthening regional trade integration, investing in rural logistics infrastructure, and developing strategic reserves are priority levers. Similarly, expanding market information systems and promoting risk management tools, such as index-based insurance or targeted safety nets, appear essential to cushion the welfare losses caused by climate variability in the most exposed areas.

5. Comparative discussion of empirical results

To place the results obtained within the existing scientific landscape, this section offers a comparative discussion, comparing them with previous work on climate effects, price dynamics, and the quantification of price bias in African agricultural economies.

The estimated nonlinear relationship between rainfall and yields, with an optimal water threshold of around 1250 mm, is consistent with the work of Schlenker and Lobell [14], Sultan and Gaetani [15], and Blanc and Reilly [11], who also identify a reversal of climate effects beyond a critical rainfall threshold. The specificity of our estimate, which is lower than that observed for millet by Emediegwu et al. [4], highlights differences in sensitivity between crops, which depend on their phenology and soil properties. This heterogeneity confirms the importance of a differentiated approach according to species and agroecological contexts.

About agricultural prices, our analysis adds a dimension that has been little explored in the literature on climate in sub-Saharan Africa. While Warsame et al. [7] focus on the relationship between climate and production, without modeling prices, our study shows that a yield shock significantly affects domestic prices with a delayed effect, which is more pronounced for wheat than for maize. This differentiation sheds light on price formation mechanisms and is consistent with the findings of Brown et al. [21] on the partial but real influence of world prices on African markets, despite limited transmission due to logistical and trade barriers.

One of the distinctive contributions of this study is the empirical measurement of price bias, which is still rarely documented at the regional level. Extending the framework of Ochou and Quirion [8], which was limited to the case of Burkina Faso, we highlight a bias of up to 5.1% of agricultural income, well above the $\approx 1\%$ reported by Mendelsohn et al. [19] in more integrated contexts, such as the United States. This divergence reflects

structural vulnerabilities specific to African agricultural markets: Weak regional integration, limited storage capacity, and inefficiencies in price transmission. These factors fully justify the joint integration of climate and economic effects in agricultural risk assessment, as well as the use of adaptation strategies combining varietal innovations, logistics infrastructure, and risk management mechanisms.

6. Conclusion

The adoption of a random effects model, validated by Hausman tests, makes it possible to capture the unobservable heterogeneity between countries—institutions, natural endowments, infrastructure—that is likely to simultaneously influence climatic conditions and agricultural performance [22]. In this perspective, our results, consistent with those of Ochou and Quirion [8] in Burkina Faso, confirm the existence of a substantial price bias when endogenous price adjustment to yield variations induced by extreme weather conditions is considered. In some scenarios, this bias can reach 5% of agricultural income, a value close to that estimated by Hertel and Lobell [18] for low-income countries, but well above the $\approx 1\%$ reported by Mendelsohn et al. [19] in more integrated institutional contexts such as the United States.

However, three sources of methodological bias remain and require further investigation. First, the endogeneity of yields: Technological decisions (irrigation, fertilization, variety adoption), which are influenced by climatic conditions, co-determine yields. As a result, the effect of precipitation estimated in the model may include both biophysical constraints and producers' adaptive responses [23], biasing the causal interpretation. The use of exogenous instruments (El Niño indices, nearby rainfall anomalies) or interactive models (rain $\times$ irrigation) would allow for more refined identification.

Second, the aggregate measurement of world prices is a potential source of mitigation of crop-specific effects. The use of the FAO global cereal index, in the absence of disaggregated series for the entire period, masks the specific dynamics of wheat or corn. The integration of disaggregated data Chicago Mercantile Exchange (CME Group, USDA), or the use of decomposition methods (wavelets, structural VAR), would make it possible to isolate the differentiated contributions of each cereal market [21].

Third, the exclusion of temperature is based on its strong collinearity with rainfall in tropical climates. To get around this constraint, approaches focused on extremes (heat waves, early season anomalies, “hot” days) and the integration of cumulative heat-stress indices can capture the complex interactions between temperature and humidity [24]. Nonparametric (random forests) or threshold (TAR) models would offer greater flexibility in understanding these nonlinearities.

Despite these limitations, the robustness tests carried out (temporal resampling, alternative FE/RE specifications, White's heteroscedasticity corrections) confirm the qualitative stability of the main estimated coefficients, reinforcing the external validity of the results.

These conclusions call for further analysis along several lines. An extension to other crops and regions would allow the generalizability of the observed price bias to be assessed. At the same time, better consideration of production costs and market structures would help to elucidate the mechanisms by which climate shocks are transmitted to agricultural prices. The integration of forward-looking climate scenarios, combined with the evaluation of adaptation strategies (new varieties, irrigation, diversification), would be a decisive contribution to anticipating the differentiated effects of climate change. Such

advances are crucial to guide the development of resilient agricultural policies in contexts characterized by high institutional and infrastructural vulnerability.

Appendix

Appendices and nomenclature

Price Bias in Partial Equilibrium: A Theoretical Analysis based on the Ochou and Quirion Model [8].

The present reasoning is based on a partial equilibrium model with a linear structure, formulated in a context of pure and perfect competition, initially proposed by Mendelsohn et al. [19] and then further developed by Ochou and Quirion [8]. This analytical framework applies to both one-off weather disturbances (e.g., affecting a single crop year) and long-lasting climatic changes. Moreover, it remains valid whether agricultural production increases or decreases in response to changing weather conditions.

Figure A1 illustrates, in a competitive context, the consequences of a 50% reduction in the quantity produced (from q_0 to q_1) on the price of the product. At the same time, the price increases by 50%, from p_0 to p_1 .

A.1 Case 1: Total cost of production considered exogenous

In the first scenario (left), total production costs remain unchanged. Consequently, the variation in farm income is exactly equal to the variation in the value of production, that is, the difference between the two rectangles ($A - C$):

$$\Delta vp = p_1 q_1 - p_0 q_0 \quad (A1)$$

The variation in well-being is reduced here to the variation in consumer utility, given the assumption of invariance of production costs. This variation, equal to ($-B - C$), is expressed as follows:

$$\Delta uc = \frac{(q_1 - q_0)(p_1 + p_0)}{2} \quad (A2)$$

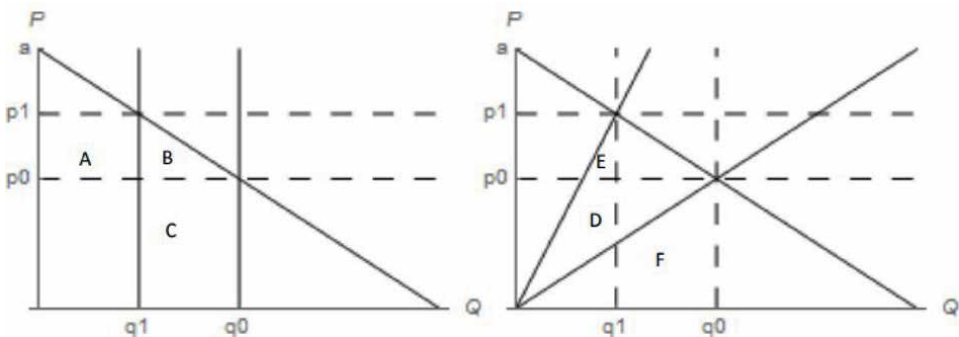


Figure A1.
Price bias in partial equilibrium. Source: Ochou and Quirion [8].

If the price remains constant ($p_1 = p_0$), then the variation in the value of production coincides with that of well-being, so that $\Delta vp = \Delta uc$. This corresponds to the situation of a purely “price-taking” zone.

When the price varies, a measurement bias, known as the “price bias,” arises. This quantifies the difference (in absolute value) between the variation in well-being and the variation in the value of production:

$$BP = |\Delta uc - \Delta vp| = \frac{(q_1 + q_0)|p_0 - p_1|}{2} \quad (A3)$$

Graphically, this bias corresponds to the area of the additional triangles (A + B). In absolute terms, it reflects the underestimation of the variation in well-being when this is approximated by the variation in the value of production alone.

A.2 Case 2: The cost of production is endogenous and increases with the quantity produced

The second diagram (right), inspired by Mendelsohn et al. [19], assumes that production costs increase with the level of output. This configuration can be considered more realistic for the analysis of long-term effects, for example, in the case of permanent climate change, insofar as production factors can be reallocated. The variation in the cost of production is then written:

$$\Delta cp = \frac{p_1 q_1 - p_0 q_0}{2} \quad (A4)$$

The variation in farm income (gross margin) is calculated by subtracting this increase in cost from the variation in production value (as in the diagram on the left), which is written: $D + E - F$, (or)

$$\Delta r = \Delta vp - \Delta cp = \frac{p_1 q_1 - p_0 q_0}{2} \quad (A5)$$

The variation in total well-being, integrating both the variation in consumer utility and that in the cost of production, is expressed as follows:

$$\Delta be = \Delta uc - \Delta cp = \frac{p_0 q_1 - p_1 q_0}{2} \quad (A6)$$

In this second case, the price bias remains identical, in absolute terms, to that observed in the first scenario:

$$\Delta be - \Delta r = \Delta uc - \Delta cp = BP \quad (A7)$$

However, the ratio between this bias and the variation in welfare (or farm income) differs according to the configuration adopted, since the distribution of costs and surpluses is affected.

In a developing economy, where production costs often remain low and the possibilities for reallocating labor are limited in the short term, it may be more appropriate to apply the first scheme (exogenous costs) to assess the impact of annual weather

shocks. However, in the longer term, when the adjustment of production factors becomes possible, the second scheme (endogenous costs) offers a more appropriate representation.

In all situations, the absolute price bias remains the same, but its relative importance varies according to the framework chosen.

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Conflict of interest

The authors declare no conflict of interest.

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COVID-19 Mortality Rate Variability Linked to Healthcare Expenditures in European Countries

Bilal Kargi and Bekir Cihan Uçkaç

Abstract

This study explores how healthcare investment influences health system capabilities during the COVID-19 pandemic across European countries. It investigates if higher healthcare spending correlates with lower COVID-19 fatality rates using data from the World Bank, OECD, and Eurostat. Examining a sample of European nations, the research identifies that countries with higher initial COVID-19 fatality rates in 2020 consistently maintained elevated rates in subsequent years. These countries generally allocated a smaller GDP percentage to healthcare, had lower healthcare spending per capita, and invested less in health research and development compared to others. Statistical analysis reveals a significant negative correlation between COVID-19 mortality rates in 2022 and healthcare expenditure as a percentage of GDP in 2020, suggesting a strong association between greater healthcare investment and reduced fatality rates. The study underscores the importance of robust healthcare funding in bolstering a nation's capacity to manage and mitigate the impacts of health crises like COVID-19.

Keywords: COVID-19, crisis management, fatality rate, health policy, health expenditure, pandemic crisis

1. Introduction

Since early 2020, the COVID-19 pandemic has profoundly impacted nations worldwide, driven by environmental, social, and economic factors [1–8], resulting in significant fatalities and broad socioeconomic consequences [1–8]. Initially, countries implemented non-pharmaceutical interventions like lockdowns, social distancing, and mask-wearing [9–14], alongside healthcare measures [9, 15, 16]. Evaluations of these strategies have provided crucial insights over time [17–20], promoting a more standardized global approach to pandemic management [21, 22].

Focusing on European countries allows for a more homogeneous comparison of healthcare systems and policies, given their shared socioeconomic context and similar levels of development. This enables a more nuanced analysis of the impact of healthcare spending on COVID-19 outcomes, controlling for other potential confounding factors.

Despite these efforts, variability in COVID-19 case fatality rates (CFRs) across nations remains a critical concern, influenced by factors such as healthcare spending, outbreak management capabilities, and demographic profiles [23–27]. Nations with larger populations tend to have higher CFRs, while age distribution and health status also play significant roles [23, 26–28]. Older individuals and those with pre-existing conditions face higher risks of severe illness and mortality [29, 30]. Additionally, healthcare infrastructure and expenditure significantly impact pandemic outcomes [24, 31, 32].

Moreover, the European context provides a rich dataset and a diverse range of healthcare systems, allowing for a robust analysis of the relationship between healthcare spending and COVID-19 outcomes. By examining this region, we can gain valuable insights into the effectiveness of different healthcare models in responding to global health crises.

Research highlights the pivotal role of healthcare capacity in reducing COVID-19 mortality rates, with stronger healthcare systems linked to lower CFRs [24]. Conversely, reduced healthcare spending has been associated with increased deaths. Effective governance enhances vaccination efforts, mitigating pandemic risks and socioeconomic impacts [32], underscoring the importance of robust healthcare infrastructure and resources like ventilators and personal protective equipment (PPE) in pandemic management [33].

This study aims to contribute to the growing body of literature on the impact of healthcare spending on health outcomes by investigating its association with COVID-19 mortality rates in European countries. By understanding the relationship between these variables, policymakers can make informed decisions about resource allocation and healthcare investments to improve pandemic preparedness and response.

Furthermore, the findings of this research can inform global health policy discussions and provide valuable insights for countries around the world, particularly those with similar healthcare systems and socioeconomic contexts.

This study investigates the relationship between healthcare spending and COVID-19 fatality rates across European nations, aiming to understand how variations in expenditure and capacity influence pandemic preparedness. Key questions include identifying nations better prepared to manage crises like COVID-19 and exploring whether higher healthcare expenditures correlate with lower fatality rates during outbreaks. Using data from OECD, World Bank, and Eurostat databases, the study employs descriptive statistics, t-tests, and regression analysis to uncover significant correlations and implications for healthcare policy and pandemic response strategies.

2. Study methodology and design

2.1 Sample

Our study uses data from 27 EU member states (Appendices 1) with comparable socioeconomic structures in order to provide a homogeneous sample for reliable statistical analysis.

2.2 Variable selection

Variable selection is a crucial step in statistical modeling, as it helps to identify the most relevant variables that contribute to the variation in the outcome variable. In

this study, a rigorous variable selection process was employed to ensure the inclusion of only the most informative variables.

The importance of variable selection lies in its ability to enhance the model's predictive power, improve its interpretability, and prevent overfitting. By carefully selecting relevant variables, we can reduce the risk of including noise variables that can obscure the true relationships between the variables of interest.

Furthermore, variable selection can help to mitigate the curse of dimensionality, which occurs when the number of variables exceeds the number of observations. By reducing the number of variables, we can improve the stability and efficiency of the statistical models.

2.3 Variables

An in-depth analysis was conducted on 17 variables encompassing population characteristics, health system resources, and the COVID-19 case fatality rate (CFR) for various years. Details regarding these specific variables can be found in **Table 1**.

Figure 1 illustrates the composition of health expenditure across countries. Health spending, measured as a percentage of GDP, encompasses various subcategories that collectively support the functioning of the healthcare system.

2.4 Hypothesis, data, and procedure

The objective of this study is to explore the potential link between healthcare spending levels and changes in COVID-19 fatality rates across European countries.

Variable, Source, Acronym	Sources	Description
Population on January 1, 2020, Popolo2020.	Eurostat [24]	The number of people who, as of January 1st of that year, were residents of that nation on a regular basis.
Population aged 65 years and older on January 1, 2020, Pop65yo2020.	Eurostat [34]	The total number of people 65 years of age or older who were residing in a nation on January 1st of that particular year.
Health expenditure as % of GDP, 2020, HealthExpGDP2020.	OECD [35]	Present spending on health (all aspects), across all payers and funding models (both government and voluntary)
Total health care expenditures per capita in current US dollars in 2020, HealthExpPC2020.	WHO [36]	The total health expenditure per capita (THE) is provided in international dollars (PPP).
Physicians per 1,000 inhabitants, 2018, Physicians1000Inh2018.	OECD [35]	Doctors in practice who offer their services to specific patients. It consists of practicing doctors who have obtained a medical degree from an accredited university and a license to practice. - Interns and resident physicians (those with the necessary training who work as medical professionals' assistants while completing a postgraduate internship or residency in a hospital) Doctors who work for themselves or are salaried and provide services regardless of where they are provided - Foreign medical professionals who hold a valid license to practice in the nation - All medical professionals who offer patient services, such as radiography, pathology, microbiology, hematology, and hygiene.

Variable, Source, Acronym	Sources	Description
Nurses per 1,000 people in 2018, Nurses1000Inh2018.	OECD [35]	Practicing nurses who offer patients direct services. Professional nurses, associate professional nurses, and foreign nurses with valid licenses who are currently employed in the nation are all included.
Total hospital beds per 1,000 inhabitants in 2019, HBeds1000Inh_2019.	OECD [35]	All hospital (HP1) beds that are constantly manned, maintained, and ready to receive newly admitted patients are included in the total number of hospital beds. They are the total of the subsequent classifications: Hospital beds in the following three categories: publicly owned hospitals (a), privately owned hospitals (b), privately owned hospitals (c), and for-profit hospitals (d).
Health expenditure in preventive care as % of GDP 2020, HealthExpPrevCare GDP2020.	OECD [35]	Present spending on health (all aspects), across all payers and funding models (both government and voluntary)
Hospitals per million inhabitants 2019, HospMillionPeople2019.	OECD [35]	Hospitals (HP1) are licensed facilities primarily engaged in providing medical, diagnostic, and treatment services, including nursing, physician, and other health services, to inpatients. They also offer specialized lodging services necessary for patient care. This category includes: -General hospitals (HP1.1); -Mental health hospitals (HP1.2); -Specialized hospitals excluding mental health institutions (HP1.3)
Curative (acute) care beds per 1000 inhabitants 2020. CurativeBeds1000Inh2020.	OECD [35]	Curative care (acute care) beds (HP1) are hospital beds available for curative care, classified under HC.1 in the SHA system. These beds are designated for managing labor (obstetrics), providing definitive treatment for illnesses or injuries, performing surgeries, alleviating symptoms of illness or injury (excluding palliative care), reducing the severity of conditions, preventing complications that could threaten life or normal functions, and conducting diagnostic or therapeutic procedures. The classification includes: -Beds for somatic curative (acute) treatment and psychiatric curative (acute) care; -All hospital beds in general hospitals (HP1.1), mental health hospitals (HP1.2), and other specialty hospitals (HP1.3).
Gross domestic expenditure on R&D in Health, Govt sector, 2020, GrossExpRANDGov2020.	OECD [35]	The data on gross domestic expenditure on research and development (GERD) by socio-economic objective (SEO) is displayed in this table. The NABS 2007 classification is used, which includes the following categories: exploration and exploitation of space, the environment, health, agriculture, transportation, energy, industrial production and technology, politics, social systems, structures, and processes, general advancement of knowledge, and defense.
Case fatality rate on 30 December 2020, Fatality 2020.	JHU [37]	The COVID-19 case mortality toll divided by the total number of COVID-19 infections
Case fatality rate on 25 December 2022, Fatality 2022.	JHU [37]	The COVID-19 case mortality toll divided by the total number of COVID-19 infections
Vaccination rate (full cycle) on 26 December 2021, VaccDec 2021.	JHU [37]	The percentage of the population that received two doses of the COVID-19 vaccination divided by the total number of individuals
Vaccination rate (full cycle) on 25 December 2022, VaccDec 2023.	JHU [37]	The percentage of the population that received two doses of the COVID-19 vaccination divided by the total number of individuals

Note: Data Sources; [34–36].

Table 1.
Data sources and variables.

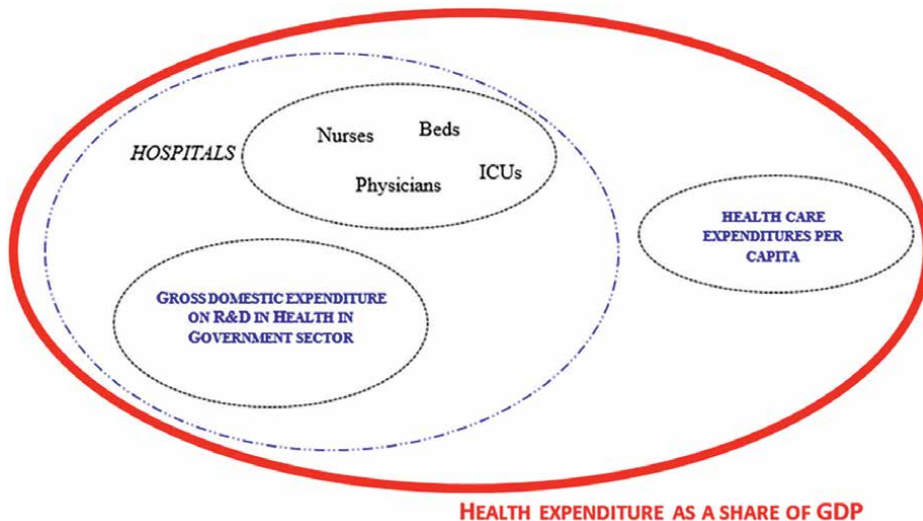


Figure 1.
The composition of national health spending.

If a significant relationship is found, the research aims to quantify the influence of healthcare expenditures on these fatality rates. Initially, descriptive statistics—including mean, standard deviation, skewness, and kurtosis—will assess the distributions and normality of variables outlined in **Table 1**. Following this, bivariate and partial correlation analyses will be conducted to identify and assess key relationships between specific study variables, while accounting for potential confounding factors such as the population aged 65 and over in 2020.

Finally, a straightforward regression analysis based on the following log-log model will be used to examine the correlations between the variables that have been chosen:

$$\log y_i = \alpha + \beta x_i + u_i \quad (1)$$

y_i = Track the COVID-19 Death Rate as of December 2020 or the Variation in the COVID-19 Death Rate from 2022 to 2020, i = countries.

x_i = Log Health Expenditure %GDP 2020, i = countries.

a = constant: the response or dependent variable's value in the absence of an associated predictor or independent variable.

b = coefficient of regression: it describes the link between a predictor and response variable by estimating the unknown parameter (Log Health Expenditure %GDP 2020).

Fourth, the sample will be divided into two groups based on the average COVID-19 fatality rate in 2020 among the European nations under investigation:

Group 1A: Nations where the 2020 COVID-19 death toll is less than the sample arithmetic mean.

A group of countries where the COVID-19 fatality rates in 2020 are below the arithmetic mean.

Similarly, for the COVID-19 fatality rate in 2022, the groups are:

Group 1B: Countries with a lower COVID-19 fatality rate in 2022 than the sample arithmetic mean.

Group 2B: Countries where the sample arithmetic mean is less than the COVID-19 fatality rate in 2022.

The sample is divided based on the average change in COVID-19 mortality rates from 2020 to 2022 across European countries:

Group 1C: Includes countries where the reduction in COVID-19 mortality rates from 2022 compared to 2020 is below the sample average. This group offers insights into factors affecting pandemic resilience. Higher fatality rates in 2022 indicate challenges in adapting response strategies over time. A smaller reduction in mortality rates may initially appear positive but suggests less significant improvements in virus management compared to other countries. This analysis underscores the need to assess trends beyond mortality rate changes to gauge countries' effectiveness in learning and adapting during the ongoing pandemic.

Group 2C: Comprises countries that may have demonstrated less effective learning in addressing the COVID-19 crisis, characterized by a larger increase in fatality rates from 2020 to 2022 compared to the overall average. These countries experienced a smaller decline in COVID-19 deaths over the period, indicating weaker adaptive capabilities and resilience in pandemic management. This pattern underscores potential challenges in enhancing response strategies over time.

Additionally, the Independent Samples Mann-Whitney U test is utilized to analyze the data. This non-parametric test compares differences between two independent groups when the dependent variable is not normally distributed. It assesses significant differences in means between groups under specific null hypotheses, supported by the Mann-Whitney U test.

HP1 A: The factors are distributed uniformly throughout the COVID-19 fatality rate category in 2022.

HP1 B: The variables are distributed uniformly throughout the COVID-19 Fatality rate differences for the 2022–2020 period.

Asymptotic significances at the level 0.05 are displayed.

3. Empirical results

Table 2 provides a comparative analysis of key variables between countries with higher and lower COVID-19 fatality rates in 2020. This table is essential for understanding the factors that may have contributed to these differences.

Demographic Differences: Countries with higher 2020 fatality rates generally had larger populations and older populations, which could be associated with increased vulnerability to severe COVID-19 outcomes.

Healthcare Expenditure and Infrastructure: Countries with lower fatality rates tended to have higher healthcare expenditure as a percentage of GDP and higher per capita healthcare spending.

However, there were no significant differences in the number of physicians, nurses, hospital beds, and healthcare expenditure on preventive care between the two groups.

Vaccination Rates: A notable difference was observed in vaccination rates. Countries with lower 2020 fatality rates had significantly higher vaccination rates in both 2021 and 2022. This suggests that a robust vaccination campaign can significantly reduce COVID-19 mortality.

Implications: Population Demographics: Countries with aging populations may require additional public health measures to protect vulnerable groups.

Variables	Countries with LOWER COVID-19 in Fatality 2020				Countries with HIGHER COVID-19 in Fatality 2020			
	N	Mean	Std. Deviation	N	Mean	Std. Deviation	Std. Deviation	
Popolo2020	16	10,607,269	19,918,336	11	25,236,692	23,576,645	23,576,645	
Pop65yo2020	16	128527.5	244528.4	11	308196.7	279641.9	279641.9	
HealthExpGDP2020	15	9.42	2.14	11	8.93	1.97	1.97	
HealthExpPC2020	16	3641.55	2150.59	11	2706.9	1858.84	1858.84	
Physiciabs1000lnh2018	9	5.09	1.53	11	3.71	1.56	1.56	
Nurses1000lnh2019	9	9.17	2.99	7	7.33	2.71	2.71	
HBeds1000lnh2019	13	4.81	1.87	9	4.68	1.51	1.51	
HealthExpPrevCareGDP2020	15	0.32	0.13	11	0.26	0.12	0.12	
HospMillionPeople2019	11	28.88	7.71	9	22.09	10.36	10.36	
CurativeBeds1000lnh2020	9	4.03	1.24	6	3.96	1.02	1.02	
GrossExpRANDGov2020	7	525.66	1244.17	5	403.52	671.51	671.51	
Popolo2020	20	15,561,361	24,217,427	7	19,441,815	16,750,658	16,750,658	
Pop65yo2020	20	186068.8	294525.7	7	246461.1	192465.9	192465.9	
HealthExpGDP2020	19	9.52	2.01	7	8.36	2.03	2.03	
HealthExpPC2020	20	3903.51	1974.24	7	1424.36	785.17	785.17	
Physiciabs1000lnh2018	14	4.56	1.45	6	3.78	2.13	2.13	
Nurses1000lnh2019	13	8.68	3.14	3	7	1.37	1.37	
HBeds1000lnh2019	18	4.56	1.65	4	5.65	1.83	1.83	
HealthExpPrevCareGDP2020	19	0.32	0.13	7	0.24	0.09	0.09	
HospMillionPeople2019	16	26.66	9.83	4	22.48	7.62	7.62	
CurativeBeds1000lnh2020	11	3.87	1.28	4	4.36	0.33	0.33	
GrossExpRANDGov2020	9	616.51	1140.79	3	49.53	15.07	15.07	

Variables	Countries with LOWER COVID-19 in Fatality 2020				Countries with HIGHER COVID-19 in Fatality 2020			
	N	Mean	Std. Deviation		N	Mean	Std. Deviation	
VaccDec2022	20	70.67	9.62		7	54.27	16.97	
VaccDec2021	19	75.06	8.89		7	57.39	17.71	
Popolo2020	15	7,575,029	9,773,081		12	27,807,874	28,346,033	
Pop65yo2020	15	101,277	134,32.4		12	327,287.4	343,268	
HealthExpGDP2020	14	8.02	1.67		12	10.6	1.52	
HealthExpPC2020	15	2425.95	1976.79		12	4304.3	1689.37	
Physiciabs1000lnh2018	10	4.54	2.13		10	4.12	1.09	
Nurses1000lnh2019	7	8.18	2.99		9	8.51	3.05	
HBeds1000lnh_2019	10	5.19	1.45		12	4.39	1.85	
HealthExpPrevCareGDP2020	14	0.26	0.12		12	0.34	0.12	
HospMillionPeople2019	9	27.18	8.85		11	24.72	10.12	
CurativeBeds1000lnh2020	7	4.01	0.9		8	4	1.34	
GrossExpRANDGov2020	8	4743	4156		4	132944	1498.9	
VaccDec2021	15	64.31	15.36		11	78.47	5.71	
VaccDec2022	15	61.04	15.1		12	73.13	8.06	

Note: (a) Countries showing a higher Difference in COVID-19 Fatality Rate for 2022–2020 than the sample mean indicate less improvement in fatality rates in 2022, suggesting weaker pandemic resilience and learning capacity. (b) Conversely, countries with a lower Difference in COVID-19 Fatality Rate between 2022 and 2020 than the sample mean demonstrate greater reduction in fatality rates in 2022, indicating stronger adaptive abilities and resilience in responding to the pandemic.

Table 2.
Descriptive separated into categories.

Healthcare Investment: While increased healthcare spending may be associated with better health outcomes, it is crucial to ensure that resources are allocated efficiently to areas with the greatest need.

Vaccination Campaigns: Prioritizing vaccination campaigns and addressing vaccine hesitancy can significantly reduce COVID-19 mortality rates.

By understanding these factors, policymakers can develop strategies to improve pandemic preparedness and response, particularly in countries with vulnerable populations and limited healthcare resources.

Table 3 provides a comparison of key indicators between countries with higher and lower COVID-19 fatality rates in 2020. This table highlights the differences in health expenditures, R&D investments, and the trajectory of COVID-19 mortality rates between these two groups of countries.

Initial Fatality Rates and Decline: Countries with lower initial fatality rates in 2020 experienced a more significant decline in mortality rates by 2022 compared to countries with higher initial rates. This suggests that countries with better-prepared healthcare systems and effective pandemic response strategies were able to mitigate the impact of the pandemic more effectively.

Healthcare Expenditure and R&D: While there were no significant differences in health expenditure as a percentage of GDP and healthcare expenditure per capita between the two groups, the countries with lower fatality rates had higher gross domestic expenditure on R&D in health in the government sector. This suggests that investing in health research and development can contribute to better pandemic preparedness and response.

Implications: Early and Effective Response: Countries should prioritize early and effective pandemic response strategies, including robust testing, contact tracing, and isolation measures.

Healthcare System Strengthening: Investing in healthcare infrastructure, including hospitals, clinics, and healthcare personnel, can enhance a country's capacity to respond to public health crises.

Research and Development: Prioritizing health research and development can lead to advancements in diagnostics, treatments, and vaccines, which can significantly reduce mortality rates.

Categories	COVID-19 fatality rate 2020	COVID-19 fatality rate 2022	Δ % 2022–2020	Health Expenditures as % GDP 2020	Health Expenditures per capita \$ 2020	Gross domestic expenditure on R&D in Health in Government sector \$ 2020
Nations with lower COVID-19 death toll	1.40	0.57	–59.29	9.42	3641.55	525.66
nations with greater COVID-19 death toll	2.83	1.21	–57.24	8.93	2706.9	403.52

Note: Values are arithmetic mean.

Table 3.
Findings comparing nations with high and low COVID-19 fatality rates.

International Cooperation: Collaborating with other countries to share knowledge, expertise, and resources can help accelerate the development of effective interventions and improve global health security.

By understanding the factors that contribute to differences in COVID-19 mortality rates, policymakers can develop evidence-based strategies to enhance pandemic preparedness and response (Figure 2).

Table 4 indicates negative correlations between COVID-19 mortality in December 2022 and health expenditure as a percentage of GDP in 2020 ($r = -0.42$, $p = 0.05$), as well as vaccinations administered by December 2021 ($r = -0.75$, $p = 0.01$). Similarly, the differences between COVID-19 mortality in December 2022 and health expenditure as a percentage of GDP in 2020, and vaccinations administered by December 2021, also show negative correlations ($r = -0.48$, $p = 0.05$ and $r = -0.52$, $p = 0.01$, respectively).

Table 5, employing partial correlation while controlling for the population aged 65 and over in 2020, confirms these findings. Higher health expenditure as a percentage of GDP in 2020 and increased immunization levels by December 2021 are associated with potential reductions in COVID-19 deaths in December 2022.

Table 6 presents results from two regression models analyzing COVID-19 mortality rates across European nations:

In Model 1, employing a linear log-log approach, a 1% increase in GDP growth in health expenditure in 2020 correlates with a 1.34% decrease in the COVID-19 fatality rate by December 2020. The model explains about 17% of the variance (R^2), with the independent variable (COVID-19 Fatality rate decrease %) significantly predicting the dependent variable (F value; $p < 0.05$).

Model 2 assesses the difference in COVID-19 mortality rates between 2022 and 2020 as a measure of pandemic adaptation and resilience. The findings reveal that a

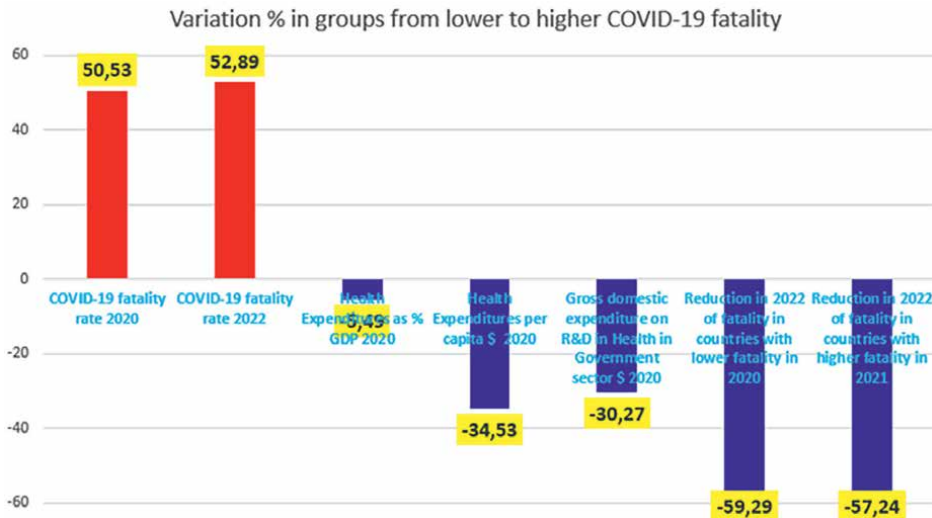


Figure 2.

Differences in outcomes between COVID-19 fatality rates in affluent and low-income nations. Note: In contrast to countries with lower COVID-19 fatality rates, those with higher rates in 2020 experienced a + 50.5% increase in fatalities in 2020 and + 52.9% in 2022. They also allocated a lower percentage of GDP to health expenditure (5.5%), had lower health expenditure per capita (34.5%), devoted a smaller proportion to R&D expenditures in health (30.3%), and saw a smaller reduction in COVID-19 fatalities from 2020 to 2022 (57.2%) compared to the other group, which experienced a reduction of 59.3%.

		COVID-19 Fatality Dec 2022	Differing COVID-19 Fatality 22-20	Pop65yo 2020	HealthExpGDP 2020	Nurses1000Inh 2019	Vaccination December 2021
COVID-19 Fatality December 2022	r	1	0.303	0.025	-.416 [*]	-.0155	-.752 ^{**}
	N		27	27	26	16	26
Differing COVID-19 Fatality 22-20	r		1	-.0379	-.482 [*]	0.21	-.518 ^{**}
	N			27	26	16	26
Pop65yo 2020	r			1	.426 [*]	0.049	0.165
	N				26	16	26
HealthExp GDP 2020	r				1	.505 [*]	.484 [*]
	N					16	25
Nurses1000Inh 2019	r					1	0.056
	N						15
Vaccination December 2021	r						1
	N						

^{*}The correlation is significant at the two-tailed 0.05 level.
^{**}At the two-tailed 0.01 significance level, there is a correlation.

Table 4.
Correlations.

		COVID-19 Fatality Dec 2022	Differing COVID-19 Fatality 22–20	HealthExpGDP 2020	Vaccination December 2021
COVID-19 Fatality December 2022	<i>r</i>	1	0.328	−0.465 [*]	−0.793 ^{**}
	<i>N</i>		22	22	22
Differing COVID-19 Fatality 22–20	<i>r</i>		1	−0.374	−0.517 ^{***}
	<i>N</i>			22	22
HealthExpGDP 2020	<i>r</i>			1	0.443 [*]
	<i>N</i>				22
Vaccination December 2021	<i>r</i>				1
	<i>N</i>				

^{*} $p < 0.05$.
^{**} $p < 0.001$.
^{***} $p < 0.01$.

Table 5.
Partial Correlation, population above 65 years of age (2020).

GDP 2020 Log Health Expenditure Percentage				
Dept. Variable	Constant α	Coefficient β_1	R ²	F
Model-1. Log COVID-19 Fatality rate December 2020, $N = 25$	2.49	−1.34 [*]	.17	5.03 ^{**}
Model-2 Differing COVID-19 Fatality rate 2022–2020, $N = 25$	.53	−1.84 [*]	.23	7.27 [*]

^{*} $p < 0.05$.
^{**} $p < 0.01$.
^{***} $p < 0.001$.

Table 6.
Log-log models and parametric estimations of the connection.

1% increase in GDP growth in health expenditure in 2020 is linked to a 1.84% decrease in the difference in COVID-19 mortality rates between 2022 and 2020, with a notable p-value of 0.01. This model accounts for approximately 23% of the variance (R²), emphasizing the robust predictive capability of the independent variable in evaluating countries' responses to the COVID-19 pandemic (significant F value; $p < 0.01$).

Table 7 displays findings from the Independent Samples Mann-Whitney U test, comparing COVID-19 fatality rates in 2022 and disparities from 2020 to 2022 among countries. It aimed to uncover differences in various variables across these groups, showing significant variability in gross domestic expenditure on health-related R&D in 2020 (in US\$), healthcare spending per capita in 2020 (in US\$), and immunizations administered in 2021 and 2022.

The analysis highlights that European countries with higher health expenditures and immunization rates exhibit notably lower COVID-19 fatality rates. These nations leverage better institutional, organizational, and technological capabilities, enhancing their readiness and response to the pandemic compared to others. Additionally, these countries allocate more resources to healthcare [34–41].

	Null hypothesis For both categories of countries with lower and higher COVID-19 fatality rates in 2022, the variable distribution is the same.		Null hypothesis The same variables are distributed among the categories of nations with differing COVID-19 fatality rates between 2022 and 2020.	
	Significance	Decision for Null H.	Significance	Decision for Null H.
Popolo2020	0.179 [*]	Retain	0.005 [*]	Reject
Pop65yo2020	0.081 [*]	Retain	0.019 [*]	Reject
HealthExpGDP2020	0.231 [*]	Retain	0.002 [*]	Reject
HealthExpPC2020	0.001 [*]	Reject	0.009 [*]	Reject
Physiciabs1000Inh2018	0.602 [*]	Retain	0.436 [*]	Retain
Nurses1000Inh2019	0.439 [*]	Retain	0.758 [*]	Retain
HBeds1000Inh2019	0.262 [*]	Retain	0.254 [*]	Retain
HealthExpPrevCareGDP2020	0.231 [*]	Retain	0.131 [*]	Retain
HospMillionPeople2019	0.554 [*]	Retain	0.603 [*]	Retain
CurativeBeds1000Inh2020	0.753 [*]	Retain	0.779 [*]	Retain
GrossExpRANDGov2020	0.727 [*]	Retain	0.008 [*]	Reject
Vaccination December 2021	0.013 [*]	Reject	0.02 [*]	Reject
Vaccination December 2022	0.010 [*]	Reject	0.004 [*]	Reject

Asymptotic meanings are presented. The degree of significance is .05. The test's exact importance is shown.

Table 7.
Mann-Whitney U test for independent samples.

Table 7 presents the results of the Mann-Whitney U test, which is a non-parametric test used to compare differences between two independent groups. In this case, the two groups are countries with higher and lower COVID-19 fatality rates in 2020 and 2022, respectively.

Significant Differences: Several variables showed significant differences between the two groups. These include:

- Population size (Popolo2020).
- Population aged 65 and over (Pop65yo2020).
- Health expenditure as a percentage of GDP (HealthExpGDP2020).
- Health expenditure per capita (HealthExpPC2020).
- Gross domestic expenditure on R&D in health in the government sector (GrossExpRANDGov2020).
- Vaccination rates in 2021 and 2022 (VaccDec2021, VaccDec2022).

No Significant Differences: For most other variables, including the number of physicians, nurses, hospital beds, and healthcare expenditure on preventive care, no significant differences were found between the two groups.

Implications: Population Demographics and Healthcare Resources: Countries with higher COVID-19 fatality rates tend to have larger populations and older populations, which may contribute to increased vulnerability to severe COVID-19 outcomes. Additionally, these countries may have lower levels of healthcare spending and fewer healthcare resources.

Vaccination Rates: The significant differences in vaccination rates between the two groups highlight the importance of vaccination campaigns in reducing COVID-19 mortality.

Policy Implications: Policymakers should prioritize strategies to improve access to healthcare, especially for vulnerable populations. Additionally, investing in public health infrastructure and promoting vaccination campaigns can help to mitigate the impact of future pandemics.

By understanding the factors that differentiate countries with higher and lower COVID-19 fatality rates, policymakers can develop targeted interventions to improve public health outcomes.

4. Discussion

The analysis shows that higher health spending correlates with lower COVID-19 fatality rates, indicating better-prepared healthcare systems capable of early diagnosis, efficient treatment, and crisis management [38–40]. Countries with greater health expenditures typically have advanced public health infrastructure, including robust outbreak response and disease surveillance, crucial for containing viral spread [12, 16]. Increased health spending can also improve overall health outcomes, potentially reducing COVID-19 severity by addressing underlying health issues and enhancing public health measures like contact tracing and vaccination rates [12, 16].

Furthermore, higher health spending facilitates investment in vaccine development, therapies, and critical medical supplies such as ventilators and PPE, which mitigate pandemic impacts [21, 41]. This underscores the importance of funding robust public health infrastructure and effective governance to enhance crisis preparedness and protect populations from emerging infectious diseases [11, 16, 42].

It is important to acknowledge the limitations of this study. While the analysis provides valuable insights into the relationship between healthcare spending and COVID-19 mortality rates, it is essential to consider the complex interplay of various factors that influence pandemic outcomes. Other factors, such as population demographics, social determinants of health, and government policies, may also play significant roles in shaping COVID-19 trajectories.

The data also reveal a modest correlation between COVID-19 fatality rates and health capacity (see **Table 1**), influenced by factors beyond infrastructure and spending alone. Healthcare system structure, governance quality, quality of care, healthcare professional accessibility and education, and collaboration between public health agencies and healthcare providers are critical for effective emergency management [40, 43, 44].

Contextual factors like population density, age distribution, climate conditions, air pollution, and other environmental variables further influence the relationship between health capacity and COVID-19 fatality rates [40, 43, 44]. Even countries with advanced healthcare systems may face higher susceptibility in densely populated areas or adverse environmental conditions, highlighting the complexities of pandemic response.

In summary, while robust public health infrastructure and healthcare systems are crucial for mitigating infectious diseases like COVID-19, multiple factors contribute to mortality rates [41]. Demographics, data reporting standards, environmental factors, technological advancements, and skilled human resources also play significant roles [45–48]. Enhancing healthcare infrastructure not only aids pandemic response but also improves overall healthcare delivery, benefiting public health beyond emergencies. International collaboration and knowledge-sharing are essential

in addressing global health challenges and promoting global health security in an interconnected world.

The relationship between public expenditure and public health has been the subject of extensive research. In recent years, there has been a growing interest in understanding the impact of public health expenditure on health outcomes, particularly in European countries. This literature review aims to synthesize the findings of key studies that have examined this relationship.

Numerous studies have established a strong positive correlation between public health expenditure and improved health outcomes. For instance, Stuckler et al. [49] demonstrated a significant association between increased public health spending and reduced mortality rates. Similarly, Gerdtham and Andersson [50] highlighted the positive impact of public health expenditure on health inequalities. Public health expenditure can significantly influence the performance of healthcare systems. Kringos, Mossialos, and Thomson [51] found that countries with higher levels of public health spending tend to have more efficient and equitable healthcare systems. This is attributed to factors such as improved infrastructure, better-trained healthcare professionals, and enhanced access to essential medicines. Public health expenditure plays a crucial role in reducing health disparities. Braveman et al. [52] demonstrated that targeted public health interventions, funded through increased public expenditure, can effectively address the health needs of marginalized populations. By investing in preventive care, health education, and social determinants of health, governments can promote health equity and reduce health disparities. Investing in public health can yield significant economic benefits. Cutler et al. [53] found that increased public health expenditure can lead to higher productivity, lower healthcare costs, and improved economic growth. By preventing illness, promoting healthy lifestyles, and reducing premature mortality, public health investments can contribute to a healthier and more prosperous society.

Our study aligns with the broader body of research that highlights the positive impact of public health expenditure on health outcomes. Similar to the findings of Stuckler et al. [49] and Gerdtham and Andersson [50], we observed a strong correlation between increased healthcare spending and lower COVID-19 mortality rates. These findings emphasize the importance of robust healthcare systems in mitigating the impact of public health crises. While our study builds upon the existing literature, it offers several unique contributions. By focusing on the specific context of the COVID-19 pandemic, we provide empirical evidence on the immediate and tangible impact of healthcare spending on mortality rates. Our findings have significant policy implications, suggesting that countries should prioritize healthcare investments as a crucial strategy to enhance pandemic preparedness and response. While our study provides valuable insights, it is important to acknowledge its limitations. Like other studies, our analysis is subject to the availability and quality of data. Future research should explore the long-term consequences of the COVID-19 pandemic, including its impact on health disparities and economic recovery. Additionally, further investigation is needed to identify the optimal level of public health expenditure and the most effective allocation of resources to maximize health outcomes.

5. Conclusions

Various factors, including environmental pollution, climate change, governance quality, healthcare systems, and national innovation frameworks, collectively shape

how COVID-19 impacts societies [45, 46, 54–59]. During pandemics, countries aim to reduce mortality and maintain socioeconomic stability. While strategies to control COVID-19 have been explored, the role of health spending in mitigating respiratory infectious diseases remains underexplored.

Section 2's hypothesis, linking COVID-19 fatality rates with health expenditures among European countries in similar socioeconomic contexts, finds support in statistical evidence. There's a negative correlation between health spending and COVID-19 fatality rates across European nations. A 1% increase in health spending as a percentage of GDP in 2020 correlates with a 1.34% decrease in COVID-19 fatality rates. Additionally, a 1% rise in health expenditure is associated with a 1.84% reduction in the difference between COVID-19 mortality rates in 2022 and 2020 (p-value 0.01), enhancing national resilience during pandemics.

Investments in healthcare infrastructure, R&D, and advanced medical technologies like ventilators strengthen national preparedness against unknown respiratory diseases [40, 42]. Therefore, countries are urged to fortify healthcare systems beyond pandemic preparedness, especially in managing acute respiratory illnesses [46, 59–61].

Initial findings linking higher per capita health spending to lower COVID-19 mortality rates in the initial wave underscore the benefits of comprehensive crisis planning for future pandemics. This planning should prioritize substantial investments in healthcare infrastructure and the adoption of advanced medical technologies to enhance national emergency readiness and mitigate public health and socioeconomic impacts.

Future research should delve deeper into the complex interplay between healthcare spending, socioeconomic factors, and environmental influences on pandemic outcomes. Exploring the impact of specific healthcare interventions, such as vaccination campaigns and public health measures, on mortality rates can provide valuable insights for policymakers. Additionally, investigating the long-term consequences of the pandemic, including mental health impacts and economic recovery, is crucial for developing effective post-pandemic strategies.

Limitations include not fully addressing all factors influencing COVID-19 fatality rates and the role of health spending. Future research should integrate economic factors to better understand these dynamics. Broader societal and environmental factors, such as robust environmental policies and effective governance, also influence pandemic resilience, complementing healthcare investments. Innovations in medical technology through strong R&D can advance pandemic management strategies, highlighting interdisciplinary approaches in global health security. Integrating these insights into future research frameworks will shape effective public health policies to mitigate future infectious disease outbreaks' impacts on global health and socioeconomic stability [62–65].

Policymakers should prioritize substantial investments in healthcare infrastructure, research and development, and public health programs. By allocating adequate resources to these areas, countries can enhance their capacity to respond effectively to future health crises. This includes strengthening primary healthcare systems, expanding access to quality care, and investing in advanced medical technologies [66–69].

International cooperation is essential for addressing global health challenges. Policymakers should promote collaboration between countries to share knowledge, expertise, and resources. This includes supporting international organizations, facilitating information exchange, and coordinating global health initiatives. By working together, countries can accelerate the development of vaccines, treatments, and diagnostic tools.

Robust public health infrastructure is crucial for early detection, rapid response, and effective control of infectious diseases. Policymakers should invest in surveillance systems, laboratory capacity, and workforce training. Strengthening public health systems will enable countries to identify and respond to emerging health threats promptly, mitigating their impact on public health and the economy.

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Conflict of interest

The authors declare no conflict of interest.

Appendix

EU members countries.

Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, and Sweden.

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This edited volume reflects a diverse array of perspectives on how economic development and growth may be facilitated. The book offers a theoretical analysis and empirical evidence, along with country and regional perspectives, to enrich our understanding of the patterns and determinants of sustainable development and growth. It seeks to bridge the developing theory and emerging realities of the 21st century, focusing on topics such as innovation, inclusiveness, digitalization, and green transition. It is a must-have reference for academics and professionals who hope to achieve inclusive, resilient, and sustainable development and growth in the 21st century.

*Taufiq Choudhry,
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