

Economic Growth: Theories, Drivers, and Contemporary Challenges in a Changing World

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How to cite this article:

Xiao, J., Xu, Z., Fan, X., Wang, X. and Skare, M. (2025). Economic Growth: Theories, Drivers, and Contemporary Challenges in a Changing World. *Acta Montanistica Slovaca*, Volume 30 (4), 947-982

DOI:

<https://doi.org/10.46544/AMS.v30i4.09>

Abstract

Traditional economic growth paradigms face both challenges and opportunities due to accelerating technological change, deepening globalization, and growing environmental concerns in the global economy. The existing research on these developments lacks an essential integrated synthesis that would connect established theories with emerging economic realities. The review examines economic growth from multiple perspectives, beginning with a detailed assessment of growth indicators and their constraints for measuring sustainability and welfare. The paper discusses the evolution of growth theories from classical models to modern frameworks that incorporate institutional factors, technological advancements, and environmental constraints, and highlights current theoretical limitations in addressing complex economic systems. The analysis of empirical evidence on growth determinants, such as physical and human capital, technological innovation, institutional quality, and international integration, yields an integrated framework that positions these factors within the context of current global challenges. The review examines how macroeconomic policies, in conjunction with trade dynamics and emerging technologies, such as artificial intelligence, influence growth patterns by affecting specific sectors. The study identifies essential research directions that unite growth economics with sustainability science and technological change and then proposes new methodological approaches to tackle these complex challenges. The comprehensive analysis provides policymakers and researchers with evidence-based knowledge to develop growth strategies that integrate economic development with social equity and environmental protection in our modern, interconnected world.

Keywords

Environmental Constraints; Economic Growth Theories; Technological Innovation and Artificial Intelligence; Globalization; Sustainability; Institutional Economics



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Introduction

Despite significant advances in theoretical developments and empirical analyses of growth determinants, the literature remains fragmented, lacking an integrated framework that connects traditional growth theories with the modern challenges of technological disruption, environmental constraints, and shifting global economic architectures (Keenan & Wojcik, 2023). In particular, there is a need for a comprehensive synthesis that addresses the transformative potential of artificial intelligence, the evolution of global value chains, and the requirements for sustainable development as emerging factors influencing economic growth.

This review addresses these critical gaps by providing three distinct contributions. We present a conceptual synthesis that links traditional growth models to institutional, technological, and environmental aspects, aiming to provide a comprehensive understanding of contemporary growth dynamics. The study systematically analyzes how key growth determinants function across different economic environments and development levels. We present an integrative theoretical framework that links traditional growth models to institutional, technological, and environmental aspects, aiming to provide a comprehensive understanding of contemporary growth dynamics.

Our review process follows a systematic approach. We began with extensive database searches in EconLit, JSTOR, and Web of Science, using keywords related to economic growth theory, determinants, and contemporary challenges. Studies were selected based on methodological rigor and citation impact, ensuring alignment with our integrative framework. While the primary focus was on literature from 2014 to 2024, foundational earlier works were also included to provide essential context. For emerging topics such as artificial intelligence and sustainable growth, we reviewed high-quality working papers and policy documents to capture recent developments. The selected literature was then critically analyzed and synthesized within our conceptual framework to identify theoretical connections, empirical consistencies and contradictions, and areas requiring further research.

Economic growth is a key driver of social progress and economic prosperity, directly affecting national income levels and shaping a country's social, political, and environmental landscape in numerous ways. First, by expanding production and fostering the development of new industries, economic growth generates more jobs, reduces unemployment, and provides increased economic opportunities for disadvantaged groups (Karahasan, 2023). Additionally, economic growth strengthens the government's fiscal capacity. Higher tax revenues enable the government to allocate more resources toward infrastructure development, public service improvements, and social welfare enhancement, thereby promoting broader social development (Zhou et al., 2023). Furthermore, economic growth is closely tied to technological innovation (Lasisi et al., 2022). Growing economies tend to have greater investment capacity, which drives technological advancements and productivity improvements, creating a positive feedback loop between innovation and growth. Moreover, economic growth is critical for enhancing international competitiveness. The expansion of an economy positions a country favorably in the global marketplace, bolstering its role in international trade and investment while simultaneously equipping the nation with greater resources and capacity to address global challenges (Rahman, 2021).

Background on economic growth

Given the profound impact of economic growth on social and economic development, understanding its driving forces, mechanisms, and evolution over time is crucial. To this end, economists have proposed various theoretical models over the centuries to explain the sources and drivers of economic growth. The classical school of economics, which emerged in the 18th century, marks the origin of economic growth theory. Key figures such as Adam Smith, David Ricardo, and Thomas Malthus represented this school of thought. Economists of this period focused primarily on the roles of production factors—labor, capital, and land—and believed that economic growth resulted from increases in labor, capital accumulation, and land utilization. Adam Smith introduced the theory of the division of labor, arguing that its expansion would enhance labor productivity and, in turn, promote economic growth (Smith, 1976). David Ricardo (2015) developed the theory of comparative advantage, which highlights the role of international trade in fostering national economic growth. He argued that by specializing in the production of goods in which they have a comparative advantage, countries can increase production efficiency and thereby achieve economic growth (Siddiqui, 2018).

In contrast, Thomas Robert Malthus focused on the pressures of population growth on resources, introducing the concept of the 'Malthusian trap.' According to Malthus, economic growth would be constrained by excessive population growth and limited resources, ultimately leading to stagnation or recession (Malthus, 1798). Moving forward to the 1930s and 1940s, Harrod (1939) and Domar (1946) independently developed what is now known as the Harrod-Domar model, which underscores the crucial role of investment in driving economic growth. They argued that capital is the primary factor contributing to economic growth, as investment increases the capital stock and thereby enhances productive capacity. However, the model has several shortcomings: it assumes a constant capital-output ratio, which is unrealistic, and it overemphasizes capital accumulation as the sole source of growth, overlooking the contributions of technological and human factors.

In the 1950s, Solow (1956) and Swan (1956) introduced the neoclassical economic growth model, also known as the Solow-Swan model, marking a significant advancement in economic growth theory. This model identified

capital, labor, and technological progress as the three primary drivers of economic growth, with particular emphasis on technological progress as the key to achieving sustained long-term growth. According to the neoclassical growth model, long-term economic growth can occur only through exogenous technological progress, while capital and labor accumulation have only a limited impact on long-term growth. Technological progress is considered the sole factor capable of sustainably increasing productivity. However, as technological progress was treated as an exogenous variable, this framework did not explain the sources of technological innovation, prompting subsequent scholars to build upon and refine the theory.

In the late 1980s, scholars such as Romer (1986) and Lucas (1988) developed the theory of endogenous growth, which challenged the exogenous assumption of technological progress in the neoclassical growth model. They emphasized that technological progress and innovation are determined by factors within the economic system. Rather than being an exogenous variable, technological progress is driven by endogenous factors such as investment, research and development (R&D), innovation, and knowledge accumulation. Technological innovation can continuously enhance productivity and sustain long-term economic growth. Romer (1994) argued that knowledge creation and diffusion are central drivers of economic growth, with R&D activities and firm-level knowledge innovation generating spillover effects that contribute to broader economic growth. Lucas, in turn, highlights the importance of human capital accumulation, noting that higher levels of education and skills training can improve labor productivity, thereby driving economic growth (Lucas, 1988).

As economic growth theories have evolved, institutions are increasingly recognized as key factors influencing endogenous elements such as technological innovation and human capital accumulation. North (1991) argued that institutions, such as legal systems and property rights frameworks, play a critical role in economic growth. Strong institutions foster economic growth by facilitating the efficient functioning of markets, stimulating innovation, and attracting investment. As the global economy gradually shifts toward a knowledge-based economy, innovation-driven and knowledge spillover theories have become significant branches of modern growth theory. Schumpeter's concept of 'creative destruction' has been further developed (Schumpeter, 1994), with scholars focusing on the positive effects of knowledge spillovers on regional and industrial growth. These theories highlight the essential role of entrepreneurial activity, innovation, and R&D in driving long-term economic growth.

As environmental issues, such as climate change, have become increasingly prominent, modern economic growth theories have begun to address the sustainability of economic growth. Economists have introduced the concept of 'green growth,' which emphasizes how economic growth can be achieved alongside the harmonious development of humanity and nature through rational resource utilization and environmental protection policies (Daly, 2005; Georgeson et al., 2017; Feng et al., 2021; Wang et al., 2021; Yin & Zeng, 2024). Furthermore, globalization and expanded international trade have facilitated the diffusion of technology and knowledge, providing countries with new opportunities for growth through trade openness and participation in global markets. Technological innovation has been further integrated into modern growth theories, with artificial intelligence (AI) and digital technologies identified as new drivers of future economic growth (Liu et al., 2024). The rapid development of emerging technologies and the ongoing digital transformation continue to reshape economic growth dynamics.

Tab. 1. The evolution of economic growth theory

Theory stage	Main contributor	Representative model/ method
Classical growth theory	Adam Smith (1776)	Theory of division of labor
	Thomas Malthus (1798)	Malthusian growth model
	David Ricardo (1817)	Comparative advantage theory
	Harrod, Roy F. (1939)	The Harrod-Domar model
	Domar, Evsey (1946)	
Neoclassical growth theory (1950s-1960s)	Robert Solow (1956)	Solow-Swan model
	Swan, T.W. (1956)	
Endogenous Growth (1980s)	Paul Romer (1986)	Knowledge spillover model
	Robert Lucas (1988)	Human capital model
New institutional economics (1990s)	Douglas North (1991)	Institutional economics theory
Innovative growth theory (1990s)	Joseph Schumpeter (1994, [1942])	Creative destruction theory
Environment and Sustainable Development Theory (2000s)	Herman Daly (2005)	Uneconomic growth

Source: Authors' representation

Tab. 1 outlines several key stages in the development of economic growth theory, highlighting the contributors, their models, and methods. From classical economics to neoclassical growth theory and, later, to endogenous growth models, theories of economic growth have evolved gradually, continually adapting to changes in the economic environment. Despite the progression through various stages, these theories have consistently provided a foundation for policy formulation at different points in history. While modern growth theories increasingly incorporate factors such as institutional quality, trade globalization, technological innovation, and environmental sustainability, the current economic landscape and technological advancements necessitate a

reevaluation of these theoretical frameworks. It is crucial to apply these frameworks to address new growth drivers and emerging challenges.

Objectives of the review

This review systematically examines and analyzes the core theories and key factors influencing economic growth, with the goal of uncovering the driving mechanisms in the current rapidly changing economic environment. Additionally, it seeks to explore the role of related policies and future research directions.

(1) Firstly, we discuss indicators used to measure economic growth. These indicators not only reflect the size and growth rate of the economy but also reveal the quality, structure, and efficiency of economic development. Analyzing these indicators and their limitations provides a clearer understanding of the economy's health, offering a foundation for policy formulation and a reference for investors and other stakeholders.

(2) Secondly, we review the evolution of endogenous growth theories, from classical economics to the modern era, focusing on the different explanatory frameworks these theories provide for economic growth and their applications in various historical contexts. This review enables us to understand the multiple sources of economic growth and to identify the limitations of these theories in addressing new economic realities.

(3) Thirdly, we analyze the main drivers of economic growth, such as capital accumulation, technological innovation, human capital, and institutional quality. Through empirical studies, we examine how these factors contribute to the economic development of different countries and regions, highlighting their impact on productive efficiency and long-term growth.

(4) Additionally, the paper examines the role of economic policies in promoting or inhibiting economic growth, with a particular focus on how instruments such as fiscal, monetary, and trade policies influence economic development by intervening in market mechanisms. As globalization accelerates and technological change progresses, particularly with the rise of AI and the digital economy, the traditional economic growth model faces new challenges and opportunities. This paper uses AI as a representative example of emerging technologies and explores how these factors reshape the path of economic growth, examining their impact on various industries and economies through specific case studies.

(5) Finally, in response to the new challenges confronting economic growth, we propose future research directions, particularly in exploring new models and policy options for economic growth in the context of environmental sustainability, demographic change, and technological revolution. Many reviews primarily focus on established theories without providing a clear path for future research. By identifying these potential challenges, this paper offers a roadmap for future research and advocates for interdisciplinary approaches to address the complexities of modern economic growth.

Therefore, this review provides a comprehensive synthesis of theoretical models, links empirical evidence to policy, explores new growth drivers such as AI, and examines the role of globalization in economic growth. It also lays the groundwork for future research by identifying emerging challenges and providing a resource for both researchers and policymakers seeking to promote sustainable economic growth in an evolving global context. Therefore, this review provides a comprehensive synthesis of theoretical models, links empirical evidence to policy, explores new growth drivers such as AI, and examines the role of globalization in economic growth.

The remainder of the paper is structured as follows: Section 2 discusses economic growth indicators and their limitations; Section 3 reviews classical, neoclassical, and contemporary growth models, including empirical validations and criticisms; Section 4 analyzes empirical methods and key determinants of growth; Section 5 examines the effects of macroeconomic regulations; Section 6 explores the impact of trade policies, globalization, and regional integration; Section 7 investigates the role of AI in economic growth through empirical evidence and case studies; Section 8 identifies emerging issues and future research directions, emphasizing interdisciplinary approaches; and Section 9 summarizes the key findings, offers policy recommendations, and highlights the need for continued research on economic growth.

Economic growth indicators

Economic growth theories provide an essential framework for understanding the drivers of economic development; however, the applicability of these theories and the formulation of effective policies rely heavily on accurate economic data and indicators.

Core indicators and their limitations

In assessing a country's economic growth, gross domestic product (GDP) and gross national product (GNP) are the most widely used indicators, each offering a distinct perspective on economic activity and national income. GDP measures the market value of all final goods and services produced within a country or region over a specific period and serves as the primary indicator of economic activity (Sözen & Arcaklioglu, 2007). The growth rate of GDP directly indicates the extent of economic expansion or contraction, helping policymakers assess economic development. Additionally, GDP serves as a benchmark for international comparisons of economic size and

development levels; when adjusted for purchasing power parity (PPP), it provides a more accurate picture of differences in living standards (Siddiqi, 1994). In contrast, GNP focuses on the global economic activities of a country's residents, offering a broader view of national income (Merko et al., 2019). Unlike GDP, GNP includes both domestic production by citizens and income earned abroad, making it especially valuable for countries that rely on foreign investment or labor exports. By capturing cross-border economic activities, GNP highlights the effects of globalization on the national economy, helping policymakers evaluate the impact of international economic shifts on national income (Afza, 2020).

While GDP and GNP are central indicators of economic growth, national income accounting has limitations that can affect reliability in practical applications. GDP and GNP typically capture only market-based goods and services, excluding non-market activities like household labor and the underground economy (Wang et al., 2021). Consequently, the true economic output of certain countries or regions may be underestimated. Additionally, GDP and GNP do not account for environmental impacts or resource depletion (Campos et al., 2019; Merko et al., 2019). Economic growth often comes at the cost of natural resources and environmental quality, yet these negative externalities are absent from national income figures (Torrás, 1999). In fact, resource over-consumption can lead to long-term economic setbacks that may be masked by GDP growth. Furthermore, while GDP and GNP reflect overall economic growth, they do not address income inequality (Fixler et al., 2017); GDP per capita, for example, overlooks disparities in income distribution, thereby failing to fully represent individuals' living conditions.

Complementary indicators and their limitations

Core indicators typically emphasize economic size, making it challenging to assess the quality and sustainability of growth. To provide a more comprehensive understanding, complementary indicators have been introduced. For instance, the human development index (HDI) combines factors such as longevity, education, and income, addressing some limitations of GDP in measuring human development (Noorbakhsh, 1998). However, HDI does not capture details on income inequality or environmental impacts. Total factor productivity (TFP), meanwhile, assesses economic efficiency by examining growth contributions beyond capital and labor, such as technological innovation (Qiu et al., 2023; Wei et al., 2024). With a growing focus on sustainability, variations of TFP—like green TFP (GTFP) (Chen et al., 2023; Zhang et al., 2024) and carbon TFP (CTFP) (Wang et al., 2022; Zhao, 2023)—incorporate environmental considerations. Nonetheless, TFP is complex to calculate and can be affected by data quality and statistical methodologies. Labor productivity (Shahnazi, 2021), another important metric, reflects labor market efficiency but overlooks capital inputs and technological contributions. Green GDP (Hoff et al., 2021; Stjepanovic et al., 2022), in contrast, seeks to adjust traditional GDP by accounting for resource consumption and environmental costs, offering a measure of sustainable growth (Ng & Rezaee, 2020), though global standards for its application are still lacking.

In the time dimension, economic growth indicators can be divided into short-term and long-term measures. Short-term indicators primarily assess the economy's immediate performance and help forecast shifts in the economic cycle. For instance, the industrial production index (Amarasinghe, 2016) gauges activity within the industrial sector, offering insights into economic fluctuations, though it may underrepresent the contribution of the service sector in service-oriented economies. The retail sales growth rate (Zhou et al., 2024), reflecting changes in consumer spending and confidence, often signals economic acceleration when consumption is strong; however, because it is susceptible to short-term variations, it may not accurately capture long-term consumption trends. Additionally, the unemployment rate indicates labor market health, with a low rate generally signifying economic vibrancy (Jo et al., 2023). Yet, as it lags behind economic shifts, it does not fully reflect issues such as job quality. Finally, the inflation rate (Jo et al., 2023) measures overall price changes; while moderate inflation supports economic growth, high inflation erodes purchasing power.

In contrast, long-term indicators emphasize the foundational factors that support sustainable economic growth. Capital accumulation (Shi & Xu, 2023) is a key driver of sustained expansion, as it enhances productive capacity through increased investment in fixed assets and infrastructure. However, excessive reliance on capital accumulation can lead to inefficient resource allocation or even resource waste. The rate of technological innovation reflects the role of technological progress in economic growth, often measured by patent counts and R&D investments (Hsu et al., 2022). Technological advancements boost labor productivity and promote economic restructuring, yet the impact of innovation on growth tends to lag and depends on institutional and market conditions, requiring sustained investment and policy support. Labor force quality (Hanushek & Kimko, 2000)—encompassing education, professional skills, and health—is essential for innovation and industrial advancement. However, improving labor quality requires long-term investment in education and training, making it challenging to achieve substantial economic impact in the short term.

International comparative indicators

In the context of globalization, international comparisons of economic growth have gained importance. The global competitiveness index (GCI), for instance, serves as a comprehensive measure of national competitiveness (Kiselakova et al., 2018; Skare & Riberio Soriano, 2021). Covering over 110 economic variables—including

infrastructure, macroeconomic stability, labor market efficiency, and innovation capacity - the GCI offers a multi-dimensional view of a country's economic strengths and weaknesses. However, because the GCI relies on extensive data and entrepreneurial surveys, it may be influenced by subjective factors. Additionally, by emphasizing short-term competitiveness, the GCI can overlook essential long-term development factors, such as education and health, potentially underestimating a country's developmental potential.

The Global Innovation Index (GII) assesses a country's innovation capabilities and outputs (Aytekin et al., 2022; Ma et al., 2023). While the GII provides valuable insights into science, technology, and innovation inputs and outcomes, the economic impact of these innovation outputs often takes time to manifest, leading to an overestimation of the short-term effects of innovation inputs on economic growth. Additionally, cross-country comparisons based on the GII may not fully capture each country's unique context, as significant differences in innovation systems, institutional environments, and markets can influence innovation effectiveness.

The globalization index (GI) measures the extent of economic, social, and political globalization in various countries. Common indices include the A.T. Kearney globalization index (Kearney & Policy, 2006) and the KOF Globalization Index (Gygli et al., 2019; Skare & Riberio Soriano, 2021). The GI provides insights into a country's engagement and openness within the global economic network, helping to analyze the effects of trade, investment, and migration on economic performance. Although the GI effectively demonstrates how globalization supports economic growth, it may not fully capture the deeper impacts on a country's economic structure and income distribution. Consequently, complementary indicators may be necessary to achieve a more comprehensive understanding in practical applications.

The economic freedom index (EFI) assesses market openness and economic freedom (Berggren, 2003), reflecting the extent of a country's economic policy openness across ten dimensions, including government intervention, property rights, trade freedom, and financial freedom. However, the EFI tends to overemphasize market freedom, often overlooking factors like social equity and environmental protection. Additionally, its applicability may be limited in countries with high welfare provisions and government intervention, as it may not fully account for the dynamics of such economic systems.

Tab. 2 summarizes the different types of economic growth indicators and their related literature.

Tab. 2. Indicators related to economic growth

	Indicators	References	
Core indicators	Gross domestic product (GDP)	(Sözen & Arcaklioglu, 2007)	
	GDP per capita	(Sözen & Arcaklioglu, 2007)	
	Gross national product (GNP)	(Merko et al., 2019)	
	Economic growth rate	(Maksimović et al., 2017)	
Supplementary indicators	Human development index (HDI)	(Noorbakhsh, 1998)	
	Total factor productivity (TFP)	(Qiu et al., 2023; Wei et al., 2024)	
	Labor productivity	(Shahnazi, 2021)	
	Green GDP	(Hoff et al., 2021) (Stjepanovic et al., 2022)	
	Short-term indicators	Industrial production index	(Amarasinghe, 2016)
		Retail sales growth rate	(Zhou et al., 2024)
		Unemployment rate	(Jo et al., 2023)
		Inflation rate	(Jo et al., 2023)
	Long-term indicators	Capital accumulation	(Shi & Xu, 2023)
		Technology innovation rate	(Hsu et al., 2022)
Labor-force quality		(Hanushek & Kimko, 2000)	
International comparative indicators	Global competitiveness index (GCI)	(Kiselakova et al., 2018) (Skare & Riberio Soriano, 2021)	
	Global innovation index (GII)	(Aytekin et al., 2022; Ma et al., 2023)	
	Globalization index (GI)	(Kearney & Policy, 2006), (Gygli et al., 2019) (Skare & Riberio Soriano, 2021)	
	Economic Freedom Index (EFI)	(Berggren, 2003)	

Source: Authors' representation

Theoretical models of economic growth

In the previous section, we provided a comprehensive analysis of key economic growth indicators and their limitations. Here, we systematically review the evolution of economic growth theories and associated models, examining their applications across various historical contexts.

Classical growth models

Classical economic growth theory has played a significant role in shaping the understanding of economic development. Adam Smith, a central figure in this theory, highlighted the importance of the division of labor and specialization as key drivers of economic growth (Smith, 1976). During England's Industrial Revolution, factories employed a structured division of labor, in which workers specialized in specific tasks, markedly improving production efficiency. For instance, in the textile industry, production was divided into stages such as carding,

spinning, and weaving, with specialized workers assigned to each stage. This segmentation significantly boosted textile output, thereby contributing to overall economic growth. Adam Smith also identified capital accumulation as a critical factor in driving economic growth. During this period, British factory owners invested in building new factories, acquiring advanced machinery, and expanding production capacity, collectively fueling rapid economic development. Additionally, Smith's growth theory emphasizes the market mechanism's role, positing that a competitive, free-market environment facilitates optimal resource allocation, thereby supporting economic growth. At the time, the relatively open market environment in the United Kingdom, combined with intense competition among enterprises, encouraged continual innovation and efficiency improvements, further contributing to economic expansion.

David Ricardo, another prominent figure in classical growth theory, concentrated on the role of production factors—land, labor, and capital—in driving economic growth. He introduced the theory of comparative advantage, highlighting the importance of international trade in fostering economic growth. In the 19th century, Britain exported manufactured goods and imported raw materials and agricultural products through trade with other countries. Leveraging its strength in industrial production, Britain specialized in textiles, machinery, and other manufactured goods, while other nations supplied the raw materials Britain required. This pattern of international trade accelerated Britain's economic development and, simultaneously, spurred economic growth in its trading partners (Gingrich, 2011).

Key models of the Keynesian school

Keynesian growth theory, rooted in John Maynard Keynes' *The General Theory of Employment, Interest and Money*, centers on the pivotal role of aggregate demand in driving economic growth. Key models associated with this theory include the Harrod-Domar model and the multiplier-acceleration model.

The Harrod-Domar model extends Keynesian short-term analysis into the realm of long-term economic growth, emphasizing the crucial role of capital accumulation in this process (Le-Van & Tran-Nam, 2023) and highlighting the importance of converting savings into investment to sustain growth (Boianovsky, 2018). This model provided a foundational framework for early development economics and was especially relevant for analyzing capital-poor economies, particularly in the post-World War II period when many countries faced acute capital shortages (Tarasova & Tarasov, 2018). However, the model has limitations: it focuses solely on capital accumulation, overlooking other important factors such as technological progress; it places excessive emphasis on government intervention while neglecting the market mechanism's regulatory role in growth; and its assumption of a fixed capital-output ratio is difficult to apply in real-world settings.

The multiplier-accelerator model combines Keynesian multiplier theory with the acceleration principle to explain the relationship between investment and income fluctuations across economic cycles (Mourao & Popescu, 2022). However, the model's parameters are difficult to determine precisely in real-world contexts, which limits its predictive accuracy. It primarily addresses the quantitative relationship between investment and income, but does not delve deeply into the root causes of economic fluctuations. Additionally, its explanation of economic cycles is relatively simplistic, falling short of capturing the complex economic phenomena observed in reality.

Neoclassical growth models

The neoclassical theory of economic growth originated as a revision and refinement of the Harrod-Domar model and sought to model growth with a microfoundation (Hagemann, 2009).

The Solow-Swan model is the seminal neoclassical growth theory, independently developed by Robert Solow and Trevor Swan in the 1950s (Solow, 1956; Swan, 1956). The model uses a production function with constant returns to scale, generally in Cobb-Douglas form, to explain the sources of economic growth. The production function in the model takes the form $Y = F(K, L)$, where Y denotes total output, K is capital input, and L is labor input. The core of the Solow-Swan model is the role of capital accumulation, which suggests that increased capital can drive economic growth. However, as capital increases, the marginal returns to capital diminish, indicating that sustained capital investment cannot support long-term growth. The model proposes that diminishing marginal returns to capital will eventually lead the economy to a steady-state level, where both output and capital growth stagnate. At this point, the economy can only achieve sustained growth through exogenous technological progress. The model also introduces the concept of the 'Solow Residual,' which represents the portion of aggregate output growth that cannot be explained by capital and labor growth. This residual is typically attributed to technological progress (TFP growth; Guo et al., 2012; Argentiero et al., 2021). A key limitation of this model is that it treats technological progress as exogenous, without examining its sources or the factors that influence it.

The Ramsey-Cass-Koopmans model is another neoclassical model of economic growth, primarily based on Frank P. Ramsey's work (1928), with significant extensions by David Cass (1965) and Tjalling Koopmans (1965). This model incorporates consumers' intertemporal optimal choices, building on the Solow model, internalizes savings, and provides a micro-foundation for economic growth theory. By doing so, it more closely aligns with the decision-making behaviors of consumers and firms in reality, offering a better explanation of the dynamic process of economic growth. On one hand, it provides a more rigorous theoretical framework for analyzing

economic growth through households' utility maximization in intertemporal consumption decisions and firms' profit maximization in the production process, along with market equilibrium conditions. On the other hand, it accounts for time and uncertainty, enabling a dynamic analysis of economic growth. The model describes changes in the state of the economic system at different points in time and traces the evolutionary paths of economic variables, thereby helping to understand both long-term trends and short-term fluctuations in economic growth, as well as the dynamic effects of policy changes. At the same time, the model analyzes the impact of policies, such as taxation, on household consumption, saving decisions, and economic growth, enabling policymakers to design better policies and evaluate those aimed at achieving stable economic growth and maximizing social welfare. However, the model assumes technological progress is exogenous and does not explain the underlying mechanisms of technological advancement, which are, in reality, influenced by internal factors such as R&D investment. Additionally, some of the model's assumptions may not hold in practice, such as the assumption that households are perfectly rational and have an infinite horizon, allowing them to predict the future and make optimal decisions accurately. In reality, consumer decisions are often shaped by factors like limited rationality (Cisek et al., 2014).

Endogenous growth models

Endogenous growth theory represents a paradigm shift in understanding economic development by internalizing technological progress and knowledge accumulation as endogenous factors, rather than exogenous factors. While neoclassical models treated technological change as an unexplained residual, endogenous growth models explicitly formalize the mechanisms through which innovation and knowledge generation emerge from within the economic system itself.

Endogenous growth theory focuses on the internal drivers of economic growth, particularly through the accumulation of knowledge, technology, and human capital (Kopf, 2007; Dai, 2023). The endogenous growth model, introduced by Paul Romer in 1986, was the first to view technological progress as an outcome of the economic system itself (Romer, 1986). Romer's model overcomes the limitation of neoclassical growth theory, which treats technological progress as exogenous, by arguing that firms' innovation and R&D activities can generate sustained productivity gains. Notably, Romer emphasizes that knowledge is non-rivalrous and partially exclusive, meaning it can be reused without being depleted. This characteristic allows knowledge to generate spillover effects throughout the economy, leading to continuous productivity increases and breaking the steady-state trap posed by neoclassical theory.

In the 1990s, Romer further refined his endogenous growth model by proposing that technological progress is driven by innovative activities in the R&D sector (Romer, 1994). These innovative activities are incentivized by market competition and the potential for gains, which in turn promote the accumulation and diffusion of knowledge, leading to sustained economic growth. Romer's model laid the foundation for subsequent research, highlighting the role of policy incentives in fostering innovation and knowledge accumulation. Meanwhile, Robert Lucas proposed a model of human capital accumulation as a source of growth in 1988 (Lucas, 1988). Lucas argued that investments in human capital, such as education and training, not only enhance workers' skills and productivity but also generate positive spillover effects across the economy. His model suggests that the continuous accumulation of human capital can create a self-reinforcing growth mechanism, leading to sustained high economic growth rates in the long run. In contrast to Romer's model, which focuses on technological innovation, Lucas's model highlights the crucial role of education and skill development, thereby enriching the broader concept of endogenous growth theory.

As the theory has evolved, endogenous growth models have increasingly incorporated knowledge spillovers and the cumulative effects of innovation. Knowledge spillovers refer to the phenomenon where the innovative activities of one firm or individual indirectly enhance the productivity of other firms, creating positive externalities within the economy (Isnaeni & Khoirunurrofik, 2021; Peng et al., 2022). Additionally, endogenous growth theory emphasizes the roles of economies of scale and market structure, arguing that larger markets and competitive environments can stimulate greater R&D activity and innovation investments. For instance, a larger market size increases return expectations, encouraging firms to invest more in technological accumulation, which, in turn, fosters broader economic growth.

Mathematical Foundations of Endogenous Growth

The fundamental contribution of Romer's (1986) model lies in its explicit treatment of knowledge as a non-rival, partially excludable input in the production process. The model can be formalized as:

$$Y_i = A(R) \cdot F(R_i, K_i, L_i), \quad (1)$$

where Y_i represents the output of the firm i , K_i and L_i are the conventional inputs of capital and labor, R_i is the firm's research and development investment, and $A(R)$ is the public stock of knowledge that depends on the aggregate R&D in the economy. The critical insight is that while each firm experiences diminishing returns to its

own R&D investments (R_i), the economy as a whole may experience increasing returns due to knowledge spillovers captured in $A(R)$.

This formulation generates sustained growth without requiring exogenous technological progress because $\frac{\partial A(R)}{\partial R} > 0$. The productivity of the entire economy increases with aggregate knowledge accumulation, creating a positive feedback loop that can sustain long-term growth. This contrasts with the prediction of eventual steady-state equilibrium in the Solow-Swan model in the absence of exogenous technological change.

Varieties and Quality Ladders: Expanding the Framework

Romer’s later work (1990) developed a more sophisticated model that incorporates horizontal innovation, in which economic growth occurs through the expansion of product varieties. The production function takes the form:

$$Y = L_Y^{1-\alpha} \int_0^A x_i^\alpha di, \tag{2}$$

where L_Y is labor used in final goods production, x_i is the input of intermediate good i , and A represents the variety of intermediate goods available. Growth occurs as innovative activity expands A over time.

Complementing this approach, Grossman and Helpman (2018) introduced “quality ladder” or vertical innovation models, where growth occurs through creative destruction—the replacement of existing products with improved versions. Their framework can be represented as:

$$Y = \sum_{j=1}^J q^{k_j} X_j, \tag{3}$$

where $q > 1$ represents the quality improvement with each innovation, k_j is the number of quality improvements that have occurred in product line j , and X_j is the quantity of product j . The economy grows as innovations increase the value k_j over time.

Human Capital and Growth: Lucas’s Contribution

Lucas (1988) emphasized human capital accumulation as a primary engine of growth. His model features two key equations:

$$\begin{aligned} Y &= AK^\beta (uH)^{1-\beta} H_a^\gamma \\ \dot{H} &= \delta(1-u)H \end{aligned}, \tag{4}$$

where H is the stock of human capital, u is the fraction of time spent in production (versus education), H_a is the average human capital in the economy (generating external effects), and δ is the efficiency of human capital accumulation. The term H_a^γ captures spillover effects, in which individual productivity benefits from society’s overall knowledge level.

The critical distinction from earlier models is that sustained growth arises endogenously from individual decisions to invest in education and skill development, rather than necessitating exogenous technical change.

Empirical Validation and Limitations

Empirical tests of endogenous growth models have yielded mixed results. Studies by Jones (1995) highlighted that the scale effects predicted by early endogenous growth models - where larger economies should grow faster due to more resources devoted to R&D - are not consistently observed. This led to the development of “semi-endogenous” growth models (Jones, 1995) that retain endogenous innovation but modify the relationship between R&D inputs and knowledge production.

Recent empirical work by Goel & Göktepe-Hultén (2020) suggests that while innovation continues to drive growth, the productivity of research efforts appears to be declining—researchers must work harder to maintain innovation rates. This “burden of knowledge” effect poses a significant challenge to simple endogenous growth models and underscores the need for more nuanced models that incorporate the complexity of modern innovation processes (Bloom et al., 2020).

Additionally, endogenous growth models have been criticized for inadequately addressing the role of institutions (North, 1991), which are fundamental to explaining cross-country growth differences. The next generation of growth models has increasingly incorporated institutional factors as endogenous determinants of both innovation and resource allocation efficiency.

Models associated with the expanded new theory of economic growth

In recent years, economic growth theory has expanded and evolved, with applications in areas such as institutions, globalization, technological innovation, and sustainable development. These models offer fresh

perspectives on the dynamics of economic growth, providing a scientific foundation for informed policy formulation.

Institutions and economic growth

Traditional neoclassical growth models attribute economic growth primarily to capital accumulation and technological progress. However, these models fail to explain why some countries struggle to achieve sustained growth despite similar levels of capital or technology. Economists have identified challenges such as information asymmetry, high transaction costs, monopolies, and the provision of public goods, which market mechanisms alone cannot adequately address and that significantly hinder economic development in many regions (North, 1991). Institutions can promote economic growth by establishing effective rules to mitigate market failures. Institutional economics emerged in response to this perspective, with Douglass North, a key founder of the theory, arguing that institutions are essential drivers of economic growth. North (1991) described institutions as the 'rules of the game' in economic systems, suggesting they lower transaction costs and enhance market efficiency by guiding individual and corporate behavior. For instance, protecting property rights ensures that firms and individuals can expect returns on their investments, thereby incentivizing innovation and long-term investment. The quality of a country's institutions is closely linked to its economic development potential. North (1989) also introduced the concept of 'path dependence,' suggesting that institutional evolution is often shaped by historical contexts and vested interests, which can restrict progress. Institutional change, therefore, may not always align with economic growth objectives. For example, some countries experience institutional rigidity due to entrenched political and social structures, which can impede necessary economic reforms (Acemoglu & Robinson, 2012).

Institutional economics models emphasize the importance of institutional quality as a key factor in economic growth (Hayat, 2019). Effective legal frameworks, property rights protection, and transparent governance reduce uncertainty, lower transaction costs, and stimulate innovation, making a country more attractive for external investment. Hayat (2019), using GMM estimation on dynamic panel data from 104 countries, examined both the direct impact of institutional quality on economic growth and its indirect impact through increased foreign direct investment (FDI). The findings indicate that both FDI inflows and institutional quality contribute to economic growth, with FDI-led growth being more prevalent in low- and middle-income countries, where strong institutions further support growth. Dada et al. (2023), in a study of 31 African countries, explored the moderating role of institutional quality on the relationship between military spending and economic growth, finding that while military spending negatively impacts growth, institutional quality has a positive influence. Similarly, Diallo and Ouoba (2024) investigated 25 sub-Saharan African countries from 2002 to 2018 and identified a significant threshold effect of institutional quality on the contribution of renewable energy to economic growth. These studies underscore the critical role of enhancing institutional quality and governance in fostering sustainable economic growth.

Globalization and economic growth

Moreover, as globalization and regional integration advance, mainstream economic theories increasingly struggle to explain complex economic phenomena. Western economists, led by Paul Krugman, have expanded the analysis of spatial economic aggregation and globalization, incorporating perspectives from economic geography. By focusing on increasing marginal returns, imperfect competition, and path dependence, they developed the framework of 'New Economic Geography' (Krugman, 1991). This model highlights the strong link between spatial economics and economic growth, asserting that economies of scale and agglomeration effects are pivotal in driving regional economic development (Krugman, 1998). The concentration of economic activities within a specific region can reduce transaction costs, boost innovation efficiency, and enhance firms' competitiveness (Guan et al., 2022). Globalization, along with the division of labor within global value chains (GVCs), has accelerated the flow of technology and resources, creating new development opportunities for underdeveloped regions (Fagerberg et al., 2018). In particular, regions such as East Asia have experienced high economic growth driven by their integration into GVCs, underscoring the role of GVCs in regional economic advancement (Kimura & Chang, 2017).

GVCs segment the global economy into production stages, enabling countries to specialize according to their comparative advantage (Dai & Xu, 2023). Participation in GVCs grants access to international markets, technology, and capital. This division of labor drives efficiency gains through cross-country collaboration. Through transnational corporations (TNCs), GVCs facilitate technology transfer and industrial upgrading. Developing countries, in particular, benefit from integrating into GVCs by gaining advanced technology and management expertise from developed nations, thereby enhancing their industrial competitiveness and technological capability (Gereffi & Luo, 2014). This process of globalization spurs technological innovation and accelerates economic growth worldwide (Ganguly & Spinola, 2024).

Technological innovations and economic growth

Theoretical models and empirical evidence consistently identify technological innovation as a primary correlate of long-term productivity, though the magnitude of this effect varies by estimation strategy (Qamruzzaman & Jianguo, 2018; Geng & Gu, 2019; Aminullah, 2024).

Modern growth theory further refines the role of technological innovation, especially with the rise of AI and digital technologies as key drivers of future economic growth (Zhao et al., 2022; Grashof & Kopka, 2023). Endogenous growth theory posits that technological innovation is an intrinsic outcome of the economic system. Projections and early firm-level data suggest AI has the potential to drive long-term growth, though macro-level productivity gains are not yet fully realized - the productivity paradox (Babina et al., 2024). The technological progress and productivity model suggests that AI increases the productivity of both capital and labor, boosting TFP (Zhao et al., 2022). Through automation and intelligent optimization, AI significantly enhances enterprise productivity and innovation (Khogali & Mekid, 2023). The skill-biased technological change model argues that AI favors high-skilled labor, driving the growth of high-skilled jobs while simultaneously increasing employment pressures and income inequality for low-skilled workers (Huu, 2023). The globalization and technology diffusion model highlights the global spread of AI technologies through international trade and technology transfer, particularly within multinational corporation collaborations. While globalization has facilitated the diffusion of technology, developing countries face unequal access to AI technologies, contributing to a “digital divide” (Sharifi et al., 2024). The innovation-driven growth model views AI as the central driver of future innovation, boosting economic growth by enhancing R&D efficiency and fostering new industries such as big data and smart manufacturing. However, a study by Nasir et al. (2023) using SDG metadata and the AI4SDG project (AI4SDG Initiative at the University of Oxford) found that while AI technologies focus on advancing economic growth, they may overlook critical social and environmental issues.

Sustainable development and economic growth

Modern theories of economic growth related to sustainable development focus on balancing economic growth, environmental protection, and social equity to ensure that current needs are met without compromising future generations' ability to thrive (Ghannouchi, 2023). Endogenous growth models typically center on a production function that highlights the role of technological innovation in driving economic growth. According to endogenous growth theory, technological innovation is crucial to economic progress, and green technological innovation is a key pathway to sustainable development (Yin & Zeng, 2024). In the context of green technological innovation, technological progress is viewed as a combination of both green and traditional technologies. Through policy incentives and R&D investment, green innovation increases the share of green technologies, thereby fostering the sustainability of economic growth.

The environmental Kuznets curve (EKC) posits that as an economy grows, environmental degradation initially increases; however, after reaching a certain income threshold, technological advancements and heightened environmental awareness lead to improvements in environmental quality (Rizzati et al., 2023; Sikder et al., 2024). The EKC is typically represented by an inverted U-shaped curve, illustrating the relationship between economic growth and environmental quality (Alola & Rahko, 2024).

Consistent with this, green economic growth theory argues that economic growth and environmental protection are not mutually exclusive. It posits that green technologies, renewable energy, and a low-carbon economy can create a win-win scenario for both economic development and environmental sustainability (Ouyang et al., 2023). Green economic growth models typically build upon neoclassical growth frameworks by incorporating environmental resources and pollution variables. The theory advocates for sustainable growth by enhancing resource efficiency, reducing carbon emissions, and fostering a green transformation of the economic structure. In contrast, circular economy theory advocates for the coordinated development of the economy and ecosystem through resource recycling (Shi, 2016). The theory emphasizes sustainable economic growth by promoting closed-loop production and consumption systems that reduce resource consumption and waste generation. Circular economy models typically assess the sustainability of economic activities by measuring resource-use efficiency and reuse rates, and by integrating resource recovery rates and reuse variables into the production function (Cifuentes-Faura, 2022).

In summary, contemporary economic growth models have been expanded and enriched to encompass institutions, globalization, innovation, and environmental sustainability, offering a comprehensive theoretical framework for understanding modern economic growth. These theories not only reveal the internal dynamics and external constraints that drive economic growth but also provide a solid foundation for countries to design effective economic policies and address the challenges posed by globalization.

Empirical measures and determinants of economic growth

To better understand the application and explanatory power of these theories, this section discusses empirical methods for measuring economic growth and explores specific factors that influence growth.

Empirical analysis methods

Empirical analysis methods for economic growth are commonly categorized by type, data structure, and application scenario, with each method offering distinct advantages depending on the research context. Cross-sectional analysis is a common method for examining economic growth. Multiple regression analysis, in particular, allows the simultaneous assessment of multiple factors influencing growth (Majumder, 2022). Cross-sectional regression analysis focuses on data across different time points and is useful for comparing economic differences between countries or regions (Restivo et al., 2022). Quantile regression analysis, on the other hand, reveals causal relationships across different quantiles, making it valuable for exploring heterogeneous effects in economic growth, such as variations in income distribution or economic inequality (Fitzenberger et al., 2002).

Time series analysis is primarily used to examine the dynamics of economic variables over time. Univariate time series analysis, using methods such as autoregression and moving averages, focuses on the trends of a single variable, making it suitable for analyzing cyclical patterns in macroeconomic variables such as GDP (Wei, 2015). Vector autoregressive (VAR) models assess the dynamic interactions among multiple variables, such as economic growth, inflation, and interest rates (Dinh, 2020). The vector error correction model (VECM) extends the VAR model and is commonly used to analyze interactions and forecast relationships among multiple macroeconomic variables (Mussaiyib & Pradhan, 2024). VECM captures long-run equilibrium relationships and models short-run dynamic adjustments, allowing for a comprehensive examination of these variables over time. For forecasting economic growth, the auto-regressive integrated moving average (ARIMA) model combines autoregression and moving averages to model trends in time series data (Hüsnuoğlu & Oda, 2023). Additionally, the structural vector autoregressive (SVAR) model builds on the VAR model by incorporating structural information, making it particularly useful for examining the impact of policy shocks on economic growth (Aliaga-Miranda et al., 2024).

Panel data analysis is ideal for handling cross-sectional data with a time component, making it particularly useful for analyzing economic growth trends across countries or regions over time. Fixed-effects models control for unobservable individual heterogeneity, increasing analytical precision in cross-country comparisons (Liu, 2019). Random effects models assume individual effects are random, providing insights into overall economic growth trends (Adeleye et al., 2022). Dynamic panel data models account for historical lag effects, making them suitable for exploring growth patterns that depend on past performance (Hayat, 2019). Additionally, two-way fixed effects models control for both time and individual heterogeneity, facilitating detailed cross-regional comparisons of economic growth (Li et al., 2025).

Other econometric methods, such as the instrumental variable (IV) method, difference-in-differences (DID) method, and synthetic control method, are designed to address endogeneity in causal identification. The IV method introduces exogenous variables to isolate causal effects, making it suitable for assessing the impact of capital formation and policy shocks on economic growth (Zhang et al., 2024). The DID approach contrasts treatment and control groups to identify causal effects, ideal for evaluating policy outcomes, reforms, or external shocks (Li et al., 2023; Guo & Xu, 2024). The synthetic control method constructs counterfactuals to analyze long-term effects of policies or interventions, making it particularly useful for examining the impact of significant policy changes (Esposti et al., 2022).

Structural models analyze economic growth dynamics using a systematic modeling approach. Computable General Equilibrium (CGE) models simulate the overall impact of policies on economic growth by modeling the interrelationships among different sectors, making them well-suited for examining fiscal and trade policies (An et al., 2023). Dynamic Stochastic General Equilibrium (DSGE) models, on the other hand, combine macroeconomic theory and data to construct dynamic sectoral relationships and analyze the long-term growth trend. This approach is particularly effective for long-term economic forecasting and studying monetary policy (Liu et al., 2018; Sun et al., 2023).

Tab. 3 summarizes the methods discussed above for analyzing economic growth, along with their specific applications.

Tab. 3. Empirical analysis methods related to economic growth

Categories	Techniques	Application scenes	References
Cross-sectional analysis	Multivariate regression analysis	Macroeconomics, Productivity	(Majumder, 2022)
	Cross-sectional regression analysis	Country comparisons, Regional analysis	(Restivo et al., 2022)
	Quantile regression analysis	Income distribution, Economic inequality	(Guo et al., 2023)
Time series analysis	Univariate time series analysis	Economic cycle, Trend analysis	(Iacobucci & Noullez, 2005; Ghosh & Parab, 2021)
	VAR model	Macroeconomic developments analysis	(Dinh, 2020)
	VECM	Macroeconomics, Relationship analysis	(Mussaiyib & Pradhan, 2024)
	ARIMA model	Economic forecasts	(Hüsnuoğlu & Oda, 2023)

	SVAR model	Policy analysis	(Aliaga-Miranda et al., 2024)
Panel data analysis	Fixed effects model	Country comparisons, Cross-country studies	(Liu, 2019)
	Random effects model	Regional analysis	(Adeleye et al., 2022)
Other econometric methods	Dynamic panel data model	Economic development trends	(Hayat, 2019)
	Two-way fixed effects model	Regional economic comparisons	(Li et al., 2025)
	IV method	Capital formation, Policy shocks	(Zhang et al., 2024)
	DID method	Policy effectiveness evaluation, Impact of reforms	(Li et al., 2023; Guo & Xu, 2024)
	Synthetic control method	Reform or major policy analysis	(Kantorowicz & Spruk, 2024)
structural model	CGE models	Fiscal policy, trade policy	(An et al., 2023)
	DSGE model	Long-term economic forecasting, Monetary policy	(Liu et al., 2018; Sun et al., 2023)

Source: Authors' representation

Determinants of economic growth

This subsection summarizes the factors influencing economic growth, addressing multiple dimensions such as physical capital, human capital, technological advancement, institutional frameworks, and policies within the context of contemporary development.

Capital accumulation remains a core driver of economic growth. Increases in physical capital—such as infrastructure, machinery, and facilities—boost productive capacity, directly contributing to output growth. Classical economic growth theories, including the Harrod-Domar and Solow models, underscore the critical role of capital in economic expansion. In today's era of digital transformation, investments in digital capital, such as information technology and automation equipment, have emerged as powerful new engines of economic growth. Afolabi (2023), analyzing multi-country data from Africa, found that investments in digital infrastructure significantly contribute to digital economic growth. While efficient capital utilization can boost labor productivity, the diminishing marginal returns of continuous capital accumulation highlight the importance of technological progress as a crucial factor in overcoming this limitation.

Technological progress is widely regarded as a fundamental driver of long-term economic growth. Through technological innovation, economies can boost productivity, develop new products and services, and improve resource efficiency (Reznakova & Stefankova, 2022). Both the Solow growth model and endogenous growth theories, such as the Romer model, emphasize technological progress as crucial for overcoming diminishing returns to capital accumulation, thereby sustaining economic growth. Technological innovation not only enhances the productivity of production factors but also facilitates structural transformation, enabling economies to adapt to the evolving global market continuously. The impact of digital technology innovations, such as AI, blockchain, and 5G, on economic growth has become increasingly significant (Esposti et al., 2022). Daud & Ahmad (2023), in a study of 84 countries since the global financial crisis, found that both digital technology and financial inclusion positively influence national economic growth, with digital technology enhancing the effects of financial inclusion. Gumbau-Albert & Maudos (2022) highlighted that investments in intangible assets, including R&D, brands, and software, are playing an ever-greater role in driving modern economic growth.

Human capital encompasses the skills, knowledge, and health of the workforce. High-quality education and training can enhance workforce productivity and drive innovation, ultimately contributing to economic growth. According to Lucas's human capital model, economic growth relies not only on the accumulation of physical capital but also significantly on the development of knowledge and skills. The health and productivity of the labor force are likewise crucial for economic growth. A study by Adeleye et al. (2022), which analyzed unbalanced panel data from 19 Middle Eastern and North African countries between 1980 and 2020, found that population growth and human capital indicators, such as education enrollment and life expectancy at birth, positively influence economic growth. Additionally, Frank et al. (2019) examined the impact of automation on the labor market, finding that its adoption and AI are reshaping labor demand. While automation is displacing some low-skilled jobs, it is simultaneously creating new growth opportunities for high-skilled labor, underscoring the importance of upgrading human capital.

Economic growth is also deeply influenced by the institutional environment. Effective institutions safeguard property rights, uphold market order, and promote fair competition, creating a conducive environment for economic activities to flourish. Douglas North's institutional economics theory highlights the crucial role of institutional factors, such as legal frameworks, political systems, and market regulations, in driving economic growth. Good governance, a stable policy landscape, and a transparent legal system can attract investment and foster the healthy development of economic activities. Xu et al. (2024) examined the effects of technology and institutions on economic sustainability, entrepreneurship, and growth across 30 regions in China from 2009 to 2020, finding that enhancing technology-institution adaptability contributes significantly to economic growth. Similarly, Pradhan et al. (2024) studied the relationship between innovation and institutions, revealing that both

typically have a positive impact on economic growth. They highlighted that high-quality regulatory regimes can serve as catalysts, helping emerging economies advance to higher levels of the global innovation value chain.

By engaging in international trade, open economies can leverage their comparative advantages, expand market sizes, and capture technological spillovers. International trade not only improves the efficiency of resource allocation within an economy but also boosts the innovative capacity of domestic industries through technology transfer and international competition. Globalization has provided a fresh impetus to economic growth in many countries, particularly emerging-market economies, where open-door policies have significantly enhanced productivity and economic scale. While globalization faces challenges from rising trade protectionism, the interconnectedness of global supply chains remains a key driver of global economic growth. Stojcic et al. (2021) examined the impact of international trade and global value chain (GVC) integration on the manufacturing sector in 11 Eastern European EU member states over the period 2011-2016. They found that exports, imports, and forward participation in GVCs contributed to an increased proportion of start-ups and high-growth firms. Rahman (2021) analyzed the BRICS countries from 1990 to 2017, as well as ASEAN countries, and found that energy consumption, international trade, capital, and FDI all had a significant positive impact on economic growth in these regions.

The abundance of natural resources can drive short-term economic growth, particularly in resource-intensive industries. However, it may also lead to the “resource curse,” in which an overreliance on natural resources inhibits technological innovation and industrial diversification, thereby limiting long-term economic growth (Huang & Ali, 2015). As environmental issues become increasingly urgent, the balance between environmental sustainability and economic growth has gained significant attention, with green growth emerging as a prominent research focus (Feng et al., 2021). The application of green technologies not only fosters new markets and creates jobs but also improves energy efficiency and reduces production costs. Based on a panel dataset from China spanning 2005 to 2018, Zhao (2023) found that promoting low-carbon technologies and renewable energy can simultaneously foster economic growth and environmental protection, with low-carbon energy technologies contributing to green Total Factor Productivity (TFP). Similarly, Siddik et al. (2023) discovered that public R&D investments in renewable energy, combined with increased natural resource consumption and trade activities, enhance carbon productivity. They recommended that governments increase such investments to stimulate technological innovations that will facilitate the transition to renewable energy and support low-carbon economic growth.

An Integrated Framework for Growth Determinants

To move beyond the analysis of individual growth factors in isolation, we propose an integrated framework that captures the complex interactions among key determinants and their context-specific effects across different developmental stages. Fig. 1 illustrates this framework, highlighting both direct effects and interaction pathways among determinants.

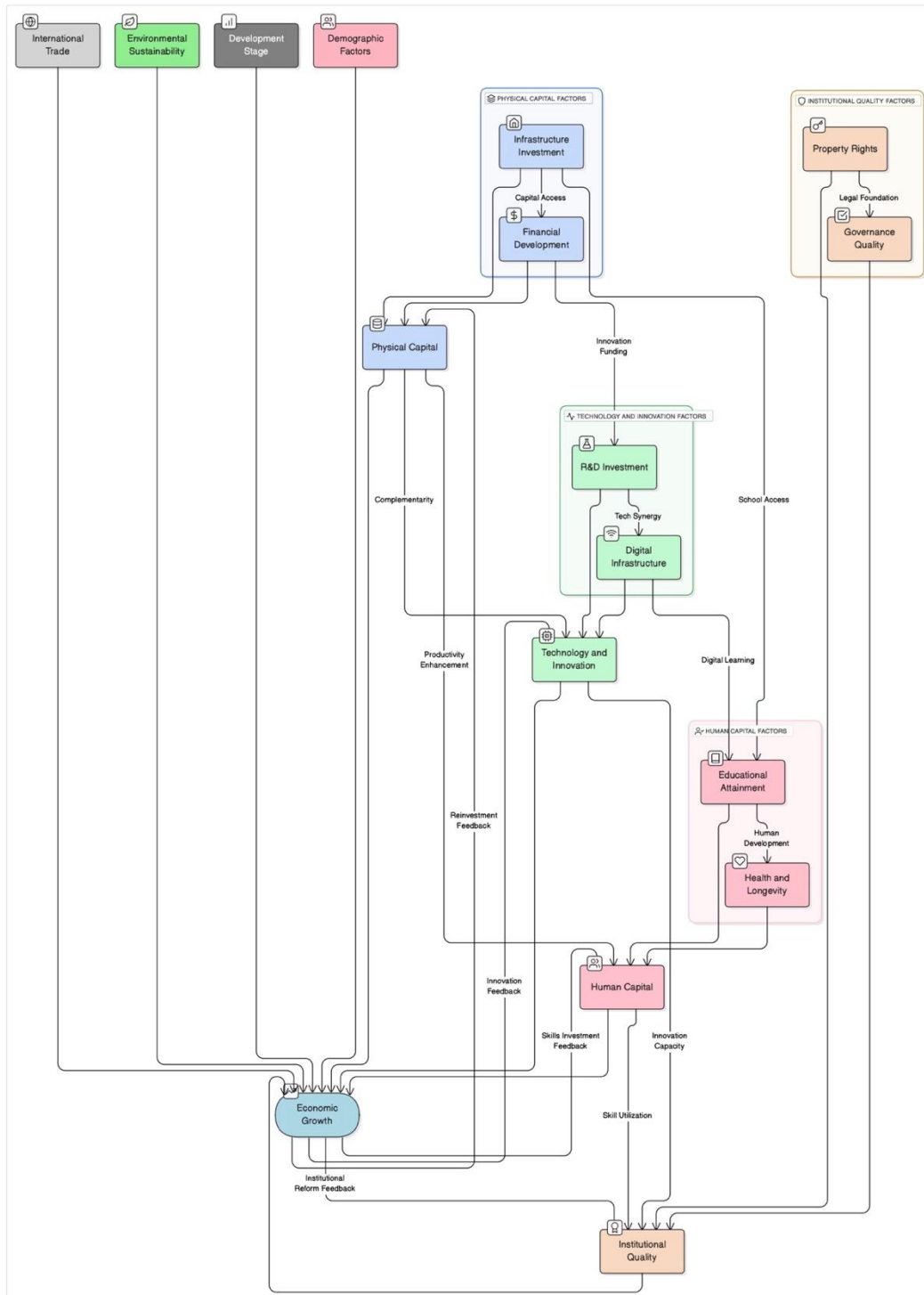


Fig. 1. Conceptual Map of Growth Determinants
 Source: Authors' contribution

Dynamic Complementarities

Our approach highlights that growth factors often exhibit dynamic complementarities, in the sense that the effect of one factor depends significantly on the quality or quantity of the others. For example, research by Hanushek and Woessmann (2012) shows that returns to human capital are significantly higher in countries with better governance and more advanced technologies. In the same spirit, Acemoglu et al. (2006) reveal that the growth advantage of trade openness is larger in countries with more developed financial markets and flexible labor markets.

These complementarities can help explain why some growth strategies are effective in some environments but not others. For instance, South Korea's export-led industrialization strategy was successful in part because it was supported by high levels of educational investment and selective institutional reform (Rodrik, 1995). In

contrast, identical trade liberalization policies implemented in Latin American countries during the 1980s-90s yielded a more limited growth performance, primarily due to poorer complementary institutions and educational bases (Ocampo, 2004).

Threshold Effects and Non-linearities

A second key insight from our framework is the prevalence of threshold effects and non-linear relationships among growth determinants. Azariadis and Drazen (1990) identified development thresholds where growth dynamics change qualitatively once certain levels of human or physical capital are reached. More recently, Eichengreen et al. (2012) documented a “middle-income trap” phenomenon where growth determinants that successfully drove initial development phases become less effective at higher income levels, requiring a transition to innovation-driven growth strategies.

These non-linearities also extend to institutional factors. Robinson and Acemoglu (2012) argue that inclusive economic institutions become increasingly important for sustaining growth as economies approach the technological frontier. In the early development stages, even imperfect institutions can support growth through factor accumulation; however, innovation-driven growth requires more sophisticated institutional arrangements that protect intellectual property and promote creative destruction.

Contextual Contingencies

The optimal growth strategies depend on both initial conditions and the external environment, as outlined in our framework. The research by Hausmann and Rodrik (2005) demonstrates that successful growth accelerations necessitate distinct policies, as each economy faces unique binding constraints. China’s growth depended on infrastructure investment, whereas Eastern European transition economies achieved growth through institutional reforms.

The external economic environment determines the effectiveness of growth strategies. According to Rodrik (2012), manufacturing-led development has become less viable in recent decades because of technological advancements and global market competition, so developing economies need to find new growth strategies. The need for customized growth strategies becomes evident in this context-dependent situation, where universal policy recommendations are ineffective.

Measurement Implications

This integrated framework has important implications for the empirical measurement of growth determinants. Conventional approaches that estimate average effects across heterogeneous contexts may mask critical nuances in how determinants operate. More sophisticated empirical strategies are needed, including:

1. Interaction models that explicitly test for complementarities among determinants.
2. Threshold regression techniques can identify non-linear relationships and structural breaks.
3. Bayesian model averaging to address model uncertainty in growth regressions.
4. Synthetic control methods for more rigorous country-specific counterfactual analysis.

Recent methodological innovations by Aghion et al. (2023) utilizing granular firm and regional data offer promising approaches to identifying causal mechanisms while accounting for contextual heterogeneity.

Macroeconomic regulations and economic growth

In the preceding discussion on the determinants of economic growth, we examined the roles of capital accumulation, technological innovation, human capital, and institutions. The practical effectiveness of these factors, however, depends greatly on the design and implementation of sound policies. As the global economic environment has become more complex and uncertain in recent years, research has increasingly focused on how investment decisions, capital allocation, and policy measures shape economic growth. Recent studies emphasize the long-term impacts of policy instruments and highlight new challenges for policymakers, such as rapid technological change, the restructuring of global supply chains, and climate change.

Investment and capital allocation

Investment decisions and the efficient allocation of capital are fundamental drivers of economic growth. The critical role of governments and firms in resource allocation has been widely discussed in the literature. Gupta et al. (2014) highlighted that public capital investment, such as infrastructure development, is a significant contributor to long-term economic growth, particularly in developing countries. Infrastructure investment enhances productive efficiency and stimulates growth in private sector investments. Similarly, Galindo-Martín et al. (2020) found that innovation has a positive effect on economic growth and entrepreneurship in both innovation-driven and efficiency-driven economies, based on their analysis of 31 countries. Liu (2023) analyzed data from 286 Chinese cities between 2001 and 2021 and found that while the expansion of natural resources and the

development of financial markets contributed to short-term economic growth, increased carbon emissions posed a significant obstacle to the advancement of China's green economy.

With the rapid development of the digital economy, digital capital investment has emerged as a key research focus. Daud and Ahmad (2023) highlighted that digital technology has a significant positive impact on economic growth. Hong (2017) investigated the Granger causality between R&D investment in the ICT industry and economic growth in Korea, finding that ICT industry investment fosters economic growth. Moreover, the study revealed that private ICT R&D investment plays a more prominent role in driving economic growth and inducing additional investment than public ICT R&D investment. Aminullah (2024) examined future scenarios of technological innovation and economic growth in Indonesia and concluded that investment in general-purpose technologies, leveraged by industrial policy, can significantly contribute to long-term economic development. Indonesia's industrial policy has undergone significant shifts before and after the pandemic, and these changes have influenced the relationship between innovation investment and economic growth. In the post-pandemic period, the promotion of general-purpose technologies is expected to foster inclusive economic growth and sustainable development. Research on global economic recovery after the pandemic underscores the critical role of policy innovations in driving growth. According to the World Bank (2023), many countries have achieved rapid recovery through policy measures such as accelerated digital transformation, supply chain diversification, and enhanced health emergency response capabilities. For instance, the European Union's Recovery Fund has provided substantial financial support for green transformation and the digital economy, a policy mix that has effectively strengthened the economic growth potential of member states.

In response to global climate change, green investment has garnered increasing attention. Balcilar et al. (2023) analyzed the role of green energy consumption and investment in driving economic growth across 23 OECD countries from 1990 to 2017. The empirical results revealed that renewable energy consumption and R&D expenditures in renewable energy positively impact economic growth. Furthermore, the study noted the potential to increase the utilization rate of green energy and investment. Continued long-term development in this area is expected to help mitigate the greenhouse effect and promote sustainable development. The OECD (2023) report highlighted that the long-term risks associated with climate change are prompting policymakers to reassess traditional economic growth models. An increasing number of countries are adopting market-based instruments, such as carbon pricing and emissions trading mechanisms, to reduce carbon emissions while simultaneously incentivizing investment in green technologies to foster the development of a "green economy." Additionally, Meckling and Allan (2020) emphasized that green innovation and industrial policies are pivotal in national climate policy strategies. Effective climate policies not only help mitigate the impacts of climate change but also create new drivers of economic growth.

Fiscal and monetary policies

Structural reform of fiscal policy represents a new avenue for promoting economic growth, with taxes and government spending playing a direct and significant role.

The literature presents conflicting views on the relationship between tax policy and economic growth. On the one hand, higher tax revenues can enable the government to invest more in public services, such as infrastructure, education, and healthcare, thereby fostering long-term economic growth. On the other hand, higher tax rates may discourage business investment and reduce consumer spending, potentially slowing economic growth. Khan et al. (2019) examined the relationship between corporate performance and overall economic growth in the U.S., finding that when tax rates are relatively high, a smaller proportion of corporate profits is reinvested domestically, which in turn hampers economic growth. Zhang et al. (2022) noted that environmental taxes, as an accepted environmental policy, have a long-term stimulative effect on the economy. Rodríguez et al. (2019), using a static general equilibrium model to simulate green tax reforms, found that moderate reforms could allow Portugal to experience a positive double dividend—improving its energy trade balance and energy independence while also reducing the economy's energy intensity.

In addition to the impact of taxes on economic growth, government expenditures play a crucial role in driving growth, particularly in areas such as infrastructure investment, education, and public health. These expenditures can enhance labor productivity and social welfare, thereby contributing to long-term economic development. A study by Okunlola et al. (2024) examined the impact of government spending on real economic growth in ECOWAS countries and found that government expenditure positively influences real economic growth. The study also emphasized that improving control over corruption can enhance the effectiveness and efficiency of government spending in fostering growth. Batayneh et al. (2024) analyzed the effects of fiscal and monetary policy, as well as the global financial crisis and the COVID-19 pandemic, on the U.S. economy. Their findings suggest that expansionary fiscal and monetary policies have positively affected economic growth, whereas the global financial crisis and the COVID-19 pandemic have negatively affected the U.S. economy. Alshammary et al. (2022) explored the dynamic heterogeneity in the impact of government spending on economic growth in 20 MENA countries over the period 1990-2016. Their findings indicated that government spending can promote economic growth, with a significant long-term effect in both oil and non-oil countries. However, the study revealed that the

impact was not observed in non-oil countries. In the MENA region, government spending exhibits a crowding-in rather than a crowding-out effect on economic growth. To sustain economic growth, non-oil countries need to implement fiscal reforms to optimize government spending, while oil-rich countries should consider the implications of short- and medium-term fiscal imbalances.

Monetary policy, through adjustments in interest rates and the money supply, is essential for maintaining economic stability and promoting growth. Abdulkadr et al. (2024) found that in Ethiopia, tight monetary policy is effective in the short term, but expansionary policy better supports long-term economic growth, with a bi-directional relationship observed between monetary policy and growth. In recent years, the scope of monetary policy has expanded to include non-traditional tools, particularly in response to the COVID-19 pandemic. The rise of digital currencies has led central banks to explore contactless payment systems and the potential for central bank digital currencies (CBDCs). For example, Zharikov (2022) discussed policy tools for the circulation of digital currency among BRICS nations, while Genc & Takagi (2024) highlighted the need for further analysis of the macroeconomic and financial stability implications of widespread CBDC adoption.

Interest rate policy is one of the most critical tools in monetary policy. Generally, low-interest rates stimulate economic growth by reducing financing costs and encouraging corporate investment and consumer spending. However, excessively low rates can also lead to asset bubbles and heightened financial risks. Hossin (2023) analyzed data from Bangladesh from 1980 to 2014 and found that deregulating deposit interest rates increased financial depth, ultimately fostering economic growth in Bangladesh. Similarly, Harvey et al. (2017) highlighted that loose monetary policy often supports rising commodity prices. While this trend bolsters GDP growth in commodity-importing countries like the U.S., it can suppress growth in commodity-exporting nations, such as Chile, when commodity prices fall. Mwiya et al. (2024) investigated the interactions among exchange rate volatility, inflation, and real interest rates on economic growth in Zambia from 1992 to 2022, finding that while interest rates positively correlate with economic growth, interest rate volatility negatively affects growth prospects in developing countries like Zambia. Similarly, Moyo and Le Roux (2019) examined interest rate reforms in SADC countries from 1990 to 2015 and concluded that these reforms promote economic growth by increasing savings and investment. In recent years, amid a low-interest-rate environment and global financial crises, many countries have adopted unconventional monetary tools like quantitative easing (QE). QE policies stimulate economic growth by injecting liquidity into the market through large-scale purchases of government bonds and financial assets. For instance, Zhang and Pan (2021) found that QE was effective in boosting China's real estate market, while in the United States, the Federal Reserve used QE following the Great Recession to counter its economic effects.

It is important to note that monetary and fiscal policies must be well-coordinated, particularly during periods of economic crisis or recovery. Kovalenko et al. (2024) emphasized that poor coordination between these policies can have severe economic consequences and that effective coordination relies on balancing interest rate regulation and inflation control. The experience in Ukraine during the war illustrates how economic and political challenges can disrupt policy coordination, underscoring the need for ongoing efforts to align monetary and fiscal policies. Similarly, Khang et al. (2024) found that flexible and responsive macroeconomic policies are crucial for stabilizing prices and supporting economic growth, as demonstrated by Vietnam's experience from 1996 to 2021, where adaptability in planning and expenditure was key to promoting growth in changing circumstances.

International trade and economic growth

Having examined the role of policymaking in economic growth, we now turn to global trade, a key external factor that influences resource allocation, production efficiency, and technology diffusion among countries. This section explores the relationship between trade policy and economic growth by analyzing the effects of trade liberalization and protectionism, as well as the impacts of globalization and regional economic integration on economic growth.

Trade liberalization and trade protectionism

Trade liberalization is widely recognized as a critical driver of economic growth, particularly due to its role in promoting efficient resource allocation, technology diffusion, and competitiveness. By reducing tariff and non-tariff barriers, countries can expand their participation in international markets and gain access to foreign technology and capital, thereby enhancing the efficiency of domestic production.

Krugman and Venables (1995) proposed, using new trade theory, that open international markets foster economies of scale, drive innovation, and thereby boost productivity. Maitra (2024) similarly emphasized that trade and investment are key engines of economic growth, suggesting that expanding trade timelines is a prudent strategy for reducing aid dependency and promoting self-reliance in developing countries. Examining Bangladesh from 1981 to 2021, Maitra found that trade liberalization has positively impacted income growth in the country. Additionally, Li et al. (2023) analyzed the context-specific impact of trade liberalization on economic stability and development across China from 1990 to 2019. Their study revealed a significant positive correlation between trade openness and economic revitalization in targeted Chinese regions, highlighting how greater openness facilitates

investment, technology transfer, and market expansion—factors that contribute to robust economic growth. Singh et al. (2023) found that trade liberalization and technological advancement have both short- and long-term positive impacts on India's economic growth. They argued that expanding the financial sector, in tandem with greater trade openness and increased technological investment, can enhance worker productivity, thereby driving economic growth. Huang (2023) analyzed data from 2000 to 2017 in China, exploring the relationships between trade, fiscal decentralization, renewable energy development, and green growth. Huang's study highlighted that trade openness has supported renewable energy development and green growth in China, identifying trade liberalization and fiscal decentralization as effective policy levers for promoting green growth through renewable energy initiatives.

In contrast to trade liberalization, protectionist policies seek to shield domestic industries by imposing higher tariffs, quotas, and other trade barriers to restrict foreign competition. Although protectionism can support domestic employment and industry development in the short term, it often leads to inefficiencies, stifled innovation, and hindered economic growth in the long run. The Smoot-Hawley Tariff Act of the 1930s exemplifies these effects; its implementation worsened the global economic crisis by sharply reducing international trade and impeding economic recovery (Kumar, 2009). More recently, in the U.S.-China trade war, the United States' tariffs on Chinese goods provided short-term relief to certain industries. However, these protectionist measures also disrupted global supply chains, increased domestic prices, and decreased productivity, ultimately constraining the U.S. economy's long-term growth potential (Salvatore, 2020). Kapustina et al. (2020) noted that trade wars produce no winners; rather, they result in three key losses: a reduction in trade between the conflicting countries, a decline in global trade, and ultimately, a slowdown in the global economy. Furthermore, some countries in international trade have employed barriers like import restrictions and higher tariffs to gain an upper hand, disadvantaging competing industries abroad and limiting the formation of resource-based advantages. According to the study of Wei et al. (2024), this approach risks creating regional monopolies within specific segments of the global value chain and obstructs the equitable distribution of benefits among countries involved.

However, Nam and Ryu (2024) found that, in the ASEAN region, reducing trade barriers can sometimes negatively affect GDP in developing economies, suggesting that excessive openness may occasionally hinder growth. Similarly, Chang (2003) noted that certain trade barriers in emerging economies can support the development of local small and medium-sized enterprises (SMEs). Despite these exceptions, trade liberalization is generally regarded as a key driver of economic growth, especially when countries deepen their participation in global value chains (GVCs). While trade openness typically enhances production efficiency and fosters innovation, protectionist measures—though they may offer short-term support to domestic industries—often disrupt global supply chains and limit the equitable distribution of GVC benefits, ultimately reducing long-term growth potential.

Globalization and economic integration

Driven by global trade, globalization, and economic integration, interdependence among national economies has deepened significantly. As an economic phenomenon, globalization involves the movement of goods, services, capital, technology, and labor across borders. It facilitates the international division of labor, technology transfer, and market diffusion by strengthening linkages between countries. This subsection explores the impact of globalization on economic growth, with a particular focus on regional economic integration and its implications for growth.

Globalization has dramatically reshaped the global economic landscape over the past few decades, with a particularly profound impact on the economic development of low- and middle-income countries. By opening markets, reducing trade barriers, and enabling the free flow of capital and technology, globalization has not only accelerated the global allocation of resources but also facilitated technological innovation and the diffusion of knowledge. These processes have contributed to increased global productivity and overall economic growth (Zheng et al., 2019). International trade and foreign direct investment (FDI) serve as crucial channels for technological progress, enabling open economies to access foreign technologies, which, in turn, boost domestic productivity and innovation (Hayat, 2019; Rahman, 2021; Tabash et al., 2024). Especially in emerging market economies, the technological advancements brought by globalization have played a crucial role in improving the competitiveness of domestic products and narrowing the technological gap with developed countries.

Additionally, globalization has facilitated the free flow of capital across borders, enabling a more efficient allocation of funds to regions with higher growth potential. These capital inflows not only provide developing countries with greater access to finance but also stimulate investment and infrastructure development, thereby fostering long-term economic growth (Langenstein et al., 2018). By participating in global markets, countries can expand their export markets and increase production scales. However, trade openness does not always lead to economic prosperity, and its effects vary across countries (Nam & Ryu, 2024). Additionally, the impact of globalization has often been uneven, contributing to income disparities. Villanthenkodath et al. (2024) observed that economic globalization has reduced income inequality in high- and middle-income countries, while exacerbating inequality in low-income countries. Similarly, trade openness has lowered income inequality in high- and middle-income countries but has had the opposite effect in low-income countries.

Regional economic integration is a key aspect of globalization, involving the promotion of economic cooperation within a region by a group of countries through the reduction or elimination of trade, investment, and tariff barriers. As globalization advances, an increasing number of countries are joining regional economic integration mechanisms to share in the opportunities and benefits of economic growth. This integration is often achieved through the signing of Regional Trade Agreements (RTAs), which can significantly reduce both tariff and non-tariff barriers within the region, promoting the free flow of goods, services, capital, and labor. Pant & Paul (2018) highlighted that RTAs can substantially increase intra-regional trade volumes, thereby stimulating economic growth among member countries. For example, the European Union, as a quintessential model of regional economic integration, has not only boosted trade and economic growth among its member states through the establishment of a customs union and a single market, but also enhanced economic stability by promoting monetary integration, such as with the eurozone. Particularly during economic crises, these integration mechanisms have strengthened the resilience of member countries to external shocks (Ioannou et al., 2015). In recent years, the Asian region has accelerated its regional integration, with the Regional Comprehensive Economic Partnership (RCEP) serving as a notable example. The RCEP, which includes 15 countries in the Asia-Pacific region—such as China, Japan, South Korea, and the ASEAN nations—further bolsters intra-regional economic linkages by reducing trade barriers. According to Chen et al. (2023), the signing of the RCEP is expected to boost economic growth across member countries, particularly for SMEs and export-oriented industries. Moreover, regional economic integration is believed to address developmental imbalances within the region and foster economic convergence. Solow's growth model (1956) suggested that the free flow of capital and technology enables lagging countries to accelerate their catch-up, and that regional economic integration provides an effective mechanism for achieving this. Such integration not only promotes trade but also stimulates economic growth in relatively underdeveloped countries by enhancing intra-regional technological cooperation and investment.

AI and economic growth

With the deepening of international trade, technological innovation has become an increasingly crucial driver of economic growth, particularly the rapid development of artificial intelligence (AI). AI not only serves as a frontier of technological advancement but also profoundly transforms production methods and value-creation models across industries. This section examines the role of AI in driving economic growth and summarizes empirical studies exploring the relationship between AI and economic performance.

Theoretical Framework for AI and Economic Growth

The analysis of the effects of artificial intelligence on economic growth requires a systematic framework that unites growth theory with labor economics and innovation studies. The framework presented in Fig. 2 illustrates both direct productivity effects and indirect structural transformation effects, while considering the distributional consequences that either enhance or limit overall growth.

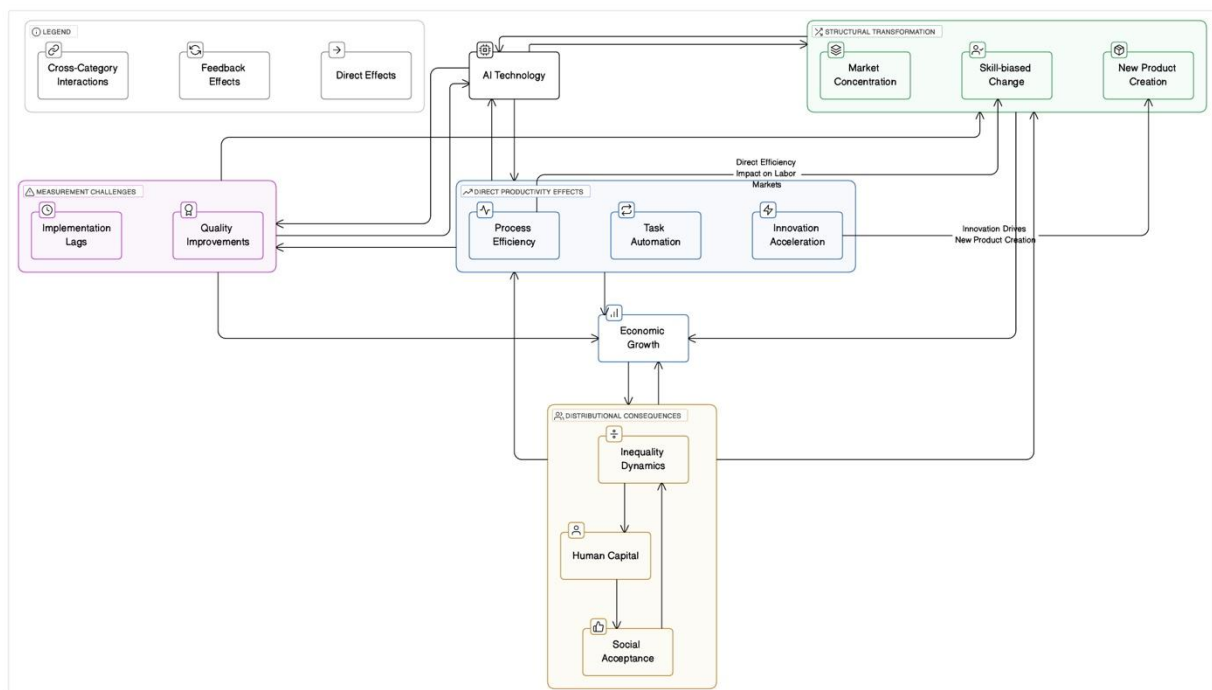


Fig. 2. Direct Productivity Effects and Indirect Structural Transformation Effects Source: Authors' contribution

Direct Productivity Effects

From a growth accounting perspective, AI as a general-purpose technology (GPT) enhances total factor productivity across multiple sectors through three primary channels:

- Process efficiency: AI systems optimize existing production processes through predictive maintenance, intelligent scheduling, and quality control. Formal models by Acemoglu and Restrepo (2018) capture this as an enhancement to the productivity parameter in a standard production function:

$$Y_i = A_i(AI) \cdot F(K_i, L_i) \tag{5}$$

where $A_i(AI)$ represents AI-augmented productivity in sector i .

- Task automation: AI enables the automation of routine cognitive tasks previously performed by human labor. This can be modeled as in Aghion et al. (2018):

$$Y = F\left(K, \int_0^1 [\gamma(j)l(j)^\beta + (1-\gamma(j))a(j)^\beta]^{1/\beta} dj\right) \tag{6}$$

where tasks $j \in [0,1]$ can be performed by either human labor $l(j)$ or AI-automation $a(j)$, with $\gamma(j)$ representing the task-specific productivity of human labor relative to automation.

- Innovation acceleration: AI tools augment R&D productivity by accelerating experimental design, materials discovery, and data analysis. The effect can be captured by modifying the knowledge production function in endogenous growth models:

$$\dot{A} = \delta(AI) \cdot R^\lambda \cdot A^\phi \tag{7}$$

where $\delta(AI)$ represents the AI-enhanced research productivity, R is research input, and A is the existing knowledge stock.

Empirical research at the firm level by Brynjolfsson et al. (2021) indicates productivity increases of 3-15% across industries, with gains in data-intensive services and in manufacturing applications with complex monitoring and control having especially large effects.

Role of AI in economic growth

AI significantly boosts productivity through automation, data processing, and intelligent decision-making. Leveraging machine learning and big data technologies, AI analyzes vast amounts of data, uncovering hidden patterns and trends that enable enterprises to make more informed decisions and optimize production processes. Automation driven by AI technology not only replaces complex and repetitive tasks but also solves intricate problems through intelligent operations, thereby significantly enhancing labor productivity. According to McKinsey (2021), AI-driven automation has led to considerable productivity gains across sectors such as manufacturing, retail, and financial services, particularly by reducing reliance on human labor and freeing up workers for more creative roles. Additionally, AI’s optimization capabilities enable industries to allocate resources more effectively and minimize waste. Through big data analysis, businesses can more accurately predict market demand, streamline supply chain management, and achieve more efficient production, resulting in stronger market competitiveness.

Beyond significantly enhancing productivity, AI’s role in promoting industrial innovation and upgrading is equally crucial. Leveraging its powerful computing capabilities and deep learning technologies, AI provides an unprecedented boost to industrial innovation. By simulating human thinking and behavior, AI is integral to advancements across numerous industries, driving both technological and product innovation. In response to the rapid development of AI, new industries have emerged, such as smart manufacturing, autonomous vehicles, smart homes, and smart healthcare. These emerging sectors not only inject fresh vitality into economic growth but also stimulate the development of related industries, creating new sources of economic expansion.

By integrating AI, traditional industries can achieve intelligent enhancements that boost production efficiency, reduce costs, and improve product quality. For instance, in the manufacturing sector, the adoption of intelligent robots, automated production lines, and other AI-driven tools enables enterprises to achieve more efficient and precise production, minimize human errors, and enhance overall productivity (Yi & Ayangbah, 2024). Additionally, AI helps businesses make accurate market forecasts, optimize inventory management, and streamline production plans and supply chains, thereby reducing operational costs (Gao et al., 2025). In agriculture, AI leverages data on soil conditions, climate, and crop growth to offer farmers tailored planting recommendations and management strategies, ultimately improving crop yield and quality (Mortazavizadeh et al., 2025). In the financial sector, AI analyzes vast amounts of data to provide more accurate and comprehensive risk assessments and investment advice, helping to mitigate financial risks (Jin, 2024).

Empirical evidence on AI and economic growth

By driving industrial innovation and facilitating industrial upgrading, AI technology has contributed to economic growth and supported the optimization and transformation of economic structures. Peretz-Andersson et al. (2024) conducted a case study of Swiss manufacturing SMEs in the packaging, plastics, and metals industries, finding that SMEs leveraging AI technology to coordinate production processes and empower technicians achieved better integration of AI and human resources. This approach not only drove digital transformation within the organization but also created a competitive advantage. In the semiconductor manufacturing and automotive industries, the enhancement of manufacturing data—such as estimating missing values using partially available measurements—and the use of machine learning models to predict product reliability and optimize production processes have led to significant increases in output (Kim et al., 2023). Siemens in Germany deployed an AI-driven automation system at its Amberg plant, automating over 90% of the plant's production processes (van Giffen & Ludwig, 2023). AI technology is used to optimize line configurations, predict equipment maintenance needs, and adjust production processes in real time. These intelligent measures have allowed Siemens to significantly reduce costs while improving production accuracy and efficiency, thereby generating additional economic value. Similarly, General Electric (GE) Vernova launched Proficy for Sustainability Insights to help manufacturers meet their sustainability goals. By driving industrial innovation and facilitating industrial upgrading, AI technology has contributed to economic growth and supported the optimization and transformation of economic structures.

The financial industry is a key frontier for AI technology, as it enhances efficiency and reduces operating costs through data analysis, risk management, and customer service optimization. JPMorgan Chase, for example, automates the analysis of complex contracts using its AI platform COiN, which can process hundreds of thousands of contract documents per day, drastically reducing the time required for manual review. COiN not only improves the efficiency of legal and finance departments but also minimizes human error, thereby boosting overall operational efficiency. Similarly, Alibaba's Ant Financial Services leverages AI for faith-based risk assessments and loan decision-making. AI analyzes customer consumption and system records to make loan decisions within seconds. This system enables Ant Financial Services to provide flexible financial solutions to thousands of micro and small businesses, significantly increasing financial inclusion. This not only drives growth within the financial sector but also supports the economic activities of SMEs.

The application of AI in the medical field is advancing rapidly, particularly in disease diagnosis, drug development, and patient care. The integration of AI technology has significantly improved efficiency and accuracy, contributing to the growth of the global healthcare industry. For instance, Google's DeepMind and the Google Research Institute have developed an AI system, CoDoC (Complementarity-driven Deferral-to-Clinical Workflow), which determines when to rely on predictive AI tools and when to defer to clinicians for the most accurate interpretation of medical images. In a real-world scenario, CoDoC reduced the number of false positives by 25% when applied to a large, de-identified UK mammography dataset compared with traditional clinical workflows, while ensuring no true positives were missed (Dvijotham et al., 2023). The application of AI technology significantly reduces diagnostic time, allowing patients to receive timely treatment, improving medical outcomes, and enhancing hospital efficiency. In 2023, IBM launched the Watson platform, which enables partners to train, fine-tune, and deploy models with generative AI and machine learning capabilities. For example, one of IBM's clients developed a predictive AI model for preterm infants, achieving 75% accuracy in detecting severe sepsis. Such personalized healthcare innovations not only improve patient outcomes but also drive advancements in disease treatment, fueling innovation and growth in the global healthcare industry.

AI has also enhanced the retail industry by improving customer experiences and optimizing logistics and inventory management through personalized recommendation systems and intelligent supply chain management. For instance, Amazon leverages AI extensively for personalized product recommendations, inventory management, and logistics optimization. By analyzing customers' browsing and purchase histories, Amazon delivers highly tailored product suggestions, boosting sales. Additionally, AI-driven robots in Amazon's distribution centers automate sorting and inventory management, greatly enhancing efficiency. Through accurate AI forecasting, Amazon has streamlined its logistics processes, reducing distribution costs and contributing to economic growth in the retail sector. Similarly, Chinese e-commerce leader Jingdong has made substantial investments in AI-driven unmanned warehouses and automated delivery systems. By utilizing AI for warehousing and distribution management, Jingdong operates 24/7 and boosts delivery efficiency through drones and autonomous vehicles. These innovations not only enhance retail logistics but also drive the economic development of the e-commerce industry.

In agriculture, particularly in precision planting, crop monitoring, and automated management, AI has significantly boosted yields and minimized resource waste. For example, John Deere, a U.S. agricultural equipment manufacturer, employs AI and computer vision technology to help farmers grow crops more efficiently. AI-powered robotic sprayers target only weeds, reducing herbicide usage, while self-driving tractors free up farmers' time for higher-value tasks. These innovations improve profitability and drive growth in the agricultural sector. In Israel, AI-driven smart irrigation systems address water scarcity by automatically adjusting irrigation frequency and volume based on climate conditions and soil moisture, thereby minimizing water waste and

improving water efficiency. This innovation has not only increased agricultural productivity in Israel but also serves as a model for global agricultural intelligence.

Policy implications of AI for economic growth

The role of AI technologies in driving economic growth requires policymakers not only to maximize their potential but also to address potential negative impacts. The labor market is undergoing a significant transformation due to the widespread adoption of AI and automation technologies (Glebova et al., 2024). Research indicates that AI is displacing low-skilled jobs while dramatically increasing demand for high-skilled workers (Glebova et al., 2024). Consequently, policymakers must prioritize labor skill-upgrading and retraining programs to help workers adapt to these changes and ensure a smooth workforce transition. The OECD (2019) reported that increased investment in education and skills training can facilitate the smoother integration of AI technologies while strengthening labor market resilience. However, as AI becomes more pervasive, concerns around data privacy and security are growing. Several studies highlight that successful AI adoption requires a robust legal framework to safeguard personal data and privacy. For instance, the European Union's General Data Protection Regulation (GDPR) serves as a model for the legal use of AI technologies, encouraging companies to uphold data ethics and innovate responsibly, thereby mitigating potential legal risks (Peck & Batista, 2022).

To fully unlock AI's potential, governments must implement proactive policies that promote the integration of AI across economic sectors. The development of AI is contingent upon the availability of robust technological infrastructure. Investing in digital infrastructure, such as 5G networks and data centers, can significantly accelerate AI adoption. For instance, China's substantial investments in the digital economy and its active promotion of AI applications in manufacturing and services have driven rapid GDP growth, positioning the country as a key global leader in AI technology (Shan & Guo, 2025). Governments can also stimulate technological innovation in AI-related companies by encouraging corporate investment in AI R&D through policy measures such as tax incentives and research grants. For example, the U.S. National Strategy for Artificial Intelligence was introduced to foster R&D in AI by offering financial support and tax incentives, ensuring that the U.S. maintains its leadership in global AI competition (Fischer et al., 2021). These policies provide long-term support, driving both technological innovation and sustained economic growth.

Challenges and future directions in economic growth research

While the previous three sections explored the impact of policy, global trade, and technological innovation—specifically AI—on economic growth, this chapter shifts focus to the future challenges facing economic growth research. It also examines potential research directions in response to the rapidly evolving global environment and technological advancements.

Emerging issues

In the current global economic context, the study of economic growth faces significant challenges, particularly amid rapid technological advancements, intensifying environmental issues, and demographic shifts, all of which pose new demands on traditional economic growth theories and models.

Firstly, technological change - particularly the rapid development of cutting-edge technologies such as AI, automation, and the Internet of Things - has significantly transformed production methods and economic structures. However, despite these technological advances, the rate of productivity growth in many countries has not kept pace. This discrepancy is often referred to as the "productivity paradox," where technological progress does not lead to the anticipated economic growth (Brynjolfsson, 1993). Empirical studies have shown that technological change often takes time to have a significant impact on the economy as a whole. This delay may be due to factors such as the low adaptability of firms and the labor market to new technologies, as well as the slow pace of technology diffusion (Chen & Xie, 2015). As technology continues to advance, particularly with the widespread use of AI and automation, jobs in certain industries are being replaced. Automation is reducing the demand for low-skilled labor, leading to higher unemployment in some sectors. This, in turn, affects consumer spending power and weakens the momentum of economic growth. At the same time, the growing demand for high-skilled labor is creating a mismatch between the supply and demand for skills. This presents new challenges in balancing short-term employment disruptions with long-term technological benefits. Moreover, technological change tends to favor individuals and firms with the necessary skills and capital, which exacerbates issues of wealth and income inequality. Piketty (2022) has argued that rising inequality can hinder economic growth by dampening consumer demand. This phenomenon is particularly pronounced in developing countries and emerging markets.

Secondly, as climate change and environmental issues intensify, achieving economic growth while minimizing environmental damage has become a major challenge for global development. The depletion of non-renewable resources and the deterioration of ecosystems have had long-term negative effects on the global economy. Studies have shown that economies heavily dependent on fossil fuels and resource-intensive production methods face particularly significant growth pressures in this context (Sikder et al., 2024). The transition to a low-

carbon economy requires substantial investments in renewable energy, environmentally friendly technologies, and infrastructure development. While a green economy is widely acknowledged as a key direction for future growth, balancing short-term economic costs with long-term environmental benefits remains a challenge for both governments and businesses (Biju et al., 2024). Currently, the policy tools to effectively incentivize green investments are inadequate, and many developing countries, in particular, lack the financial and technological support to complete the green transition (Faccioli et al., 2023). Furthermore, natural disasters driven by climate change, such as extreme weather events, sea-level rise, and droughts, directly affect agricultural production, infrastructure, and the livelihoods of communities. These disruptions not only reduce productivity but also cause unpredictable economic losses that undermine the foundation of economic growth (Nordgren, 2021).

In addition, global demographic structures are undergoing significant changes, with many developed countries facing population aging, leading to a decline in the working-age population and a corresponding decrease in economic growth potential. Aging exacerbates labor shortages, increases labor costs for businesses, and raises the burden of social security and healthcare expenditures, all of which weaken governments' fiscal capacity to promote economic growth. Japan, for instance, is one of the countries most affected by aging, and its economic growth has long been constrained by a shrinking workforce and reduced consumer demand (Oliver, 2015). The demographic dividend is also fading as population growth slows. For a populous country like China, a declining working-age population means the economy must transition from a labor-dependent growth model to one driven by technology and innovation, or risk prolonged stagnation (Fang & Wang, 2005). Furthermore, global immigration policies have become increasingly restrictive in recent years, limiting labor mobility. Immigration has long been a key strategy for many countries to address labor shortages (Connor & Krogstad, 2018), particularly in technology- and innovation-intensive industries. By restricting immigration, countries not only reduce the dynamism of their labor markets but also hinder the diffusion of technology and innovation, which, in turn, stifles economic growth.

Future research directions

To address the new challenges and opportunities for economic growth amid technological, environmental, and demographic changes, economists can explore and innovate along the following lines. This involves combining advanced theoretical approaches with interdisciplinary methods to advance the study of economic growth.

Traditional economic growth models often assume that systems are linear and predictable. However, real economic systems are more complex and exhibit nonlinear characteristics. Economies are intricate networks composed of countless interacting individuals and organizations. Researchers can use complex network analysis to explore how interactions between different economic agents influence growth (Wang et al., 2024). For example, by analyzing the structure of global supply chains or financial systems, it becomes possible to understand mechanisms of economic volatility, crisis propagation, and the diffusion of innovation (Angelidis & Varsakelis, 2023). Moreover, economic growth is not always stable; it can be affected by external factors such as technological innovations, financial crises, and environmental shocks, leading to non-linear outcomes. Future research could apply chaos theory, nonlinear equations, and other methods to examine the nonlinear feedback among various economic factors, thereby helping predict and respond to the dynamics of economic growth under uncertainty.

The use of big data and AI technology is becoming a crucial trend in future research on economic growth. Big data technology enhances the accuracy of economic growth forecasts and allows researchers to uncover the impact of micro-level behaviors on the macroeconomy—insights that are difficult to capture through traditional statistical methods (Li et al., 2025). Machine learning algorithms, in particular, can help economists identify hidden patterns in growth, especially when dealing with large volumes of unstructured data (Gentzkow et al., 2019). Moving forward, researchers can leverage machine learning to develop new forecasting models that analyze complex, nonlinear relationships within economic systems, offering more precise predictions of future economic trends. Additionally, AI can be used to run policy simulations, in which different policy parameters are fed into the model to assess their impact on economic growth.

As environmental issues intensify, future research on economic growth should pay more attention to incorporating the economics of climate change and green growth theories. This would involve examining how innovation can drive the development of green technologies, reduce carbon emissions, and stimulate economic growth (Feng et al., 2021; Bruzón et al., 2022; Huang, 2023). Researchers could analyze the role of renewable energy technology development in economic growth, explore the investment needs and returns associated with the green transition, and identify policy tools to accelerate the diffusion of green innovations.

With changing global demographics and the profound impact of AI and automation technologies on the labor market, future research should explore the dual role of the disappearing demographic dividend and the digital workforce in driving economic growth. In response to the aging issue in both developed and emerging economies, research should focus on how policy tools can sustain economic growth. Additionally, it is essential to examine the long-term effects of aging on innovation and productivity, as well as assess structural changes in the labor market. Given the widespread adoption of AI and automation technologies, future studies could investigate the

substitution and complementary effects of labor across different skill levels, and analyze the impact of AI on global employment, wage disparities, and overall economic growth.

Additionally, the complexity of global supply chains and the impact of regional economic integration on growth are critical topics in the contemporary globalized economy. Research on the dynamic changes in GVCs, the risks associated with supply chain disruptions, and the intricate relationship between technology transfer and economic growth is essential for developing new strategies to foster global economic growth. As the digital economy continues to rise, global economic growth will increasingly depend on cross-border cooperation and coordination in areas such as digital currencies, data privacy, and cross-border e-commerce.

Structured Research Agenda for Economic Growth Studies

Our analysis of emerging challenges has led us to develop a research agenda that encompasses three time horizons and four methodological innovations. The research agenda addresses key questions about economic growth while creating innovative methods to tackle complex growth challenges.

Short-Term Research Priorities

The first research priority focuses on developing new metrics to measure intangible capital formation resulting from AI and digital technologies, while enhancing measurement techniques for quality improvements and the introduction of new digital services. Additionally, it involves studying the “productivity paradox” in AI adoption contexts through lag analysis and organizational complementation. The second research priority examines the distributional effects of technological change through three objectives: analyzing how AI and automation affect labor-market outcomes at the task level across skill categories and regions; quantifying the impact of technology on wage polarization and labor share dynamics; and developing policies to manage distributional effects while maintaining innovation incentives. The dynamics of AI adoption were significantly altered during the pandemic. We need studies evaluating three post-pandemic growth recovery strategies by comparing different fiscal stimulus and industrial policy approaches for sustainable recovery and their impact on AI adoption dynamics. This includes analyzing pandemic-accelerated digital transformation and its long-term productivity implications, as well as assessing global value chain resilience for trade-led growth strategies in the evolving economic landscape.

Medium-Term Research Priorities

The primary objective is to establish environmentally sustainable growth models through the theoretical development and practical application of “green growth” frameworks. These frameworks assess natural capital and evaluate the impact of climate policy on economic growth across various developmental contexts, while also quantifying the growth advantages from circular-economy practices and improvements in resource efficiency. The second objective is to investigate how digital technologies and remote work are reshaping the spatial distribution of economic activity, analyzing emerging patterns of innovation diffusion and technology transfer during periods of geopolitical tension, and examining how cities and industrial clusters adapt to the digital economy. The third objective involves studying the effects of digital currency and fintech on the transmission of monetary policy, developing fiscal frameworks for intangible assets and digital business models, and analyzing the challenges in managing global financial flows to ensure macroeconomic stability.

Long-Term Research Priorities

Research priorities for the long term should focus on essential changes that will transform economic knowledge and policy strategies. The first priority is to develop new economic growth measurement tools that combine indicators better to reflect welfare, sustainability, and distributional aspects. The research needs to explore the fundamental theoretical aspects of multidimensional growth beyond production metrics, while building data systems and statistical methods to track economic progress in its various dimensions. Assessing future technological transformations requires examining how quantum computing, biotechnology, and fusion energy will impact economic growth. The development of future-oriented regulatory systems requires establishing an equilibrium between technological progress and risk control, and researchers must investigate how technological unification will reshape economic frameworks. The study of sustainable growth models for declining-population societies necessitates economic frameworks to manage migration responses to demographic imbalances, as well as an analysis of how changing age structures affect savings, investment, and innovation in diverse demographic settings.

Methodological Innovations

The research priorities require substantial methodological progress across four innovative domains. The first domain of integration between machine learning and econometrics uses supervised learning to enhance identification methods in growth empirics. In contrast, unsupervised learning is employed to detect hidden growth patterns and heterogeneities. This approach develops hybrid methods that combine machine learning prediction

with econometric causal inference. Agent-based computational modeling necessitates the development of technological diffusion models that simulate complex adaptive systems and the creation of multi-scale models that link individual behaviors to national growth outcomes.

Additionally, it involves simulating policy interventions through empirically validated models that incorporate diverse agents and spontaneous system effects. The third domain of interdisciplinary synthesis methods requires the development of formal frameworks that merge ecological economics with complexity science and evolutionary economics, while creating quantitative growth model-qualitative institutional analysis bridges and establishing statistical-case-based mixed-methods approaches. The development of high-frequency economic monitoring systems for providing timely growth indicators requires the integration of alternative data sources, such as satellite imagery, mobile phone data, and online platforms, into growth measurement and the creation of early warning systems for identifying structural breaks and regime shifts in growth processes.

Conclusion

The evaluation conducts a thorough investigation of economic development, drawing on classical economic theories and modern growth models that account for institutional factors, technological progress, and environmental constraints. We demonstrate that basic growth models provide valuable insights into fundamental processes, yet require substantial improvements to address contemporary economic complexities, as systems are subject to rapid technological evolution, shifting global connections, and ecological constraints.

This paper introduces three essential additions to the literature about economic growth. Our research develops a unified theoretical framework that establishes connections between classic growth variables and institutional, technological, and environmental factors. The method enables more accurate growth dynamic analysis across diverse development scenarios. The framework illustrates the essential relationships among growth determinants, emphasizing that successful growth plans must account for specific conditions.

This review compiles empirical data on fundamental economic growth factors, including physical and human capital, as well as technological advancements and institutional quality, which reveals their differential impact on various economic systems at different stages of development. The research synthesis addresses the existing theory-evidence divide to develop a more comprehensive understanding of growth elements that operate in real-world economic systems.

Our research presents a strategic plan that demonstrates how scientists can utilize innovative methods in conjunction with interdisciplinary research to address current growth challenges. Our research outlines specific time-based research directions and methodological enhancements that will help improve both theoretical comprehension and policy-oriented research.

The analysis yields several important policy recommendations to promote sustainable economic development. Policymakers should tailor their strategies to their country's stage of development, institutional capacity, and external environment. The proposed framework can help design targeted policies by identifying key growth barriers and supportive factors within specific economic contexts. Public policies should balance the promotion of innovation with the management of distributional impacts, as technological progress - particularly in artificial intelligence and automation - continues to reshape economic structures. Achieving broad-based prosperity from technological advances requires coordinated efforts to develop human capital, strengthen labor market institutions, and enhance social protection systems.

Environmental sustainability needs to be systematically integrated into growth strategies through policy frameworks that combine private motivations with social objectives. The transition to sustainable growth patterns can be achieved through carbon pricing systems, support for green innovation, and the implementation of natural capital accounting to protect economic dynamism. Effective growth policies require international cooperation on global trade rules, intellectual property protection, tax standards, and environmental protection agreements in today's interconnected world economy. Global governance system fragmentation poses a significant obstacle that must be addressed for sustainable growth to become possible.

The field of economic growth research continues to evolve its approach to address new challenges and capitalize on emerging opportunities. The research paths we have identified will improve both theoretical knowledge and practical use in the field. Machine learning techniques, when combined with traditional econometric methods, enable researchers to uncover intricate patterns and variable growth effects in economic systems. Agent-based computational models excel at modeling emergent patterns and complex adaptive economic systems, which standard equilibrium models cannot effectively handle.

Research areas where growth economics meets sustainability science and technological change hold great promise for tackling present-day problems. The field requires advanced conceptual frameworks that examine environmental limitations on economic performance and methods to assess the social impacts of technology, as well as new growth assessment methods beyond GDP.

Our approaches to understanding and promoting economic growth need to evolve because economic systems adapt to technological advancements while navigating environmental impacts and shifting social norms. Research

and policy development will benefit from methodological innovation, interdisciplinary perspectives, and context-specific analyses to develop robust, sustainable, and inclusive growth strategies.

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