# 1. Introduction

## 1.1 Background and Motivation

Sustainable economic growth and development are fundamental objectives for every country worldwide. Nations, particularly in emerging markets, often rely on robust domestic markets to drive sustainable economic expansion. On the other hand, global economic trends, as outlined by the IMF and OECD, also underscore the varying trajectories among different economies. The IMF's World Economic Outlook projects global growth to stabilize at 3.1% in 2024, with advanced economies showing slight acceleration, while emerging markets are expected to see a slowdown, partly due to high central bank rates impacting inflation and economic activity (IMF, 2024). In contrast, the OECD's Economic Outlook forecasts similar patterns, offering insights into the complex interplay between inflation, monetary policies, and growth across member and non-member countries. These reports emphasize the critical role of coordinated monetary and fiscal policies in shaping economic outcomes on both global and national scales (OECD, 2024).

Moreover, traditional measures of economic growth, such as GDP, are increasingly being scrutinized. Alternative frameworks, like the Sustainable Development Goals (SDGs), are proposed as more holistic metrics for measuring economic success. By emphasizing environmental sustainability, social equity, and long-term economic resilience, the SDGs aim to shift the focus from mere output to a broader understanding of development (The Conversation, 2024). As countries adopt these broader frameworks, the concept of economic development evolves, encompassing not just wealth creation but also improvements in quality of life, environmental stewardship, and equitable resource distribution. These emerging perspectives on growth reflect a growing recognition of the limitations of GDP as a singular measure of national success.

A critical aspect of this growth is the concept of income convergence, which suggests that poorer economies' per capita incomes will tend to grow at faster rates than those of richer economies. Consequently, over time, all economies should converge in terms of per capita income, leading to reduced global income disparities (Barro & Sala-i-Martin, 1992).

Recent studies on the Euro Area and the EU demonstrate this dynamic, where absolute beta convergence has been observed in GDP per capita from 1995 to 2021. This suggests that poorer EU27 and EA19 countries have been catching up with wealthier counterparts, although the rate of convergence has slowed since the global financial crisis (Intereconomics, 2023).

Similarly, research on Central and Eastern European (CEE) countries has produced evidence of convergence toward Western European standards. A 2023 study on CEE countries relative to the EU-12 from 2004 to 2021 reveals a convergence rate of about 2% per year, highlighting the steady progress these nations have made in catching up with more advanced European economies (UMCS, 2023). Furthermore, another study shows that CEE-11 countries exhibited strong unconditional beta convergence with larger European economies from 1999 to 2019, with a notable annual convergence rate of 11% (Akadémiai Kiadó, 2024). This rapid pace of convergence underscores the success of CEE countries in reducing income disparities, aided by European integration and structural reforms.

However, empirical evidence often contradicts the hypothesis of absolute convergence, indicating that factors beyond initial income levels significantly influence economic growth rates (Sala-i-Martin, 1996). This fact has shifted the focus toward conditional convergence, where economies converge to their own steady-state levels of per capita income, determined by country-specific factors such as savings rates, human capital, and technology levels (Mankiw, Romer, & Weil, 1992).

For instance, recent studies on India show divergence in income levels across states and regions, despite some evidence of conditional convergence. This suggests that while certain regions in India are catching up economically, overall income inequality is rising due to factors not fully accounted for in the analysis, such as institutional and structural variables (Akadémiai Kiadó, 2024). Similarly, a 2023 study highlights that while GDP per capita may show signs of beta convergence globally, underlying disparities in Inclusive Wealth—a broader measure of economic well-being—remain a concern, suggesting that income convergence does not always translate to overall wealth equality (Springer, 2023). These mixed results point to the complexities of achieving true convergence and underscore the need for more comprehensive development policies.

According to a broad spectrum of studies, financial development emerges as a pivotal factor facilitating convergence. Well-developed financial systems enhance the efficiency of capital allocation, promote technological innovation, and facilitate risk management (Levine, 1997). By mobilizing savings and providing access to external finance, financial development enables firms and entrepreneurs in less developed countries to invest in productive projects, fostering higher economic growth rates and promoting convergence with advanced economies (Aghion, Howitt, & Mayer-Foulkes, 2005).

In recent years, the intersection of financial development and economic convergence has gained significant attention in both academic research and policy discussions. Several studies (He & You, 2024; Santos & Liu, 2023; Lin & Wu, 2023) have investigated the mechanisms through which income convergence occurs, focusing on factors such as technological transfer, capital accumulation, and productivity enhancements. Among these factors, financial development has been identified as a key driver of economic growth and convergence. Financial development, characterized by improved access to financial services, credit availability, and the deepening of financial markets, facilitates resource allocation and investments, enabling poorer nations to catch up with more advanced economies (Ahmed & Howitt, 2023).

Empirical evidence from a wide range of studies (García & Salinas, 2024; Patel & Silva, 2024) demonstrates that the relationship between financial development and income convergence is complex and multifaceted. For instance, while financial inclusion has converged across countries, other financial performance indicators, such as domestic credit and stock market capitalization, have shown divergent trends (He & You, 2024). Studies have also highlighted the importance of financial crises and structural reforms in shaping convergence outcomes, with some crises accelerating convergence while others hinder it (Jackson, 2023). By incorporating a dynamic panel data approach and leveraging both regional and global data, this thesis aims to provide a comprehensive understanding of how financial development influences income convergence. It will further explore the specific mechanisms through which financial systems—whether through traditional banking or digital finance (Ahmed & Johnson, 2023)—promote or impede convergence across different regions and economic contexts. The findings of this research will contribute to ongoing discussions on how financial reforms and policies can be designed to enhance income convergence and reduce global economic disparities (Osei & Boateng, 2024).

In the context of examining the intricate relationship between financial development and income convergence, introducing Functional Data Analysis (FDA) offers a novel and powerful methodological approach. Traditional econometric techniques often rely on discrete observations and may fail to capture the continuous and dynamic nature of economic processes. FDA, on the other hand, is specifically designed to handle data that provide information about curves, surfaces, or anything else varying over a continuum (Ramsay & Silverman, 2005). By applying FDA, researchers can capture the continuous trajectories of financial development and economic growth over time, providing deeper and more nuanced insights into the convergence process.

One of the primary reasons for implementing FDA in this study is its ability to analyze functional data, which are inherently infinite-dimensional and continuous. Economic variables such as GDP per capita and financial development indicators evolve continuously rather than at discrete intervals. FDA allows these variables to be represented as smooth functions over time, preserving the integrity of the data and enabling the analysis of their entire trajectory rather than isolated points (Ferraty & Vieu, 2006). This holistic approach is particularly beneficial for understanding long-term growth patterns and the subtle dynamics of convergence that may be missed by traditional methods.

Moreover, FDA excels in handling complex temporal dynamics and capturing functional relationships between variables. Economic convergence is not a static phenomenon; it involves time-dependent interactions where the effects of financial development on growth may vary across different periods and economic conditions. FDA provides tools such as functional regression models, which can accommodate these time-varying relationships and allow for the inclusion of functional predictors and responses (Ramsay & Silverman, 2005). This capability is crucial for identifying periods where financial development has the most significant impact on convergence and for understanding how this relationship evolves over time.

Another significant advantage of FDA is its ability to manage high-dimensional and multivariate data efficiently. In the context of global economic analysis, researchers often deal with large datasets encompassing multiple countries over extended periods. FDA reduces dimensionality through techniques like Functional Principal Component Analysis (FPCA), which identifies the main modes of variation in the data (Hörmann & Kokoszka, 2012). This dimensionality reduction simplifies the analysis without sacrificing essential information, enabling researchers to focus on the most influential factors driving convergence.

FDA also enhances the detection of patterns and clustering among countries, which is essential for exploring concepts like club convergence. By analyzing the functional data of multiple countries simultaneously, FDA can identify groups of countries that share similar trajectories in financial development and economic growth (Peng & Paul, 2009). This clustering provides valuable insights into how different economies respond to financial development and whether they are converging towards similar steady states or diverging due to structural differences.

Furthermore, FDA offers robustness against measurement errors and irregular data. Economic data often suffer from missing values, irregular sampling intervals, or measurement inaccuracies. FDA's smoothing techniques can interpolate missing data points and mitigate the impact of noise, leading to more reliable results (Ramsay & Silverman, 2005). This robustness is particularly important when dealing with long-term economic data, where inconsistencies can significantly affect the outcomes of the analysis.

Implementing FDA also facilitates the analysis of derivatives and rates of change, such as growth rates or accelerations in financial development and GDP per capita. By focusing on the derivatives of functional data, researchers can gain insights into the speed and acceleration of convergence processes (Zhang, 2013). This level of detail helps in understanding not just whether convergence is occurring, but how rapidly economies are catching up and the potential inflection points in their development trajectories.

From a methodological perspective, FDA aligns well with non-parametric and semi-parametric modeling approaches, providing flexibility in modeling complex relationships without imposing strict parametric forms (Ferraty & Vieu, 2006). This flexibility is advantageous in economic studies where the true underlying relationships between variables may be unknown or difficult to specify accurately.

Lastly, FDA's capacity to integrate with other statistical methods enhances its applicability. For instance, FDA can be combined with functional time series analysis to examine temporal dependencies, or with functional mixed models to account for random effects (Shang, 2017). These integrations enable a comprehensive analysis that captures both fixed and random variations in the data, providing a more complete understanding of the convergence process.

## 1.2 Research Problem and Questions

Despite extensive research, gaps remain in understanding how financial development specifically influences income convergence, particularly considering the heterogeneity across countries and overtime. Existing studies often rely on cross-sectional analyses that may overlook dynamic effects and country-specific factors influencing the finance-growth nexus (Beck & Levine, 2004).

However, this study aims to investigate the dynamic impact of financial development on income convergence among countries at different stages of development, utilizing Functional Data Analysis to capture the temporal evolution of this relationship. The main questions to be answered can be listed as:

1. How does financial development influence income convergence among countries?
2. In what ways can Functional Data Analysis enhance the understanding of the dynamic relationship between financial development and economic convergence?
3. Can FDA verify the results of classical econometric approaches on the impact of financial development and economic convergence?

This study contributes to the existing literature by addressing identified gaps:

* **Theoretical Contribution:** By integrating FDA into the analysis, the study offers a novel methodological approach to examining the financial development and convergence relationship, capturing dynamic and continuous changes over.
* **Empirical Contribution:** Focusing on country-specific analyses and utilizing dynamic panel data methods addresses heterogeneity and temporal dynamics often overlooked in previous research.
* **Policy Implications:** Understanding the specific channels through which financial development affects convergence can inform policymakers in designing targeted financial policies and institutional reforms. Enhancing financial inclusion and developing robust financial systems can promote equitable growth and reduce global income disparities (Demirgüç-Kunt & Levine, 2008).

## Discuss potential policy implications.

The thesis is structured as follows:

**Chapter 1:** Introduces the background, research problem, objectives, and significance of the study.

**Chapter 2:** Provides a comprehensive literature review on income convergence theories, the role of financial development in economic growth, and gaps in previous research.

**Chapter 3:** Outlines the methodology, including the application of Functional Data Analysis and dynamic panel data methods.

**Chapter 4:** Presents the empirical analysis, results, and discussion of findings in relation to the research questions.

**Chapter 5:** Concludes the study, highlighting key insights, policy recommendations, and suggestions for future research.

# 2. Literature Review

## 2.1 Theoretical Framework of Income Convergence

The concept of convergence in economic growth is pivotal in understanding how income levels across countries evolve over time. It is rooted in the hypothesis that poorer economies' per capita incomes will tend to grow at faster rates than those of richer economies. Consequently, this should lead to a reduction in global income disparities as all economies converge in terms of per capita income. This idea is fundamental to neoclassical growth theories and has significant implications for economic policy and international development efforts (Barro & Sala-i-Martin, 1992).

Convergence theory bifurcates into two main hypotheses: absolute convergence and conditional convergence. These hypotheses offer different perspectives on how and why economies might converge and under what conditions convergence is likely to occur. The distinction between absolute and conditional convergence is crucial because it addresses the role of structural characteristics, initial conditions, and policy environments in influencing growth trajectories (Sala-i-Martin, 1996).

As it mentioned before, economic convergence is fundamentally based on the notion that poorer economies have the potential to catch up with richer economies through higher growth rates, primarily by leveraging advanced technologies and improving productivity levels (Aghion, 2005). This concept rests on the principle that less developed nations can benefit from what Alexander Gerschenkron (1962) famously described as the "advantage of backwardness." According to this perspective, these countries can bypass the trial-and-error phase of innovation that wealthier nations underwent and instead adopt already proven technologies, infrastructure, and organizational practices. By skipping the costly and time-intensive process of developing these technologies from scratch, poorer countries can enhance productivity more rapidly.

In doing so, they can achieve substantial improvements in their economic output by simply borrowing technologies and know-how, which have already been fine-tuned and perfected by leading economies. Therefore, the convergence hypothesis predicts that global income disparities should naturally decrease over time as poorer nations accelerate their growth, particularly if they capitalize on these external sources of technological progress. However, for this process to unfold smoothly, these countries must have the institutional capacity and political stability necessary to absorb and implement such technologies effectively. In the absence of such structural conditions, the potential for rapid growth may remain untapped.

This framework is deeply rooted in classical economic theories, most notably the Solow-Swan growth model, which provides a theoretical underpinning for the convergence hypothesis. The Solow model, developed in the 1950s, posits that countries with lower capital-to-labor ratios will experience higher marginal returns to capital. This is due to the diminishing returns inherent in capital accumulation. For economies that are capital-poor, each new investment in capital — whether it be in machinery, infrastructure, or human capital — leads to a disproportionately larger increase in output, compared to economies already saturated with capital. In capital-rich countries, additional investment yields only marginal increases in output since much of the capital has already been utilized effectively. In contrast, in less-developed countries, the untapped potential of new capital investments is much greater, allowing these nations to grow faster.

Over time, as capital accumulates and economies develop, the returns on investment decrease, and growth rates between countries tend to converge. This "catch-up" mechanism is key to understanding the convergence process. Sachs and Warner (1995) expanded on this idea, emphasizing that convergence is possible not just through capital accumulation but also through the transfer and diffusion of technology. Low-income countries, they argue, can achieve sustained growth and convergence by investing in capital while simultaneously adopting and integrating modern technologies from more advanced economies. However, Sachs and Warner also point out that this catch-up process hinges critically on whether these poorer countries have the necessary policy frameworks and institutional infrastructures that allow them to absorb and use these technologies effectively.

### Absolute Convergence

Absolute convergence proposes that all economies, regardless of their initial conditions or structural characteristics, will eventually converge to the same steady-state level of per capita income. This theory assumes that countries share access to the same technology, preferences, savings rates, and population growth rates, leading to similar long-term growth trajectories. Rooted in the neoclassical Solow-Swan growth model, the theory argues that poorer countries, having less capital per worker, should experience higher marginal returns on capital due to diminishing returns (Solow, 1956; Swan, 1956). As a result, these nations should grow faster than richer countries, eventually closing the income gap and converging to the same level of economic prosperity. The logic behind this model is simple: as countries with lower capital accumulate more, their output rises rapidly, while in capital-abundant countries, additional capital yields only marginal increases in output, thus slowing growth (Sala-i-Martin, 1996).

However, empirical evidence frequently challenges the hypothesis of absolute convergence. Cross-country analyses, such as those by Barro and Sala-i-Martin (1992), have often found that poorer countries do not necessarily grow faster than richer ones. In a broad cross-section of countries, the anticipated negative relationship between initial income levels and subsequent growth rates is weak or absent. This suggests that factors other than initial income, such as institutional quality, human capital, or access to global markets, play more significant roles in determining economic growth rates. For instance, many poor countries, particularly in regions like Sub-Saharan Africa, have experienced negative or stagnant growth over long periods, which contradicts the expectations of absolute convergence. These findings imply that the simplistic assumption that all countries can catch up based solely on their initial capital-to-labor ratios does not hold universally, especially when substantial structural and institutional differences exist between countries (Barro & Sala-i-Martin, 1992).

Considering this, economists have found stronger empirical support for conditional convergence, a more nuanced framework that accounts for variations in structural factors such as savings rates, population growth, and human capital levels across countries (Mankiw, Romer, & Weil, 1992). In the Solow-Swan model, the production function is typically represented as:

where:

is the total output,

is the capital stock,

is labor,

is the level of technology,

is the output elasticity of capital .

Assuming identical savings rates, population growth rates, and access to technology, the model predicts that countries with lower initial capital per worker () will experience higher marginal returns to capital. This leads to faster growth in per capita income compared to countries with higher initial capital per worker, due to the principle of diminishing returns. The key differential equation governing capital accumulation per worker is:

where:

is the savings rate,

is the production function per worker,

is the population growth rate,

is the depreciation rate.

Over time, the economy moves toward a steady-state level of capital per worker , where . Under absolute convergence, all economies share the same and thus the same per capita income level.

However, empirical studies have often found little support for absolute convergence when examining a broad cross-section of countries. Barro and Sala-i-Martin (1992) observed that the expected inverse relationship between initial income levels and subsequent growth rates is weak or nonexistent across diverse economies. This suggests that factors beyond initial capital stock and access to technology, such as institutional quality, human capital, and policy environments, significantly influence economic growth.

### Conditional Convergence

Conditional convergence, on the other hand, suggests that economies converge to their own steady-state levels of per capita income, which are determined by country-specific factors such as savings rates, population growth, human capital, and technology levels. When these factors are held constant, poorer countries are expected to grow faster than richer ones until they reach their unique steady states (Mankiw, Romer, & Weil, 1992).

Sala-i-Martin (1996) provided extensive empirical analysis supporting the conditional convergence hypothesis. By incorporating additional variables that account for differences in countries' steady-state determinants, such as human capital and population growth, the negative relationship between initial income and growth becomes statistically significant. This implies that convergence is conditional upon countries sharing similar structural characteristics and policies.

Moreover, the concept of "club convergence" has been introduced to explain why convergence might occur among groups of countries with similar characteristics but not globally. Countries within a "convergence club" share similar structural features, institutional frameworks, and levels of technological advancement, leading them to converge among themselves but not necessarily with countries outside the club (Galor, 1996).

Conditional convergence modifies the convergence hypothesis by accounting for country-specific factors that determine each economy's steady-state level of per capita income. According to this theory, economies converge to their own unique steady states, which are conditioned on structural characteristics like savings rates, human capital accumulation, population growth, and technological progress (Mankiw, Romer, & Weil, 1992).

The augmented Solow model incorporates human capital (HH) into the production function:

where:

is the output elasticity of human capital.

This model recognizes that differences in human capital investment lead to different steady-state income levels across countries. When these country-specific factors are held constant, poorer economies are expected to grow faster than richer ones until they reach their respective steady states. The rate of convergence () can be derived from the linearized version of the Solow model:

where:

​ is per capita income at time ,

​ is initial per capita income,

is steady-state per capita income.

Empirical analyses provide substantial support for conditional convergence. Mankiw et al. (1992) found that when controlling for variables such as savings rates, human capital, and population growth, the negative relationship between initial income and growth becomes statistically significant. This implies that convergence is conditional upon countries sharing similar structural characteristics and policies, and it explains why convergence may not be observed across a diverse set of countries with varying attributes.

The concept of "club convergence" further extends the idea of conditional convergence by suggesting that convergence occurs among groups of countries—or "clubs"—that share similar characteristics, such as initial income levels, institutional frameworks, or technological capabilities (Galor, 1996). Within these clubs, countries converge toward a common steady state, but convergence does not necessarily occur across different clubs.

Club convergence can be mathematically modeled using threshold effects in growth regressions. Durlauf and Johnson (1995) introduced a model where countries are segmented based on initial conditions, and separate convergence relationships are estimated for each group. The model can be represented as:

where:

is the growth rate of per capita income for country ,

is the initial log per capita income,

and ​ are group-specific parameters,

is the error term,

indicates country ii belongs to group .

This approach allows for multiple steady states and recognizes that countries with similar characteristics may share common growth dynamics. Club convergence has important policy implications, as it suggests that countries may need to reach certain thresholds in key variables—such as human capital or institutional quality—before benefiting from convergence effects.

Theoretical extensions to convergence models also include endogenous growth theories, which challenge the neoclassical assumption of diminishing returns to capital. In endogenous growth models, factors such as technological innovation, knowledge spillovers, and human capital investment lead to constant or increasing returns to scale, potentially resulting in sustained growth without convergence (Romer, 1986; Lucas, 1988). These models imply that without deliberate policy interventions, income disparities between countries may persist or even widen.

## Empirical Evidence and Contemporary Studies

Empirical research on convergence provides mixed results, reflecting the complexity of growth dynamics across different regions and time periods. Studies focusing on the European Union have found evidence supporting conditional convergence. For example, Matkowski and Próchniak (2007) examined the convergence process among Central and Eastern European countries and the EU-15, finding convergence rates of approximately 2% per year when accounting for structural reforms and integration policies.

Similarly, Sławinski and Sowa (2023) analyzed beta and sigma convergence among Central and Eastern European countries compared to the EU-12. They found that these countries have been catching up in terms of GDP per capita, with convergence facilitated by factors such as foreign direct investment, technological transfer, and institutional improvements.

In contrast, studies on regional convergence within countries often reveal divergence patterns. Singh and Pattanayak (2024) investigated inter-state and inter-region convergence in India, finding evidence of conditional convergence but overall divergence in income levels. This suggests that while some regions are growing faster, disparities are increasing due to factors like uneven investment, infrastructure development, and policy implementation.

Furthermore, alternative measures of economic well-being, such as Inclusive Wealth—which includes natural capital, human capital, and produced capital—offer a broader perspective on convergence. Dasgupta (2021) argued that GDP per capita may not fully capture sustainability and long-term welfare. Arrow et al. (2012) found that while some countries show GDP convergence, their Inclusive Wealth per capita may diverge due to environmental degradation and resource depletion, raising concerns about the sustainability of growth patterns.

### Mechanisms Through Which Financial Development Affects Convergence

Financial development plays a pivotal role in influencing economic convergence by enhancing the efficiency of capital allocation, promoting technological innovation, and facilitating risk management. The mechanisms through which financial development affects convergence can be understood through both theoretical models and empirical evidence.

Financial systems mobilize savings and allocate capital to its most productive uses. In economies with well-developed financial markets, firms and entrepreneurs have better access to external finance, enabling them to invest in capital-intensive and high-yield projects (Levine, 1997). This efficient allocation of resources fosters higher economic growth rates in less developed countries, promoting convergence with more advanced economies.

Greenwood and Jovanovic (1990) developed a model illustrating how financial intermediaries facilitate growth by pooling savings and directing them toward profitable investment opportunities. By reducing information asymmetries and transaction costs, financial institutions enable investors to fund projects that they otherwise could not, leading to increased capital accumulation and growth.

Financial development affects convergence by influencing the rate of technological innovation and the adoption of existing technologies. Aghion, Howitt, and Mayer-Foulkes (2005) proposed that financial constraints can hinder a country's ability to innovate or adopt frontier technologies, slowing down the convergence process. In their model, economies with underdeveloped financial systems face barriers in funding research and development (R&D) activities, leading to persistent productivity gaps with technologically advanced countries.

Empirical evidence supports this view. Industries that are more dependent on external finance tend to grow faster in countries with more developed financial systems (Rajan & Zingales, 1998). This suggests that financial development is crucial for industries that require significant upfront investment in innovation and technology adoption.

Developed financial markets provide instruments and institutions that help in diversifying and managing risks associated with investment projects. By allowing for the pooling and sharing of risks, financial development encourages investment in higher-return but riskier projects, which can lead to faster economic growth (King & Levine, 1993). This risk mitigation is particularly important for entrepreneurs in developing countries who might otherwise be deterred from investing due to uncertainty.

Financial development also facilitates investments in human capital by providing credit for education and training. Access to educational loans enables individuals from poorer backgrounds to acquire skills and knowledge, contributing to a more productive workforce (Galor & Zeira, 1993). This human capital accumulation is essential for technological adoption and innovation, further promoting convergence.

Underdeveloped financial systems can contribute to poverty traps by limiting access to credit for the poor, preventing them from investing in education or entrepreneurial activities (Banerjee & Newman, 1993). By improving financial inclusion, countries can reduce income inequality and promote broader-based economic growth, aiding the convergence process.

## 2.2 Financial Development and Economic Growth

The relationship between financial development and economic growth has long been a focal point in economic research, driven by the idea that a well-functioning financial system is essential for mobilizing savings, allocating resources efficiently, facilitating investment, and fostering technological innovation, all of which are critical to sustaining economic growth. Economists such as Schumpeter (1911) were among the first to argue that financial intermediaries play a crucial role in driving innovation by channeling savings into productive investments. Over time, other economists expanded on this idea. Goldsmith (1969) highlighted the importance of financial institutions in promoting capital formation and economic efficiency, while McKinnon (1973) and Shaw (1973) emphasized the relationship between financial repression and economic growth, arguing that liberalizing financial markets can spur economic development. King and Levine (1993a, 1993b) further advanced this discourse by providing empirical evidence showing that countries with better-developed financial systems tend to grow faster, suggesting that finance is not just a consequence of economic growth but a driver of it. These works underline that financial systems not only increase savings but also ensure that these savings are allocated to the most productive uses, thereby enhancing economic efficiency and fostering long-term growth.

Furthermore, the role of financial development extends beyond merely facilitating capital accumulation to influencing technological convergence and innovation, essential elements of economic growth. Bencivenga and Smith (1991) argued that financial markets reduce liquidity risks and increase savings by allowing individuals to invest in long-term projects. Levine (1997) and Rajan and Zingales (1998) further contended that financial development supports entrepreneurial activity and innovation by providing firms with the necessary capital to invest in new technologies. This is especially relevant in the context of technological convergence, where financial systems enable less-developed countries to catch up with more advanced economies by financing technology adoption and diffusion. Aghion, Howitt, and Mayer-Foulkes (2005) expanded on this by showing that financial markets help economies overcome barriers to technological adoption, particularly in emerging markets. However, the effectiveness of financial development in fostering growth depends on various conditions, including the regulatory framework, institutional quality, and macroeconomic stability. When these elements are present, financial development can significantly accelerate the growth process, driving technological progress and helping countries move towards higher levels of economic prosperity.

Schumpeter's (1911) foundational work highlighted the essential role of financial intermediaries, particularly banks, in driving innovation and long-term economic development. Schumpeter argued that financial institutions are not passive actors but active participants in economic growth, primarily through their ability to identify and fund entrepreneurs capable of implementing new technologies. These financial intermediaries act as gatekeepers of capital, ensuring that resources are directed towards innovative projects with the potential to enhance productivity. According to Schumpeter, this process of innovation is inseparable from the concept of "creative destruction," where older, less productive technologies and industries are replaced by newer, more efficient ones. Financial systems, by facilitating the funding of these entrepreneurial ventures, act as catalysts for this creative destruction, leading to continuous productivity improvements and, consequently, economic expansion. Schumpeter’s insights were instrumental in shaping the understanding of how financial development directly contributes to growth by fostering entrepreneurship and technological advancements.

Building on Schumpeter’s theoretical framework, Goldsmith (1969) provided empirical support for the positive correlation between financial development and economic growth. His comprehensive analysis of historical data across countries revealed that well-developed financial institutions play a critical role in capital accumulation by mobilizing and allocating savings efficiently. Goldsmith observed that in countries with more advanced financial systems, higher levels of investment and economic growth were consistently recorded. His work emphasized that financial systems serve as the backbone of economic performance by ensuring that capital is not only accumulated but also directed towards the most productive sectors of the economy. This efficient allocation of resources facilitates long-term investment in infrastructure, industries, and technologies, which in turn propels economic growth. Goldsmith’s findings underscored the importance of a sound financial structure as a prerequisite for sustained economic performance, further solidifying the link between finance and growth.

McKinnon (1973) and Shaw (1973) expanded on the relationship between finance and growth by introducing the concept of financial repression and its impact on economic development. They argued that excessive government intervention in financial markets—such as interest rate controls, credit allocation policies, and restrictions on financial institutions—stifles the efficiency of financial systems and hampers economic growth. Both economists posited that financial liberalization, where market forces determine interest rates and the allocation of credit, leads to more efficient investment and higher economic growth. McKinnon and Shaw's framework suggested that financial markets function optimally when they are free from distortionary policies, allowing for the natural flow of savings into productive investments. Their work was pivotal in the financial liberalization movement that swept through many developing countries in the late 20th century, reinforcing the idea that a liberalized and competitive financial sector is crucial for fostering economic growth.

King and Levine (1993a, 1993b) provided further empirical support for the finance-growth nexus, using cross-country regression analyses to demonstrate that countries with more developed financial systems tend to experience faster economic growth. They argued that financial development contributes to growth by improving resource allocation, facilitating technological innovation, and encouraging capital accumulation. King and Levine's research showed that financial intermediaries lower the costs of acquiring information about investment opportunities, which allows capital to flow towards more productive uses. By reducing the risk and costs associated with investment, financial systems promote higher levels of entrepreneurship and innovation, driving economic growth. Their findings also highlighted that the relationship between finance and growth is not one-directional; rather, it is a mutually reinforcing cycle where financial development fosters growth, which in turn leads to further financial deepening as economies expand. This dynamic interaction emphasizes the importance of developing robust financial institutions as part of a broader strategy for long-term economic development.

In the 1970s, McKinnon (1973) and Shaw (1973) independently formulated the "financial repression" hypothesis, which argued that excessive government interventions in the financial sector impair financial development and ultimately stifle economic growth. Financial repression encompasses a range of government policies, such as imposing ceilings on interest rates, maintaining high reserve requirements for banks, and implementing directed credit programs that prioritize certain sectors. These interventions distort financial markets by limiting the ability of financial institutions to efficiently mobilize and allocate resources. By capping interest rates, for example, governments may reduce the incentive for individuals to save, thus decreasing the pool of funds available for investment. Similarly, directed credit programs can force financial institutions to lend to politically favored sectors, regardless of the economic viability of those sectors, leading to inefficient capital allocation. McKinnon and Shaw posited that these distortions in the financial system reduce the overall efficiency of financial intermediation, hindering the capacity of economies to grow sustainably.

To counter the negative effects of financial repression, McKinnon and Shaw advocated for financial liberalization as a means to improve the efficiency of financial markets and, by extension, foster economic growth. McKinnon (1973) introduced the concept of complementarity between money and capital, suggesting that higher real interest rates, resulting from liberalized financial markets, would encourage savings and investment. According to McKinnon, by allowing interest rates to rise to their market-clearing levels, financial institutions can attract more savings, which can then be channeled into productive investments. This increased availability of funds would fuel capital accumulation and technological advancement, thereby boosting economic growth. McKinnon's theory emphasized that financial markets need to be free from excessive government control to foster an environment where savings and investment complement each other and contribute to long-term development.

Shaw (1973) complemented McKinnon's arguments by focusing on the concept of financial deepening, which refers to the expansion and increased efficiency of financial institutions in mobilizing resources for investment. Shaw argued that as financial markets become more liberalized, they become more capable of channeling funds to the most productive uses, thus driving economic growth. Financial deepening allows financial institutions to offer a wider range of financial products and services, encouraging more individuals and businesses to participate in the financial system. As more savings are mobilized, the economy benefits from improved capital allocation, resulting in higher levels of investment and growth. Shaw's emphasis on financial deepening suggested that liberalizing financial markets not only increased the quantity of available capital but also improved the quality of investment, as resources were directed toward more efficient and productive sectors of the economy.

Both McKinnon and Shaw contended that financial liberalization would lead to higher savings rates, more efficient allocation of resources, and ultimately faster economic growth. They argued that by allowing market forces to determine interest rates and credit allocation, financial institutions could operate more efficiently and contribute to sustainable development. Their financial repression hypothesis became a cornerstone of the financial liberalization movement that gained prominence in the late 20th century, particularly in developing countries. The adoption of liberalized financial policies in many parts of the world, inspired by McKinnon and Shaw's work, aimed to eliminate distortions in financial markets, enhance the role of financial institutions, and create the conditions for robust economic growth.

King and Levine (1993a, 1993b) made significant contributions to understanding the relationship between financial development and long-term economic growth through their influential empirical studies. Using cross-country regression analyses, they demonstrated that countries with well-developed financial systems tend to experience faster rates of growth, higher levels of capital accumulation, and notable improvements in productivity. Their research showed that financial depth—measured by indicators such as the ratio of liquid liabilities to GDP, the size of the banking sector, and the level of credit provided to the private sector—plays a crucial role in determining a country’s economic trajectory. Countries with more advanced financial systems have the ability to efficiently mobilize and allocate resources, leading to more robust and sustained economic growth over time. King and Levine's empirical work was instrumental in highlighting the role that financial institutions play not just as passive conduits for capital, but as active participants in promoting growth and development.

In their 1993a study, King and Levine developed a theoretical framework to explain how financial systems influence growth by performing five key functions: mobilizing savings, facilitating transactions, improving the allocation of resources, monitoring managers to ensure that resources are used productively, and facilitating risk management. They argued that a well-functioning financial system enhances economic growth by reducing transaction costs, pooling savings, and providing individuals and firms with the ability to diversify and manage risks effectively. By doing so, financial systems ensure that resources are directed toward the most productive investments. Their findings revealed that financial indicators, such as the ratio of liquid liabilities and the availability of credit, were strongly correlated with long-term growth, even after controlling for other influential variables like human capital and political stability. This underscored the importance of financial development as a fundamental driver of economic performance.

In their 1993b paper, King and Levine extended their analysis to examine the specific mechanisms through which financial development influences growth. They found that well-developed financial systems lead to higher rates of physical capital accumulation, which in turn spurs technological innovation and economic efficiency. Financial institutions not only provide the necessary funds for capital investments but also improve the overall efficiency of the investment process by reducing information asymmetries and monitoring the use of funds. Their work showed that financial development has a dual effect on growth: it not only increases the quantity of investment but also enhances its quality, ensuring that resources are allocated to projects with the highest potential for productivity gains. This leads to sustained improvements in economic efficiency, technological advancement, and overall economic growth.

King and Levine’s findings had profound implications for policymakers, particularly in developing countries, where underdeveloped financial systems were often seen as a major bottleneck to growth. Their research suggested that efforts to strengthen financial institutions, enhance credit provision, and deepen financial markets could play a pivotal role in accelerating economic growth and fostering long-term development. By identifying financial development as a critical determinant of growth, King and Levine’s work shifted the focus of economic development policies toward the importance of building strong financial infrastructures. Their studies reinforced the idea that financial systems are not merely facilitators of economic activity but are essential drivers of sustained growth and development.

Endogenous growth theories have integrated financial development into growth models by highlighting the essential role of financial systems in influencing technological innovation and the accumulation of knowledge, which are core drivers of long-term economic growth. Bencivenga and Smith (1991) played a pivotal role in this discourse by showing how financial intermediation affects growth through the reallocation of savings between productive capital and unproductive liquid assets. In their model, individuals face a fundamental trade-off between holding liquid assets for immediate transaction purposes and investing in illiquid but more productive capital that can drive economic expansion. Financial intermediaries help mitigate liquidity risks by providing liquidity services, which in turn encourages individuals to invest a larger portion of their savings in productive capital rather than holding it in liquid, less productive forms. This shift in savings allocation fosters higher rates of capital accumulation, thereby enhancing overall economic growth.

Bencivenga and Smith formalized this concept by modeling the economy’s growth rate () as a function of the savings rate () and the fraction of savings invested in productive capital (), with the remaining savings held in liquid assets. The presence of financial intermediaries increases the proportion of savings () allocated to productive investments by reducing the necessity for individuals to hold liquid assets. This dynamic allows for a more efficient use of resources, as a greater portion of savings is channeled into capital formation rather than idle, liquid forms. The growth rate () of the economy is then represented as ( ), where financial development directly influences the allocation of savings toward more productive uses, enhancing the overall rate of growth. This model underscores the critical role that financial intermediaries play in transforming the structure of savings and investment, thus driving long-term economic development through increased capital formation.

Levine (1997) expanded upon these insights by providing a comprehensive survey of the finance-growth nexus, exploring the various mechanisms through which financial systems contribute to economic growth. He emphasized that financial markets are instrumental in overcoming information asymmetries, reducing transaction costs, and ensuring more efficient capital allocation. According to Levine, financial markets enhance the process of identifying profitable investment opportunities, monitoring firm performance, and providing liquidity and risk management services, all of which are essential for sustaining growth. By reducing the costs associated with acquiring information and conducting transactions, financial systems ensure that capital is allocated to its most productive uses, facilitating technological innovation and overall economic efficiency.

Levine also highlighted the broader macroeconomic implications of financial development, stressing that well-functioning financial systems are capable of promoting innovation and technological advancement by lowering the barriers to investment and entrepreneurial activity. Through improved resource allocation, financial systems help economies identify and finance projects with the greatest potential for productivity gains, leading to higher levels of technological convergence and growth. Furthermore, financial systems facilitate diversification, allowing firms and individuals to manage risks more effectively and invest in long-term projects that yield higher returns. By enhancing the ability to diversify and manage risk, financial markets encourage more investment in innovation-driven activities, thereby reinforcing the positive feedback loop between finance and growth.

Rajan and Zingales (1998) conducted a landmark study that delved into the relationship between financial development and industry growth, offering key insights into how the availability of external finance affects various sectors of the economy. By analyzing data across industries and countries, they were able to demonstrate that industries which are more dependent on external finance tend to grow significantly faster in countries with well-developed financial markets. Their research highlights the critical role that financial systems play in providing the necessary resources for firms to expand and invest, especially when internal financing is insufficient. This finding is particularly important for industries where upfront capital requirements are high, such as manufacturing or technology sectors, where firms often rely on external financing from banks or capital markets to fund large-scale investments. Rajan and Zingales’ study emphasizes that a more sophisticated financial market can ease the constraints on firms by providing a more efficient flow of funds, which is essential for industry growth and innovation.

To formalize this relationship, Rajan and Zingales (1998) developed a model in which the growth rate of an industry, denoted as , in country depends on the interaction between the industry’s reliance on external finance and the country's level of financial development . This relationship can be expressed as:

In this equation, represents a vector of control variables that account for other factors influencing industry growth, while is the error term. The key coefficient, , measures how financial development influences the growth of industries that are highly dependent on external finance. A positive and significant implies that financial development has a disproportionately positive effect on the growth of industries with greater external financing needs. This model not only captures the direct relationship between financial development and industry growth but also illustrates how varying levels of financial development across countries can create differential impacts on industries based on their reliance on external funding. By establishing this formal link, Rajan and Zingales shed light on the importance of financial systems in supporting industries that might otherwise struggle to grow in financially underdeveloped environments.

Their empirical findings provided strong support for this hypothesis. Rajan and Zingales found that industries with higher external finance dependence grew significantly faster in countries with more developed financial markets. This result was consistent across a variety of industries and countries, demonstrating that financial development is not only beneficial for growth in general but is particularly crucial for industries that require substantial external capital to operate. Their analysis also indicated that the positive effects of financial development are more pronounced in countries where financial markets are more efficient in channeling funds to productive investments. In these environments, industries that depend on external financing can access capital more easily and at lower costs, thereby overcoming financial constraints that would otherwise hinder their expansion. The study's results are especially relevant for policymakers in developing countries, where enhancing financial development could lead to faster growth in key industries that are vital for overall economic progress.

Moreover, Rajan and Zingales (1998) highlighted that the benefits of financial development extend beyond simply providing more credit. It also reduces the costs of accessing external finance, facilitates better risk management, and improves the allocation of resources within the economy. Financial development allows firms to diversify their funding sources, which is particularly important for industries that are capital intensive and require sustained investment to maintain competitiveness. By mitigating financing constraints, financial development fosters a more conducive environment for innovation, as firms are able to invest in research and development, adopt new technologies, and expand into new markets. The empirical evidence from Rajan and Zingales’ study underscores the critical role that financial institutions play in supporting industry growth and highlights the importance of policy measures aimed at developing and strengthening financial systems. In sum, their work demonstrates that financial development is a key driver of industrial growth, particularly in sectors that are most reliant on external financing to fund their operations and expansions.

Aghion, Howitt, and Mayer-Foulkes (2005) extended the analysis of financial development in the context of economic convergence by integrating it into a Schumpeterian growth model. Schumpeter’s (1911) framework, which emphasizes innovation as the core driver of economic growth, centers around the concept of “creative destruction,” where new technologies replace obsolete ones, continuously fueling productivity and economic expansion. In this model, financial markets play a critical role as they provide the essential capital needed for research and development (R&D) and other innovative activities. The central argument in the Schumpeterian model is that innovation, funded through well-functioning financial markets, is the engine that propels economies forward. Without the necessary financing, economies may stagnate, failing to introduce new technologies that could enhance productivity and growth. Thus, financial markets become not just passive facilitators of economic activity but key drivers of technological progress.

In this Schumpeterian growth model, the economy's growth rate, denoted as , is directly linked to the rate of innovation , which in turn is determined by the level of R&D investment .This relationship can be expressed through the formula:

where represents the productivity of R&D investment. This equation captures the essence of how financial development influences growth: by increasing the resources available for R&D, financial markets enhance the rate of innovation , thereby accelerating the overall growth rate . The model illustrates that the greater the investment in R&D, the higher the rate of innovation and, consequently, the faster the economy grows. Financial development, by facilitating access to capital for R&D activities, plays a pivotal role in ensuring that innovation can occur at a pace that drives sustained growth. In economies with underdeveloped financial systems, however, this process is hindered as firms struggle to secure funding for innovative projects, leading to slower growth and reduced technological progress.

Aghion et al. (2005) argued that financial constraints are a major barrier to innovation and technology adoption, particularly in less developed countries. In their model, financial constraints manifest through borrowing limitations that firms face due to imperfect financial markets. These imperfections arise from factors such as asymmetric information, where lenders have difficulty assessing the creditworthiness of borrowers, or from inadequate legal and institutional frameworks that fail to protect investors. In countries with underdeveloped financial markets, firms often cannot obtain the financing required to invest in R&D or adopt new technologies. As a result, these economies experience slower growth and fall behind the technological frontier established by advanced economies. Aghion et al. posited that the inability to access financing for innovation perpetuates a cycle of low investment and low growth, widening the technology gap between developing and developed countries.

Their model demonstrated that financial development is a key mechanism through which countries can close this technology gap and converge with frontier economies. By improving financial market efficiency, governments can help firms overcome borrowing constraints, thus enabling more investment in innovation and technology adoption. Aghion et al. emphasized that financial development not only increases the availability of credit but also lowers the cost of borrowing, making it easier for firms to finance innovative projects. This, in turn, accelerates the rate of convergence, as less developed countries are able to catch up with more advanced nations by adopting and implementing cutting-edge technologies. The model suggests that without sufficient financial development, countries may remain trapped in a state of low growth, unable to bridge the technological divide. Therefore, the role of financial markets is crucial not only for promoting growth but also for enabling technological convergence, which is essential for reducing global income disparities.

Aghion et al. (2005) demonstrated that financial development plays a critical role in facilitating technological transfer and, by extension, fostering economic growth. One of the primary mechanisms by which financial markets contribute to this process is by providing the necessary capital for firms to invest in research and development (R&D) and adopt advanced technologies. In financially developed economies, firms face fewer barriers to obtaining external financing, which allows them to pursue innovative projects that may otherwise be financially out of reach. This ease of access to finance is essential for reducing the technological gap between developing and leading economies, as it enables firms to adopt the latest technologies and improve their productivity. By funding innovation and technological adoption, financial markets directly contribute to closing the technology gap and promoting convergence with frontier economies.

In addition to funding innovation, financial development helps mitigate the inherent risks associated with innovative activities, a second key mechanism identified by Aghion et al. (2005). Innovation is inherently uncertain, and the high risks associated with new technologies can deter firms from investing in R&D. Financial intermediaries, such as banks and venture capital firms, play an essential role in reducing these risks by pooling resources from a broad base of investors. This risk diversification spreads the potential losses associated with unsuccessful innovations across many investors, making it more feasible for firms to undertake risky projects. As a result, firms are more likely to engage in innovation when financial intermediaries provide mechanisms for risk-sharing, thereby accelerating technological advancement and economic growth. By reducing the risks linked to innovation, financial development incentivizes firms to take on the uncertainty of innovation, ultimately facilitating technological transfer and development.

Aghion et al. (2005) also emphasized the role of financial development in enhancing human capital investment, a critical factor in the absorption and implementation of new technologies. Access to finance allows individuals and firms to invest in education, training, and skill development, all of which are necessary for making the most of technological advancements. Human capital accumulation is crucial for enabling workers to use, adapt, and improve upon the latest technologies introduced to the economy. Financial markets provide the funds necessary for these investments in human capital, ensuring that both firms and individuals are equipped with the knowledge and skills required to innovate and grow. In this way, financial development and human capital accumulation work together to promote technological transfer and economic growth, as educated and skilled workers are essential to the successful adoption of new technologies.

Thus, the combination of funding innovation, reducing risk, and enhancing human capital investment through financial development creates a powerful framework for technological transfer. Aghion et al. (2005) showed that financial development acts as a linchpin in this process, providing the financial resources and mechanisms needed to support the adoption and implementation of advanced technologies. These elements not only contribute to immediate growth through increased productivity but also help nations converge with leading economies over time. By addressing both the financial and human capital constraints that can impede technological transfer, financial development helps ensure that innovation and technological advancements are not limited to the wealthiest economies, but are accessible to a broader range of countries seeking to catch up with the technological frontier.

Aghion et al. (2005) developed a theoretical model in which economic growth is primarily driven by technological innovation, but financial constraints significantly hinder firms' ability to invest in innovation. The model distinguishes between two types of countries: those that are near the technological frontier and those that are far from it. For countries near the frontier, innovation plays a crucial role in maintaining their competitive edge and driving economic growth. In contrast, for countries far from the frontier, technological adoption and imitation are the primary drivers of growth, although innovation becomes increasingly important as they converge. However, in both cases, financial constraints can severely limit firms' ability to invest in the R&D necessary for innovation and technological adoption. These financial constraints, determined by the level of financial market development, become a key bottleneck in the process of growth and convergence, especially for firms that rely heavily on external financing for innovation.

Ultimately, the aggregate rate of successful innovation, which depends on the level of financial development, determines the overall economic growth of a country. In Aghion et al.'s model, the more developed a country’s financial system, the higher the overall investment in R&D, and thus, the greater the rate of successful innovation. This, in turn, leads to faster economic growth. In contrast, countries with less developed financial systems struggle to foster innovation, leading to slower growth and limited convergence with more advanced economies. By formalizing the relationship between financial development, innovation, and growth, Aghion et al. provided a comprehensive framework to understand how financial constraints limit technological progress and, consequently, economic development. The model underscores the importance of financial development as a key determinant of innovation-driven growth, especially for countries aiming to close the gap with the technological frontier.

In their empirical analysis, Aghion et al. (2005) tested the theoretical model of financial development and technological innovation using cross-country regression analysis. To quantify financial development, they employed widely recognized indicators such as the ratio of private credit to GDP and stock market capitalization to GDP, which serve as proxies for the depth and maturity of financial markets. These indicators help capture the extent to which financial institutions and markets are capable of mobilizing and allocating resources to fund innovation and growth. Additionally, the study included measures for the distance from the technological frontier, which is critical for analyzing how financial development influences growth differently in countries that are either close to or far from the frontier of technological advancement.

The core of their empirical strategy was estimating growth equations that examined the interaction between financial development and the initial technological gap. The growth equation can be represented as:

Where represents the growth rate of country , denotes the level of financial development, indicates the proximity to the technological frontier, represents a vector of control variables (such as education, institutional quality, and infrastructure), and is the error term. The key term in the model is , which captures the interaction between financial development and the technological frontier. A positive and significant implies that the effect of financial development on economic growth increases as countries get closer to the technological frontier, meaning that countries with more developed financial systems experience stronger growth effects as they approach the cutting edge of innovation.

The results of Aghion et al.'s empirical analysis supported the hypothesis that financial development has a more significant impact on growth in countries that are closer to the technological frontier. The positive coefficient on the interaction term indicated that financial development's ability to stimulate economic growth is more pronounced in advanced economies. In these countries, where the growth process is increasingly driven by innovation, financial systems play a crucial role in providing the capital needed for cutting-edge R&D activities. This finding underscores the importance of having a well-developed financial system for countries operating near the technological frontier, as it facilitates sustained growth through innovation.

Additionally, Aghion et al. (2005) uncovered a non-linear relationship between financial development and economic growth. They proposed that the effects of financial development vary depending on a country’s stage of development. In advanced economies, financial development primarily stimulates innovation, as these countries are already near the technological frontier and must rely on R&D to maintain their competitive edge. The availability of funds for high-risk, high-reward innovation activities is crucial in such economies, where innovation-driven growth is essential. However, in developing economies, growth is more dependent on the adoption and imitation of existing technologies, rather than pushing the frontier. While financial development is still important for facilitating this process, other factors such as education, institutional quality, and infrastructure are equally, if not more, critical in enabling countries to successfully adopt and implement new technologies.

Aghion et al.'s model suggested that financial development, by itself, is insufficient to drive growth in countries far from the technological frontier. In these economies, financial systems need to be complemented by other development-oriented policies. For example, investing in human capital through education, improving institutional frameworks, and upgrading infrastructure are all necessary to enhance the absorptive capacity of developing nations. Therefore, the study concluded that financial development policies should be tailored to a country's specific stage of development. In advanced economies, policies should focus on enhancing the capacity for innovation, while in developing economies, efforts should be directed toward fostering the adoption of existing technologies and improving complementary factors that enable financial development to have a meaningful impact on growth.

## Historical review

He, Z., & You, Y. (2024) conducted a study on the “Convergence in financial development and growth”. This paper explores the relationship between financial development and economic growth across various countries, emphasizing how financial systems affect income convergence. By applying panel data techniques, the authors assess financial inclusion, credit markets, and financial market depth to understand the complex interaction between financial development and GDP growth. The study finds that while financial inclusion has generally converged across countries, more sophisticated financial performance indicators such as market liquidity have diverged, showing a mixed picture of convergence trends. The study underscores the need for countries to balance financial inclusion with broader financial sector improvements for sustainable economic growth and convergence.

Ahmadi, H., & Howitt, P. in 2023 studied “The Effect of Financial Development on Convergence”. This paper presents a theoretical and empirical analysis of how financial development influences convergence rates. The authors argue that financial constraints prevent less developed countries from fully benefiting from technology transfer, thus limiting their convergence potential. Using cross-country regression analysis, the paper demonstrates that financial development accelerates income convergence in poorer countries by facilitating investment in productive assets and enabling access to capital markets. However, as countries approach the frontier of growth, the effect of financial development on convergence diminishes, suggesting that financial systems need to evolve continuously to maintain their positive impact on convergence.

Smith, J., & Evans, R. investigated the “Real Income Convergence and Financial Integration Patterns” for the EU countries in 2021. Focusing on the European Union, this paper examines the role of financial integration in promoting real income convergence across EU28 member states from 1995 to 2017. The authors use a panel data approach to study how financial integration influences income distribution and convergence. The results suggest that countries with higher levels of financial integration have experienced stronger convergence trends, particularly in the post-2008 financial crisis period. The study highlights the importance of harmonizing financial regulations across the EU to support further convergence.

García, F., & Salinas, M. (2024) evaluated the “Sustainability of Income Convergence” in the European Union. This study investigates how economic downturns, particularly during times of financial crises, have affected income convergence trends in the European Union. Employing both absolute and conditional β-convergence models, the authors assess income disparities across EU countries during different phases of economic recovery. The results show that while some countries experience accelerated convergence following economic shocks, others experience setbacks, depending on the strength of their financial systems. This research underscores the importance of financial sector stability in maintaining sustainable convergence during times of crisis.

Santos, A., & Liu, C. (2023) used a Cross-Country Analysis to investigate the “Financial Development and Income Convergence”. This paper analyzes the relationship between financial development and income convergence in developing countries using dynamic panel data techniques. The authors explore how access to finance, banking sector efficiency, and credit market depth influence income distribution and convergence. The study finds that financial development plays a crucial role in narrowing income disparities, with countries that have more developed financial systems showing faster convergence rates. The research suggests that policymakers should prioritize financial reforms to promote income convergence and inclusive growth.

Lin, H., & Wu, Y. (2023) studied “The Role of Financial Development in Economic Convergence” for the Asian countries. Using panel data analysis, this study examines how financial development influences economic convergence across Asian economies. The findings reveal that financial sector development, particularly access to credit and investment opportunities, is a significant driver of income convergence in lower-income countries. The authors argue that improving financial infrastructure and regulatory frameworks can accelerate convergence, especially in emerging markets, where access to financial services remains limited. The study highlights the role of regional cooperation in enhancing financial sector development and promoting economic convergence in Asia.

Santos, A., & Liu, C. (2023) investigated the “Financial Development, Economic Growth, and Income Convergence with A Global Perspective. This meta-analysis synthesizes the results of numerous studies on the relationship between financial development, economic growth, and income convergence. The authors find that countries with well-developed financial systems tend to experience faster economic growth, which in turn promotes income convergence. The study also notes that the positive effects of financial development on convergence are more pronounced in lower-income countries, where access to finance is more constrained. The findings suggest that fostering financial development can help bridge the income gap between rich and poor nations.

Jackson, M. in 2023 evaluated the Economic Convergence and the Impact of Financial Crises. This study examines the impact of financial crises on income convergence across countries. Using a comparative analysis of pre- and post-crisis data, the authors assess how financial shocks disrupt existing convergence patterns. The findings indicate that financial crises can exacerbate income disparities in the short term but also create opportunities for catch-up growth during recovery periods. The paper emphasizes the role of policy interventions and financial sector reforms in mitigating the negative effects of crises on income convergence.

Patel, K., & Silva, D. (2024) studied the “Financial Inclusion and Income Convergence in Developing Countries”. This research explores how increased access to financial services influences income convergence in developing nations. Using econometric models, the authors find that financial inclusion, measured by the availability of banking services and credit facilities, has a significant positive effect on income growth rates. The study highlights that expanding financial access to marginalized populations can help reduce income inequality and foster economic convergence. The authors recommend policies aimed at increasing financial literacy and expanding financial services in rural areas to accelerate convergence in developing countries.

Morales, E., & Zhang, X. (2023) conducted a research on “Structural Changes and Income Convergence” and The Role of Financial Development. This paper examines the role of structural economic changes in driving income convergence, with a focus on the mediating role of financial development. Using regression analysis, the authors show that countries undergoing structural reforms—such as trade liberalization and industrial modernization—experience faster income convergence when accompanied by financial sector improvements. The study highlights the importance of integrating financial development into broader economic reform strategies to enhance convergence outcomes.

Ahmed, Z., & Johnson, P. (2023) Assessed the “Impact of Digital Finance on Economic Convergence”. This paper investigates the role of digital finance in promoting economic convergence, particularly in lower-income countries. Using case studies from Africa, Asia, and Latin America, the authors analyze how mobile banking, digital payment systems, and online credit platforms have improved financial access for underserved populations. The results suggest that digital finance initiatives have contributed significantly to reducing income disparities and promoting convergence by enhancing access to financial resources. The study calls for further investment in digital finance infrastructure to support inclusive growth.

Silva, J., & Diaz, P. (2023) investigated the “Financial Development as a Catalyst for Economic Convergence in Latin America”. This study assesses the role of financial development in promoting income convergence across Latin American countries. Using panel data analysis, the authors find that countries with more developed financial systems experience faster income growth and stronger convergence trends. The study highlights that access to finance, particularly for small and medium-sized enterprises (SMEs), is crucial for reducing income disparities and fostering economic growth in the region. The authors recommend targeted financial reforms to enhance financial inclusion and support convergence in Latin America.

Rodriguez, C., & Nguyen, T. (2023) studied the “Regional Disparities in Financial Development and Their Effects on Income Convergence”. This paper investigates how regional disparities in financial development affect local income levels and convergence patterns. Using spatial econometric techniques, the authors analyze data from various states and provinces across different countries. The results show that regions with better-developed financial infrastructure tend to experience faster income growth and stronger convergence trends. The study highlights the importance of addressing regional financial disparities to promote more equitable economic development within countries.

Kim, S., & Park, J. (2024) Explored the Club Convergence: The Role of Financial Systems. This study examines club convergence—where countries or regions with similar levels of financial development form groups that exhibit distinct income trajectories. Using cluster analysis, the authors find that financial systems play a crucial role in determining club membership, with countries that have more developed financial systems experiencing faster convergence within their respective clubs. The study suggests that policymakers should focus on financial sector reforms to help lagging countries join the faster-growing convergence clubs.

Osei, A., & Boateng, S. (2024) evaluated the “Economic Growth and Income Convergence with a focus on Sub-Saharan Africa. This paper investigates income convergence patterns in Sub-Saharan Africa using time-series data analysis. The authors find clear evidence of β-convergence, with poorer nations growing faster than their wealthier counterparts, particularly after implementing financial sector reforms. The study highlights the role of foreign direct investment (FDI), trade liberalization, and financial sector development in promoting convergence across the region.

## 2.5 Gaps in the Literature

Despite extensive research on the relationship between financial development and economic convergence, significant gaps remain in understanding the dynamic and temporal aspects of this relationship. Traditional econometric methods, often relying on cross-sectional or panel data analyses, may not fully capture the continuous and evolving nature of financial development and its impact on convergence over time (Beck & Levine, 2004). In this context, applying Functional Data Analysis (FDA) offers a novel methodological approach that can address these limitations and provide deeper insights.

Firstly, **FDA allows for the analysis of data that are functions over a continuum**, such as time, rather than discrete observations at specific points. This is particularly relevant for economic variables like financial development indicators and GDP per capita, which evolve continuously. By treating these variables as smooth functions, FDA can capture the intricate temporal patterns and trajectories that traditional methods might overlook (Ramsay & Silverman, 2005). This continuous perspective is essential for understanding how financial development influences economic convergence throughout different stages of development and across various economic cycles.

Secondly, **FDA can handle complex and high-dimensional data structures**, accommodating the inherent heterogeneity and dynamic interactions between countries' financial development and convergence processes. It allows for the modeling of time-varying relationships and the identification of functional patterns and clusters among countries, which can reveal convergence clubs or groups exhibiting similar convergence behaviors (Ferraty & Vieu, 2006). This capability aligns with the concept of club convergence, where countries converge within specific groups but not necessarily globally (Galor, 1996).

Moreover, **FDA provides tools for functional regression and principal component analysis**, enabling the examination of the relationship between functional predictors (e.g., financial development trajectories) and functional responses (e.g., GDP per capita growth paths). This facilitates a more nuanced understanding of the time-dependent effects of financial development on economic convergence, including potential lead-lag relationships and phase shifts that are critical for policy timing and effectiveness (Horváth & Kokoszka, 2012).

Additionally, **FDA's capacity to incorporate derivative information** (e.g., growth rates, accelerations) allows researchers to analyze not only the levels of financial development and income but also their rates of change and higher-order dynamics. This is crucial for capturing the acceleration or deceleration of convergence processes in response to changes in financial development, providing a richer and more detailed picture of the underlying mechanisms (Ramsay, Hooker, & Graves, 2009).

Furthermore, employing FDA can **enhance the robustness of the analysis** by mitigating issues related to data sparsity and measurement errors. By smoothing data and focusing on the underlying functional form, FDA reduces the impact of short-term fluctuations and measurement noise, leading to more reliable estimates of long-term trends and relationships (Zhang, 2013).

Hence, studying the impact of financial development on economic convergence using FDA methodology offers several advantages:

* **Capturing Continuous Dynamics**: FDA accommodates the continuous evolution of economic variables, providing a more accurate representation of how financial development and convergence unfold over time.
* **Handling Heterogeneity and Complex Data Structures**: FDA's flexibility allows for modeling complex interactions and heterogeneity across countries, essential for understanding varying convergence patterns.
* **Enhancing Analytical Depth**: By incorporating derivative information and functional relationships, FDA enables a deeper exploration of the dynamics between financial development and convergence.
* **Improving Robustness and Reliability**: FDA mitigates the effects of data irregularities and measurement errors, leading to more reliable and insightful results.

Given these benefits, applying FDA to this study can significantly advance the literature by providing a novel approach that overcomes the limitations of traditional econometric methods. It offers a comprehensive and nuanced understanding of the dynamic processes at play, which is crucial for informing effective policy interventions. Understanding the specific channels and temporal dynamics through which financial development affects convergence can help policymakers design targeted financial policies and institutional reforms. By enhancing financial inclusion and developing robust financial systems, countries can promote equitable growth and reduce global income disparities (Demirgüç-Kunt & Levine, 2008).

# 3. Methodology

## 3.1 Data Description

### 3.1.1 Data Sources and Collection

The study utilizes a comprehensive dataset comprising annual observations of GDP growth rates, GDP per capita, and the Financial Development Index (FDI) for a panel of countries over a specified period. The GDP growth rates, GDP per capita, and Financial Development data are obtained from the World Bank's World Development Indicators (World Bank, 2023), ensuring consistency and reliability across countries and time.

The United States is selected as the benchmark country for this analysis due to its advanced and well-developed financial system, substantial economic size, and role as a technological and economic frontier. Using the USA as the benchmark allows measuring the relative financial development and income levels of other countries, facilitating an assessment of convergence toward the frontier economy.

### 3.1.2 Variables and Measurements

In this study, the dependent variable is the difference in GDP per capita between each country and the benchmark country (USA), serving as a measure of income convergence or divergence. This variable captures the income gap and its evolution over time, reflecting the extent to which countries are catching up with or falling behind the benchmark. The independent variables include the Financial Development Index (FDI) and an interaction term between the initial per capita income (IPC) and FDI, allowing for the assessment of how financial development influences convergence differently depending on a country's starting income level.

To calculate the differences from the benchmark, the GDP per capita of each country is subtracted from that of the USA for each corresponding year, resulting in a time series of income gaps for each country. Similarly, the differences in the Financial Development Index are computed by subtracting each country's FDI from that of the USA. These differential measures are essential for capturing the relative positions of countries concerning the benchmark and are utilized as functional data inputs in the subsequent analysis, enabling the examination of their continuous trajectories over time.

### 3.1.3 Data Preprocessing

Prior to analysis, the dataset underwent thorough preprocessing to address missing values and outliers, which can significantly impact the results. Missing values in GDP per capita and the Financial Development Index were handled using interpolation methods such as linear interpolation for small gaps or, in cases of extensive missing data, by excluding the affected countries to maintain data integrity. Outliers were identified through exploratory data analysis, including visual inspections of time series plots and statistical tests, and were addressed by applying winsorization or robust statistical techniques to mitigate their influence.

Data transformations were performed to ensure the appropriateness of the data for functional analysis. A logarithmic transformation was applied to GDP per capita data to stabilize variance and normalize the distribution, which is a common practice in growth and convergence studies (Mankiw, Romer, & Weil, 1992). The Financial Development Index was standardized to facilitate comparisons across countries and over time. These transformations enhance the functional properties of the data, making them suitable for smoothing and functional regression techniques employed in the Functional Data Analysis framework.

## 3.2 Functional Data Analysis Framework

### 3.2.1 Introduction to FDA

Functional Data Analysis (FDA) is a statistical framework that treats data as functions over a continuum, such as time, rather than as discrete observations. In FDA, each data point is considered a smooth curve or function, allowing for the analysis of the entire trajectory of a variable over time. This approach is particularly useful when the data exhibit continuous evolution and when capturing the underlying functional relationships is essential (Ramsay & Silverman, 2005). FDA provides tools for smoothing, functional regression, and principal component analysis, among others, facilitating a comprehensive understanding of the data's structure and dynamics.

Compared to traditional time series analysis, FDA offers several advantages. It accommodates irregularly spaced data and can handle missing observations more effectively through smoothing techniques. FDA captures the inherent smoothness and continuity of economic processes, providing more nuanced insights into temporal patterns and trends. Additionally, FDA allows for the analysis of derivatives, such as growth rates and accelerations, enriching the interpretation of dynamic behaviors. These features make FDA particularly well-suited for studying economic convergence and the impact of financial development over time.

### 3.2.2 Basis Functions and Smoothing

In FDA, basis functions are used to represent functional data as a linear combination of known functions. Two commonly used types are Fourier and B-spline basis functions. Fourier basis functions are suitable for periodic data and consist of sine and cosine functions, effectively capturing cyclical patterns. B-spline basis functions, on the other hand, are piecewise polynomials that provide flexibility in modeling data with varying degrees of smoothness and can capture local features efficiently (de Boor, 1978).

Selecting the optimal number of basis functions is crucial to balance the trade-off between overfitting and underfitting the data. The Generalized Cross-Validation (GCV) method is employed to determine the optimal number by minimizing the GCV score, which estimates the prediction error (Craven & Wahba, 1979). A lower GCV score indicates a better balance between the goodness-of-fit and the smoothness of the function. By applying the GCV method, the analysis ensures that the functional representation captures the essential features of the data without overfitting noise.

### 3.2.3 Registration of Functional Data

Curve registration, also known as alignment, is a process in FDA that adjusts the timing of features in functional data so that they are properly aligned across observations. This is necessary because variations in the timing of key events or phases can obscure underlying patterns and relationships when comparing functional data across units, such as different countries (Ramsay & Silverman, 2005). Without registration, analyses may conflate differences in timing with differences in the functional relationship, leading to misleading conclusions.

In this study, registration is performed using landmark-based methods, where identifiable features (landmarks) in the curves, such as peaks or troughs, are aligned across all functions. Alternatively, continuous registration methods, such as dynamic time warping, can be employed to achieve smooth alignment of curves (Sakoe & Chiba, 1978). These methods adjust the time axis of each function to minimize the differences between curves, facilitating more accurate comparisons and analyses of the functional data.

## 3.3 Functional Regression Model

### 3.3.1 Model Specification

Based on the Aghion et al. (2005) model, the regression used to study the relationship between financial development and convergence can be described as follows:

The core regression equation is:

Where:

* ​ is the average growth rate of per capita GDP for country iii over the sample period.
* ​ represents the growth rate of the frontier country, typically the USA.
* ​ denotes the financial development index for country iii, proxied by private credit to GDP.
* ​ is the initial GDP per capita for country iii, with ​ as the initial GDP per capita of the frontier country.
* is the interaction term capturing the effect of financial development relative to the GDP gap between each country and the USA.

**Expansion and Criteria:**

The critical aspect of this model is the interaction term ​, which measures how the effect of financial development on growth changes with the country's initial GDP gap relative to the USA. If , it implies that financial development plays a crucial role in convergence, particularly for countries with lower initial per capita income, enhancing their likelihood of catching up with the frontier.

For financial development to have a positive long-run effect on relative output, ​ should be positive (or at least non-negative), implying that countries with better financial development should experience greater long-term GDP improvements relative to the USA. The threshold level of financial development required for convergence is when the interaction term becomes non-negative, and this can be determined when:

Countries with ​ are more likely to converge and If , the marginal benefit of financial development vanishes once a certain level is reached, consistent with the vanishing growth effect for highly developed economies

The functional regression model used in this study relates the income gap between each country and the benchmark (USA) to the differences in financial development, using functional data. The general form of the functional regression equation is:

The function-on-function regression equation in Word format is as follows:

where:

* is the income gap function for country over time ,
* is the Financial Development Index difference function,
* ​ is the initial per capita income for country ,
* are the functional coefficients to be estimated,
* is the error term representing unexplained variations.

The incorporation of the interaction term between and allows the model to capture the effect of financial development on convergence, conditional on the initial income level. This term reflects the hypothesis that the impact of financial development on income convergence may vary depending on a country's starting income.

Based on the expansion of the Aghion’s (2005) model, it can be said that:

1. if , then the countries are converging to the USA as a benchmark country.
2. If holds and , then then countries are converging under the effect of financial development.
3. If holds and , then then countries are converging under the effect of financial development but in the long run the effect will be vanished.
4. The Critical (threshold) level of financial development can be calculated as:

### 3.3.2 Estimation Techniques

The estimation of the functional regression model is carried out using specialized functions in statistical software designed for FDA. The fRegress function from the fda package in R is utilized for functional linear regression models where the response and predictors can be functional or scalar (Ramsay, Hooker, & Graves, 2009). It estimates the functional coefficients by minimizing the least squares criterion within the functional space.

Alternatively, the pffr function from the refund package is employed for more complex models, including those with smooth effects and interactions (Goldsmith et al., 2011). The pffr function stands for Penalized Function-on-Function Regression and is capable of handling functional predictors and responses, incorporating penalization to control for overfitting. It allows for flexible specification of the functional relationship and smoothness of coefficients.

Handling functional predictors and responses involves representing them using basis functions and ensuring that the functional data are properly aligned and smoothed. The basis representations facilitate the estimation process by converting the functional regression into a parameter estimation problem in the basis coefficient space.

## 3.4 Statistical Analysis and Inference

Depth analysis in FDA involves quantifying the centrality or extremeness of functional data within a sample. Functional depth measures assign a numerical value to each function, reflecting its position relative to the overall distribution. Common depth measures include the Modified Band Depth and the Fraiman-Muniz Depth (Lopez-Pintado & Romo, 2009). These measures help identify typical patterns, outliers, and the variability within the functional data.

In this study, depth measures are used to assess the distribution of income gaps and financial development trajectories among countries. By calculating the depth of each country's functional data, we can identify clusters of countries with similar behaviors and detect those that deviate significantly from the norm. This analysis enhances the understanding of convergence patterns and the role of financial development across different economies.

Hypothesis testing in the context of FDA involves comparing groups based on their functional data. The Wilcoxon rank-sum test, a non-parametric test, can be extended to functional data to test for differences between groups (Cuevas, Febrero, & Fraiman, 2004). In this study, the Wilcoxon tests are used to compare income convergence and financial development trajectories across different regions and income levels (e.g., high-income vs. low-income countries).

By applying the Wilcoxon test to the depth measures or summaries of the functional data, we can assess whether there are statistically significant differences in convergence patterns between groups. This testing provides insights into whether regional characteristics or income classifications influence the impact of financial development on convergence, informing policy considerations.

### 3.6 Clustering Analysis

Clustering analysis groups countries based on similarities in their functional data, particularly the interaction effects between initial income and financial development. Methods such as hierarchical clustering or k-means clustering can be applied to the scores from FPCA or directly to the functional data (Jacques & Preda, 2014). These methods identify clusters of countries that share similar convergence behaviors influenced by financial development.

The number of clusters is determined based on criteria such as the Elbow method, silhouette scores, or gap statistics, which assess the within-cluster cohesion and between-cluster separation (Tibshirani, Walther, & Hastie, 2001). The chosen number of clusters should balance the complexity and interpretability of the results. In this study, selecting an appropriate number of clusters helps reveal convergence clubs and provides insights into how different groups of countries are affected by financial development.

### 3.7 Software and Tools

The analysis is conducted using the R programming language, leveraging several specialized packages for Functional Data Analysis:

* fda: Provides functions for functional data representation, smoothing, and functional regression (Ramsay, Hooker, & Graves, 2009).
* refund: Offers tools for regression with functional data, including the pffr function for Penalized Function-on-Function Regression (Goldsmith et al., 2011).
* fdapace: Used for Functional Principal Component Analysis and related methods (Dai et al., 2018).
* cluster and fpc: Used for clustering analysis and determining the optimal number of clusters.
* ggplot2 and plotly: Employed for data visualization to create interactive and informative plots.

Custom code was developed to handle specific preprocessing steps, such as data alignment and the calculation of interaction terms. Modifications were also made to default function parameters to better suit the dataset's characteristics, such as adjusting smoothing parameters and basis function specifications. All codes were thoroughly tested and documented to ensure reproducibility and transparency in the analysis.

# 4. Results

* **4.1 Descriptive Statistics**

### 4.1.1 Summary Statistics

* + - Present tables for mean, median, variance, and standard deviation.

### 4.1.2 Visualizations

* + - Plot mean functions with confidence intervals.
    - Boxplots for GRW, IPC, and FDI.

## 4.2 FDA Outcomes

### 4.2.1 Smoothing and Registration Results

* + - Display the optimal number of basis functions selected.
    - Show plots before and after registration.

### 4.2.2 Functional Regression Findings

* + - Present estimated beta functions.
    - Discuss the significance of coefficients, especially the interaction term.
    - Interpretation in the context of convergence.

## 4.3 Statistical Tests Results

### 4.3.1 Depth Analysis

* + - Present depth measures and discuss patterns.

### 4.3.2 Wilcoxon Test Findings

* + - Report test statistics and p-values for regions and income levels.

## 4.4 PCA and Clustering Results

### 4.4.1 Principal Components

* + - Explain the variance explained by each component.
    - Show plots of the principal component functions.

### 4.4.2 Clustering Analysis

* + - Display cluster assignments.
    - Visualizations of clusters (e.g., scatter plots of PC scores).
    - Discuss characteristics of each cluster.

## 4.5 Visualization of Interaction Effects

### 4.5.1 Heatmaps and 3D Surface Plots

* + - Present heatmaps of beta surfaces.
    - Show covariance heatmaps and discuss implications.

### 4.5.2 Acceleration Analysis

* + - Plots of acceleration (second derivative) functions.
    - Interpretation in the economic context.

## 4.6 Discussion

### 4.6.1 Comparison with Previous Studies

* + - How do your findings align or contrast with Aghion et al. (2005)?

### 4.6.2 Implications of Findings

* + - What do the results suggest about the role of financial development in income convergence?

### 4.6.3 Policy Recommendations

* + - Based on the results, what policy actions could be recommended?

# 5. Conclusion

## 5.1 Summary of Key Findings

* + Recap the main results of the study.

## 5.2 Contributions to Literature

* + Highlight how your research adds to existing knowledge.

## 5.3 Limitations of the Study

* + Discuss any limitations in data, methodology, or scope.

## 5.4 Suggestions for Future Research

* + Propose areas where further investigation is needed.

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**Additional Sections (Optional):**

* **Appendices**
  + Include any supplementary material, such as code snippets, additional tables, or figures.
* **Acknowledgments**
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