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**-RESEARCH ARTICLE-**

# ECONOMIC DYNAMICS IN THE DIGITAL AGE: A PANEL ANALYSIS OF FINTECH AND ECONOMIC GROWTH ON G20 COUNTRIES

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**─Abstract─**

In an era marked by the transformative impact of financial technology (FinTech) in the world, this study aims to analyze the implications of FinTech on economic growth within specific G20 nations such as Brazil, China, Germany, France, India, and Indonesia. Employing a robust framework encompassing panel unit root test and the Autoregressive Distributed Lag (ARDL) approach within a Panel Mean Group (PMG) framework, the analysis spans the years 2005 to 2020. The long-run PMG estimates reveal the significant impact of FinTech adoption on economic growth. Additionally, the study identifies substantial impacts of financial efficiency, development, R&D expenditure, energy consumption, population size, and capital accumulation on

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economic growth. Furthermore, our findings indicate that all economies demonstrate a prompt adjustment toward long-term equilibrium following a shock, displaying varied adjustment speeds dependent on their maturity and resilience. This research extends the existing literature by providing context-specific insights into the impact of financial and non-financial factors on economic growth in diverse G20 economies. The findings of the study suggest that governments should encourage and support the adoption of FinTech to leverage its positive impact on economic growth. Policies that facilitate FinTech innovation, collaboration, and investment can contribute to enhanced financial efficiency and development.

**Keywords**: Economic Growth; Financial Development, Financial Efficiency, FinTech, G20 Economies.

## INTRODUCTION

Financial technology (FinTech) represents the convergence of financial services and information technology which embodies various components such as payment and settlement systems, risk management, networking channels, and resource allocation functions (Arner et al., 2020; Gomber et al., 2018; Haddad & Hornuf, 2019). The significant expansion of Fintech within the financial industry is attributed to the rapid growth of the internet, information technology, mobile phones, and digital technologies (Zaheer, 2022). The flow of these innovative financial solutions reached an estimated USD 223 billion in 2019 (Alattass, 2023; Cornelli et al., 2020). Particularly, the prominent role played by China, the United States, and the United Kingdom, which stand out as the largest markets for FinTech. It is characterized by platforms like peer-to-peer lending, cryptocurrencies, and mobile payments, has brought revolutionary changes to the financial industry, particularly in enhancing financial inclusion for marginalized groups and small businesses.

Recent studies showed a positive significant role of FinTech in economic growth (Alfaro, Kalemli-Ozcan, & Sayek, 2009; Demir et al., 2022; Song & Appiah-Otoo, 2022; Sudrajad et al., 2023). Investments in telecommunication infrastructure and the transformative potential of FinTech contribute to new business models and job creation (Barth et al., 2019; Matalqah & Warad, 2017). The global recognition of FinTech's role in achieving financial inclusivity and its impact on a nation's income highlights its growing importance (Antonijević, Ljumović, & Lukić, 2021; Demirgüç-Kunt et al., 2022; World Bank, n.d.-b).

Harnessing state-of-the-art technological innovations, FinTech has not merely garnered widespread interest from individuals and businesses worldwide, but it has also ignited pivotal discussions among international leaders. This phenomenon bears considerable significance for G20 economies. This group of countries includes economic giants that actively endorse and nurture the growth of FinTech, positioning themselves as leaders

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in harnessing its transformative potential. The collective GDP share of these nations is over 80% of the world's GDP (Yao, Feng, & Hubacek, 2015). The economic dynamics and contributions of these key members within the G20 framework amplify the impact and implications of the observed trend on a global scale. The upsurge of FinTech in these countries poses both opportunities and challenges, shaping discussions around regulatory frameworks, cross-border collaborations, and the potential impact on traditional financial systems.

The increasing investment and usage of FinTech prompts crucial questions regarding its contribution to economic growth. Within the context of selected G20 countries, this study seeks to address pertinent questions such as (1) to what extent does FinTech contribute to economic growth? (2) what role does financial efficiency play in economic growth? and (3) how does financial development impact economic growth?

The global financial system shaped by factors such as economic development and regulatory frameworks, sees developed nations with sophisticated financial systems while smaller economies aim to provide basic financial services. The concept of financial inclusion, ensuring access for traditionally excluded individuals and businesses, is vital for economic growth, particularly in underdeveloped nations (Kim, Yu, & Hassan, 2018; Sang, 2023; Van et al., 2021). This research highlights the role of financial inclusion in advocating for comprehensive financial development, as it not only boosts accessibility and efficiency but also contributes significantly to economic growth.

Despite the critical link between FinTech, financial development, and economic growth, there remains a notable gap in research in this area, emphasizing the need for further investigation. The prior studies such as those conducted by Beck & Demirguc-Kunt (2006) and King & Levine (1993) consistently highlight a positive relationship between economic growth and well-developed financial sectors. This suggests that FinTech can act as a potent catalyst for fostering economic progress in nations with advanced financial infrastructures. In contrast, less developed countries may benefit more from focusing on enhancing financial infrastructure, promoting financial literacy, and implementing stricter regulations to play more substantial roles in driving development. To assess the influence of financial technology on economic growth, the first step entails a thorough developmental evaluation, investigating the correlation and direction of financial development in relation to the growth of GDP. These variables, including financial efficiency, financial development, R&D expenditure, energy consumption, population size, and capital accumulation, are deemed essential for analysis.

The objectives of the study are structured to provide a thorough investigation into the impact of FinTech on economic growth within the selected G20 countries. By dissecting the various dimensions of the FinTech-GDP nexus and considering temporal dynamics,

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this study endeavors to offer valuable insights for policymakers, financial institutions, and stakeholders. By analyzing historical data and employing robust econometric models, this study aims to discern the extent to which FinTech advancements contribute to overall economic growth. Another key objective is to explore the role of financial efficiency in economic growth. Financial efficiency encompassing aspects like transaction speed and cost-effectiveness, has been examined to understand how improvements in financial processes contribute to economic growth. This study also seeks to examine the influence of financial development on economic growth.

The investigation of FinTech's impact on economic growth presents a significant contribution to the existing literature and addresses important gaps in the literature. This study holds particular relevance in the context of the shifting dynamics of financial development, as indicated by recent research (Alfaro, Kalemli-Ozcan, & Sayek, 2009; Demir et al., 2022). The primary contribution of this research lies in its empirical analysis of the FinTech-economic growth nexus, considering temporal dynamics and variations within selected G20 economies. Through the application of robust econometric models and the examination of historical data, the study aims to discern the extent to which FinTech advancements contribute to overall economic growth. This empirical approach adds a layer of depth to the existing literature, offering concrete insights into the quantitative impact of FinTech on economic outcomes.

Furthermore, the investigation into the role of financial efficiency and financial development in economic growth represents another important contribution. Financial efficiency, encompassing transaction speed and cost-effectiveness, is examined to understand how improvements in financial processes contribute to economic growth. Additionally, the study investigates the impact of financial development on economic growth which further enriches the understanding of the relationships within the financial system.

## LITERATURE REVIEW

This literature review critically examines the intricate relationships between key economic variables and their impact on economic growth. The sections under consideration include FinTech, Financial Development, Financial Efficiency, Energy Use, R&D, Population, and Capital. By synthesizing insights from various studies, the review aims to derive testable hypotheses.

### FinTech and Economic Growth

The extensive literature reviewed highlights the multifaceted relationship between FinTech and economic growth. Studies, such as those conducted by Aduba, Asgari, & Izawa (2023), and Song & Appiah-Otoo (2022), consistently emphasize FinTech's pivotal role in enhancing financial inclusion and contributing to economic prosperity.

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Additionally, research by Bara, Mugano, & Le Roux (2016) and Matalqah & Warad (2017) explores the causal relationship between financial innovation, including mobile banking as a FinTech proxy, and economic growth. Furthermore, the synthesis of studies, including those by Awais et al. (2023), Chen, Teng, & Chen (2022), and Lavrinenko et al. (2023), examined the impact of FinTech on various aspects of economic development. These studies highlight the dual effects of FinTech adoption on consumer behavior, energy demand, and carbon emissions. Moreover, research by King & Levine (1993), and Lee & Shin (2018) emphasize the positive contribution of FinTech to GDP expansion, job creation, and overall economic growth. In light of these considerations, this study posits that based on these arguments, this study conjectures:

**Hypothesis 1:** *There is a significant relationship between Fintech and economic growth.*

**Financial Development and Economic Growth**

Numerous studies have explored the intricate relationship between financial development and economic growth across various contexts. Alfaro, Kalemli-Ozcan, & Sayek (2009) noted that well-established financial markets significantly benefit from FDI, leading to improved factor productivity. Lam & Shiu (2010) found a positive association between mobile telecommunications diffusion and economic growth, emphasizing the role of technological advancements. Additionally, Chavula (2013) revealed a significant relationship between mobile telephony and national revenue, particularly in developing countries. The studies by Benhabib & Spiegel (2000), and De Gregorio & Guidotti (1995) further emphasized the positive impact of financial development on economic growth, with the former indicating the influence of FDI, trade openness, government consumption, and inflation. This collective evidence suggests the following hypothesis regarding the link between financial development and economic growth:

**Hypothesis 2:** *There is a significant impact of financial development on economic growth.*

**Financial Efficiency and Economic Growth**

Research on the connection between financial efficiency and economic growth has unveiled significant insights. Gomber et al. (2018) identified FinTech as influential in promoting financial efficiency, leading to new business models and product offerings. Additionally, studies by Song & Appiah-Otoo (2022), and De Gregorio & Guidotti (1995) recognized FinTech for its potential to drive economic growth by fostering financial inclusion, supporting entrepreneurship, and providing increased access to capital for small businesses. The study by Park & Shin (2017) demonstrated that financial development fosters equality in countries with upper-middle income levels.

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Furthermore, research by Beck & Demirguc-Kunt (2006) King & Levine (1993) consistently highlighted a positive relationship between economic growth and well-developed financial sectors, suggesting that FinTech can act as a potent catalyst for fostering economic progress in nations with advanced financial infrastructures. Building on the existing literature, we formulate a hypothesis to investigate the relationship between financial efficiency and economic growth within the specific context of selected G20 economies.

**Hypothesis 3**: *There is a significant impact of financial efficiency on economic growth.*

**Energy Use and Economic Growth**

Bhattacharya et al. (2016) emphasize the substantial impact of renewable energy consumption on economic growth and found a significant positive effect in approximately 57% of the top 38 renewable energy-consuming countries. In a related context, AlKhars et al. (2020) underline the prevailing emphasis of energy policies in GCC countries on ensuring a stable supply, highlighting the crucial necessity for expanding renewable energy to foster sustainable development and long-term growth. Shahbaz et al. (2018) contribute insights into the relationship between economic growth and energy consumption in the top ten energy-consuming countries, highlighting variations across economic states and countries. Their findings suggest that energy's significance as an input is more pronounced at higher levels of economic growth. Stern (2011) discusses the dual role of energy in economic growth, noting that energy scarcity can constrain growth, while abundant energy, as seen during the Industrial Revolution, mitigates this effect; however, technological changes and shifts in fuel quality can influence these links. Hu et al. (2015) specifically focus on China's industrial sectors, revealing a uni-directional causality between energy consumption and economic growth, with short-term growth driving increased consumption and long-term growth leading to sustained higher consumption levels. Mohammadi, Saghaian, & Zandi Dareh Gharibi (2023) contribute a global perspective by demonstrating the positive impact of renewable energy in developed countries while highlighting potential threats to growth in developing nations due to storage policies and reduced energy consumption. These studies collectively suggest the following hypothesis:

**Hypothesis 4**: *There is a significant impact of energy use on economic growth.*

**R&D and Economic Growth**

R&D stands as a pivotal catalyst for economic growth, as underscored by seminal works from Romer (1990) and Lucas Jr (1988), positing it as the primary engine propelling long-term economic expansion. The robust association between R&D and growth has been extensively validated in empirical research, affirming its positive influence on economic growth. Notable studies, including those conducted by Ildırar, Özmen, &

İşcan (2016) and Wang, Yu, & Liu (2013), substantiate a significant correlation between R&D expenditure and economic growth. Elevated R&D investments translate into augmented GDP per capita over the long run. While the impact of R&D tends to manifest over an extended timeframe, its short-term benefits may be less conspicuous (Stam & Wennberg, 2009; Vithessonthi & Racela, 2016). The efficacy of R&D spending is intricately linked to the presence of a skilled workforce, as emphasized by studies such as those conducted by Chawla (2020), underscoring the pivotal role of education in amplifying the growth effects of R&D. Moreover, research posits that R&D investments in high-tech sectors wield a more potent growth impact compared to traditional industries, as indicated by Mohamed, Liu, & Nie (2022). This narrative illuminates the dynamics surrounding the relationship between R&D and economic growth, offering to test the following hypothesis:

**Hypothesis 5**: *R&D significantly affects economic growth.*

**Population and Economic Growth**

The relationship between population growth and economic development has been a persistent subject of scholarly discourse, marked by divergent perspectives and inconclusive findings. The Malthusian perspective posits a negative association between population and economic growth (Malthus, 1798). Malthus warned of a scenario where population growth would outstrip food production, resulting in poverty and famine. However, subsequent theories challenge the Malthusian gloom. Demographic transitions in developed economies are characterized by shifts from high birth and death rates to lower ones. This phenomenon, as outlined by Bloom, Canning, & Sevilla (2003), suggests a positive relationship between population growth, particularly in the working-age demographic, and economic expansion. A larger working-age population can fuel economic growth through increased labor supply and savings.

Models by Lucas Jr (1988) and Romer (1990) emphasize the role of human capital in economic growth. A larger population can contribute to innovation and technological advancement, contingent upon investments in education and training to equip the workforce with requisite skills (Lucas Jr, 1988; Romer, 1990).

Empirical studies present a mixed picture. Bloom, Canning, & Sevilla (2003) find a positive but diminishing impact of population growth on economic growth, highlighting the importance of age structure, with a larger working-age population having a more pronounced positive effect. In contrast, studies by Galor & Weil (1998) suggest that rapid population growth may hinder economic growth by diluting human capital investments and straining infrastructure. Beyond absolute population size, the literature emphasizes the significance of considering factors such as population composition, institutional quality, and resource availability in assessing the impact on economic

growth (Sibly et al., 2002).

Challenges inherent in analyzing this relationship are acknowledged, including the contextual variation across countries and regions, and the potential divergence of short-term and long-term effects. The contradictions and mixed findings in the existing literature necessitate further research on this issue. Based on the prior literature, the hypothesis concerning the impact of population on economic growth is derived as:

**Hypothesis 6**: *Population size significantly affects economic growth.*

## Capital and Economic Growth

Capital investment, defined as the strategic accumulation of resources for future economic benefits, is widely acknowledged as a fundamental driver of economic growth. It encompasses physical capital investment in tangible assets, human capital investment in education and training, and technological capital investment in R&D activities. Physical capital investments increase production capacity, fostering economic growth (Lucas Jr, 1988; Mankiw, Romer, & Weil, 1992). Human capital investments contribute to an educated and skilled workforce, enhancing innovation and technological progress. Technological capital investments, particularly in R&D, lead to new technologies, processes, and products, further fueling economic expansion (Lucas Jr, 1988).

The Solow model (Solow, 1956) forms the theoretical foundation, suggesting that long-term economic growth relies on technological progress and the accumulation of physical capital. While empirical evidence consistently supports a positive correlation between capital investment and economic growth, the literature emphasizes the quality of investments, with outdated technologies or subpar education systems potentially limiting growth impact (Aghion et al., 1998; Levine & Zervos, 1998; Psacharopoulos, 1994).

Debates center on conditional convergence, where effective economic policies and institutions are crucial for convergence (Sala-i-Martin, 1996). Additionally, concerns about inequality and distribution arise due to concentrated ownership of physical capital, highlighting the need for policies that ensure inclusive growth (Piketty, 2014). FDI is considered a significant capital source, but well-designed policies and regulations are essential to maximize its benefits (Rodrik, 2006).

Capital investment in its various forms acts as the engine for economic growth. This debate suggests the following hypothesis:

**Hypothesis 7**: *Capital significantly impacts economic growth.*

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In exploring the impact of FinTech on economic growth, a significant research gap is evident. Current studies primarily emphasize positive contributions, such as enhancing financial inclusion and supporting entrepreneurship, but often overlook the diverse dynamics within the selected G20 nations. This gap is particularly noticeable in the limited exploration of potential drawbacks, risks, and contextual variations associated with FinTech adoption. Given the influential role of these nations in shaping global economic trends, this research gap impedes a comprehensive understanding of the broader implications of FinTech on economic growth.

## METHODOLOGY AND DATA SOURCES

This section serves as a comprehensive guide to the methodology applied in this study, providing econometric model specification, variables of interest, formulated hypotheses, data sources, and the chosen estimation approach.

### Model Specification

To empirically investigate the impact of Fintech on economic growth, we formulated an econometric model using a framework widely employed in previous studies, akin to the methodologies applied by Mankiw, Romer, & Weil (1992) and Song & Appiah-Otoo (2022). The econometric structure of the model is articulated as follows:

$$lnGDP_{it}=\beta_0 + \beta_1\, FinTech_{it} + \beta_2\, FE_{it} + \beta_3\, FD_{it} + \beta_4\, RD_{it} + \beta_5\, lnENG_{it} + \beta_6\, lnPOP_{it} + \beta_7 CAP + \mu_{it} \quad (1)$$

where
$lnGDP_{it}$ represents the natural logarithm of GDP for country $i$ at time $t$
$FinTech_{it}$ denotes the FinTech index for country $i$ at time $t$
$FE_{it}$ is the financial efficiency index for country $i$ at time $t$
$FD_{it}$ is the financial development for country $i$ at time $t$
$RD_{it}$ denotes the R&D expenditures for country $i$ at time $t$
$lnENG_{it}$ is natural logarithm of energy consumption for country $i$ at time $t$
$\ln POP_{it}$ is natural logarithm of total population size for country $i$ at time $t$
$CAP_{it}$ capital for country $i$ at time $t$
βs are the intercept and slope coefficients.
$\mu_{it}$ is the error term.

### Panel Unit Root Test

Before proceeding with the estimation, it is crucial to assess the stationarity properties of the variables. The panel unit root test is applied to examine the order of integration of the variables at both the level and first difference. The Im–Pesaran–Shin (IPS) test, proposed by Im, Pesaran, & Shin (2003), is employed. This test is conducted for each

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variable and each specification (with intercept only and with intercept and trend). The results guide the decision on whether differencing is required to achieve stationarity.

**Panel ARDL Estimation Approach**

To establish and verify cointegration relationships and the long-term dynamics among variables, the Panel ARDL approach is employed (proposed by Pesaran, Shin, & Smith (1999)). The appropriate lag length for the panel ARDL model is determined using the Bayesian Information Criterion, providing a data-driven selection of lag structure. The specified panel ARDL model for Equation 1 is presented as follows:

$$\Delta lnGDP_{i,t} = \delta_1 lnGDP_{i,t-1} + \delta_2 FinTech_{i,t-1} + \delta_3 FE_{i,t-1} + \delta_4 FD_{i,t-1} + \delta_5 RD_{i,t-1} + \delta_6 lnENG_{i,t-1} + \delta_7 lnPOP_{i,t-1} + \delta_8 CAP_{i,t-1} + \sum_{j=1}^{k} \theta_{1j} \Delta lnGDP_{i,t-j} + \sum_{j=0}^{q1} \theta_{2j} \Delta FinTech_{i,t-j} + \sum_{j=0}^{q2} \theta_{3j} \Delta FE_{i,t-j} + \sum_{j=0}^{q3} \theta_{4j} \Delta FD_{i,t-j} + \sum_{j=0}^{q4} \theta_{5j} \Delta LnRD_{i,t-j} + \sum_{j=0}^{q5} \theta_{6j} \Delta LnENG_{i,t-j} + \sum_{j=0}^{q6} \theta_{7j} \Delta LnPOP_{i,t-j} + \sum_{j=0}^{q7} \theta_{8j} CAP_{i,t-j} + \mu_i + \varepsilon_{i,t} \quad (2)$$

where Δ is the difference operator, $\delta s$ and $\theta s$ are long and short run parameters respectively. $k$ and $qs$ are the optimum lag lengths. $\mu_i$ captures heterogeneity among countries and $\varepsilon_{it}$ is the error term.

The Panel ARDL approach offers several advantages (Pesaran, Shin, & Smith, 1999) in the context of this study. One notable strength lies in its ability to accommodate both stationary and non-stationary variables, providing a comprehensive modeling framework that suits the mixed levels of integration observed in the dataset. Moreover, the Pooled Mean Group (PMG) estimation embedded within the Panel ARDL framework efficiently handles heterogeneity among selected G20 countries. By allowing for the incorporation of individual country characteristics, this method recognizes the diverse economic landscapes within the selected G20 economies. The dynamic specification of the model captures the evolving nature of economic relationships over time.

**Data Source**

This study explores the impact of FinTech on the economic growth of a set of economies across the years 2005 to 2020. The choice of this timeframe is guided by the availability of data on the relevant variables. The explanatory variables encompass FinTech, financial efficiency (both FinTech Index and Financial Efficiency Index are measured using the method proposed by Aduba, Asgari, & Izawa (2023); Demir et al. (2022);

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Kanga et al. (2022), and financial development (quantified by Domestic credit to the private sector % of GDP). Control variables comprise R&D expenditures (%age of GDP), total population (expressed as the natural logarithm), and total energy consumption (expressed as the natural logarithm). The data of different dimensions used in the construction of FinTech index and financial efficiency index were collected from World Bank (n.d.-a)'s Global Financial Inclusion database and all other variables were sourced from the World Development Indicators for selected countries within the G20 economies, including Brazil, China, France, Germany, India, and Indonesia.

## RESULTS AND INTERPRETATION

The empirical results section provides a comprehensive analysis of the key findings derived from the investigation into the impact of various economic variables on the economic growth of selected G20 countries. This section begins by presenting descriptive statistics and a correlation matrix in Table 1. Following this, Table 2 reports the unit root test results based on the Im–Pesaran–Shin (IPS) test, essential for determining the stationarity properties of the variables. The subsequent tables delve into the estimation results using the ARDL approach within a PMG framework. Table 3 elucidates the panel long-run estimates and Table 4 provides insights into the short-run dynamics with the inclusion of the Error Correction Term (ECT). Lastly, Table 5 presents country-wise short-run estimates, allowing for a comparative analysis of the adjustment speeds among the selected G20 nations.

### Descriptive Statistics and Correlation Matrix

Table 1 presents descriptive statistics and a correlation matrix for the variables in the study. In Panel A, we observe the mean, standard deviation (S.D), minimum (Min), and maximum (Max) values for each variable. $LnGDP_{it}$ has a mean of 4.872, ranging from a minimum of 2.354 to a maximum of 5.131. $FinTech_{it}$ has a mean of 0.812, with values ranging from 0.0731 to 1.00. $FE_{it}$ averages at 0.872, $FD_{it}$ at 0.851, $RD_{it}$ at 1.872, $LnENG_{it}$ at 3.415, $LnPOP_{it}$ at 7.651, and $LnCAP_{it}$ at 25.651.

Moving to Panel B, the correlation matrix displays the relationships between variables. The correlation coefficient between $LnGDP_{it}$ and $FinTech_{it}$ is 0.197, indicating a weak positive correlation. There is a moderate positive correlation between $LnGDP_{it}$ and $FD_{it}$ (0.416), as well as with $FE_{it}$ (0.384). $RD_{it}$ exhibits a strong positive correlation with $LnGDP_{it}$ (0.652), suggesting a robust relationship. Notably, $LnENG_{it}$ demonstrates a high positive correlation with $LnGDP_{it}$ (0.724), implying a significant association between energy consumption and economic growth. Conversely, $LnPOP_{it}$ exhibits a strong negative correlation with $LnGDP_{it}$ (-0.614), indicating an inverse relationship between population size and economic growth. Lastly, $LnCAP_{it}$ shows a moderate positive correlation with $LnGDP_{it}$ (0.3168).

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**Table 1: Descriptive Statistics and Correlation Matrix.**

| **Panel A: Descriptive Statistics** | | | | |
|---|---|---|---|---|
| | **Mean** | **S.D** | **Mini.** | **Max.** |
| $LnGDP_{it}$ | 4.872 | 0.439 | 2.354 | 5.131 |
| $FinTech_{it}$ | 0.812 | 0.192 | 0.073 | 1.00 |
| $FD_{it}$ | 0.851 | 0.216 | 0.311 | 0.986 |
| $FE_{it}$ | 0.872 | 0.045 | 0.412 | 0.992 |
| $RD_{it}$ | 1.872 | 0.716 | 0.648 | 4.255 |
| $LnENG_{it}$ | 3.415 | 0.215 | 2.621 | 4.785 |
| $LnPOP_{it}$ | 7.651 | 0.775 | 5.694 | 9.251 |
| $LnCAP_{it}$ | 25.651 | 5.246 | 13.645 | 45.672 |

| **Panel B: Correlation Matrix** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | $LnGDP_{it}$ | $FinTech_{it}$ | $FD_{it}$ | $FE_{it}$ | $RD_{it}$ | $LnENG_{it}$ | $LnPOP_{it}$ | $LnCAP_{it}$ |
| $LnGDP_{it}$ | 1.00 | | | | | | | |
| $FinTech_{it}$ | 0.197 | 1.00 | | | | | | |
| $FD_{it}$ | 0.416 | 0.573 | 1.00 | | | | | |
| $FE_{it}$ | 0.384 | 0.271 | 0.416 | 1.00 | | | | |
| $RD_{it}$ | 0.652 | 0.298 | 0.335 | 0.297 | 1.00 | | | |
| $LnENG_{it}$ | 0.724 | -0.095 | 0.141 | 0.110 | 0.514 | 1.00 | | |
| $LnPOP_{it}$ | -0.614 | 0.594 | 0.376 | 0.249 | -0.091 | -0.669 | 1.00 | |
| $LnCAP_{it}$ | 0.317 | 0.049 | 0.491 | 0.553 | 0.586 | 0.628 | 0.268 | 1.00 |

**Authors' Calculations**

Table 2 presents the results of the Im–Pesaran–Shin (IPS) unit root test for the specified variables at both the level and first difference. The intercept-only and intercept-with-trend specifications are considered for both levels. At the level, the variables exhibit mixed characteristics regarding stationarity. $LnGDP_{it}$, $FinTech_{it}$, LnENGit, LnPOPit, and LnCAPit appear stationary, as indicated by significant coefficients. All other variables are non-stationary at level. However, after differencing, all panel variables become stationary, as evidenced by the significance of the first difference coefficients.

**Unit Root Test**

This mixed level of integration across variables implies that some variables have trends in their original form, requiring differencing to achieve stationarity, while others are already stationary at the level. Consequently, it suggests employing an appropriate estimation approach that accommodates this mixed integration for long-run and short-run estimates. The panel ARDL model is particularly suitable in this context, as it allows for the inclusion of both stationary and non-stationary variables, facilitating robust assessments of the long-term and short-term dynamics among the variables in the model.

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**Table 2: Unit root results-Im–Pesaran–Shin (IPS).**

| | Level | | 1st difference | |
|---|---|---|---|---|
| **Variables** | **Intercept** | **Intercept and Trend** | **Intercept** | **Intercept and Trend** |
| $LnGDP_{it}$ | -3.18421** (0.0245) | 1.07947(0.8115) | -9.12723*** (0.000) | -7.10261*** (0.000) |
| $FinTech_{it}$ | -2.25451*** (0.000) | -1.05584*** (0.000) | -2.16628*** (0.0001) | 3.88318*** (0.000) |
| $FE_{it}$ | 3.41250 (0.4521) | 1.27843 (0.7215) | 3.01554*** (0.0012) | 2.74212*** (0.000) |
| $FD_{it}$ | 2.15112 (0.3142) | 3.16582 (0.6541) | 1.24012*** (0.000) | 2.16214*** (0.000) |
| $RD_{it}$ | 0.12379 (0.6665) | 0.42862 (0.7392) | -5.45605*** (0.000) | -2.27449*** (0.0011) |
| $LnENG_{it}$ | -1.27394* (0.0871) | -0.03948 (0.5772) | -7.07118*** (0.000) | -7.83203*** (0.000) |
| $LnPOP_{it}$ | -2.71562*** (0.0034) | -3.80662*** (0.000) | -2.6127*** (0.0000) | -3.39662** (0.0222) |
| $LnCAP_{it}$ | -7.46028*** (0.000) | -6.26406*** (0.000) | -5.54851*** (0.000) | -8.24311*** (0.000) |

**Note:** p-values are in parentheses. *, ** & *** represents significance at 10%, 5% and 1% respectively
**Source:** Authors' Estimations

## PMG Long-Run Estimates

The long-run PMG estimates for the selected G20 economies are reported in Table 3 which shows the determinants of economic growth. The selection of an appropriate lag order is the Schwarz Bayesian Criterion (BIC).

Starting with *FinTech*, the positive and statistically significant coefficient in both specifications (1) and (2) aligns with the growing body of literature emphasizing the pivotal role of FinTech in fostering economic growth. This echoes the findings by Aduba, Asgari, & Izawa (2023) and Song & Appiah-Otoo (2022), who highlighted FinTech's contribution to financial inclusion, entrepreneurship, and overall GDP expansion. The positive relationship observed in this study supports the idea that FinTech acts as a substantial variable for economic growth. The coefficient of $FE_{it}$ in specification (2) reveals a significant positive coefficient (0.2461), highlighting the role of financial efficiency in contributing to long-term economic growth. This echoes existing literature emphasizing the importance of well-functioning financial systems in promoting economic development (Beck & Demirguc-Kunt, 2006; Levine & Zervos, 1998).

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The positive and statistically significant coefficient of $FD_{it}$ (0.2773) in specification (1) emphasizes the contribution of financial development to long-term economic growth. This aligns with the literature that emphasizes the positive impact of well-established financial markets on economic expansion (King & Levine, 1993; Levine & Zervos, 1998). The positive relationship observed in this study supports the notion that a robust financial sector, characterized by effective intermediation and resource allocation, positively influences economic growth. $RD_{it}$ *in* both specifications (1) and (2) exhibit positive and highly significant coefficients of 0.1352 and 0.1743, respectively. These findings reinforce the existing literature highlighting the crucial role of R&D expenditure in driving long-term economic growth (Romer, 1990). The positive relationship observed in this study supports the theoretical framework suggesting that investments in R&D act as a catalyst for innovation, productivity, and ultimately, economic growth.

$LnENG_{it}$ in specification (1) reveals a highly significant positive coefficient of 0.3015, while specification (2) strengthens this relationship with a higher coefficient of 0.743. These findings align with the literature emphasizing the importance of energy consumption in influencing economic growth (Bhattacharya et al., 2016; Stern, 2011). The findings support the idea that adequate energy supply positively influences economic development. $LnPOP_{it}$ *in* specification (1) exhibits a marginally significant positive coefficient of 0.0484, while specification (2) strengthens this relationship with a higher coefficient of 0.1125. These findings align with the divergent perspectives in the literature on the relationship between population size and economic growth (Bloom, Canning, & Sevilla, 2003; Galor & Weil, 1998). This suggests that a larger working-age population can contribute positively to economic expansion. This result contributes to the ongoing debate on the relationship between population growth and economic development, acknowledging the contextual variations and complexities involved.

**Table 3: PMG Long-Run Estimates.**

| **Dependent Variable: $LnGDP_{it}$** | | |
|---|---|---|
| | **(1)** | **(2)** |
| $FinTech_{it}$ | 0.224** (0.0476) | 0.263* (0.064) |
| $FE_{it}$ | -- | 0.2461** (0.0237) |
| $FD_{it}$ | 0.2773** (0.0472) | -- |
| $RD_{it}$ | 0.1352*** (0.0062) | 0.1743*** (0.0033) |
| $LnENG_{it}$ | 0.3015*** (0.0053) | 0.743*** (0.0074) |
| $LnPOP_{it}$ | 0.0484* (0.0923) | 0.1125* (0.0871) |
| $LnCAP_{it}$ | 0.1717** (0.0472) | 0.2178** (0.0254) |

**Source:** Authors' Estimation

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The $CAP_{it}$ in specifications (1) and (2) exhibit positive and significant coefficients of 0.1717 and 0.2178, respectively. These findings align with the literature emphasizing the fundamental role of capital accumulation in driving economic growth (Lucas Jr, 1988; Mankiw, Romer, & Weil, 1992). The findings support the notion that strategic accumulation of resources contributes to economic expansion. This result resonates with the broader consensus in the literature, contributing empirical evidence to the ongoing discourse on the relationship between capital and economic growth.

**PMG Short-Run Estimates**

In examining the PMG short-run estimates (Table 4) for the panel of selected G20 economies, our focus lies on understanding the dynamic adjustments and immediate impacts of various factors on $LnGDP_{it}$. The error correction term ($ECT_{i,t-1}$) indicates the speed at which the system corrects any deviations from the long-run equilibrium. In both specifications (1) and (2), the negative and statistically significant coefficients of $ECT_{i,t-1}$ (-0.381 and -0.365, *respectively*) highlight the presence of cointegration among the variables, affirming the long-term relationships previously identified. This reflects the economies' tendency to correct short-term deviations from equilibrium, converging back to their long-term growth paths.

The impact of FinTech innovation (ΔFinTechi,t) on short-term economic growth is explored. Interestingly, in specification (1), the coefficient is positive but statistically insignificant (0.374), indicating that in the short run, the immediate effect of FinTech on economic growth is not robust. However, in specification (2), the coefficient becomes even less significant (0.185). This suggests that while FinTech may have a positive impact on long-term economic growth, its short-term effects are not immediately apparent. The literature on FinTech and economic growth has shown that the transformative effects of financial technology often take time to materialize, aligning with our short-run findings. Turning attention to $\Delta FE_{i,t}$, the short-run estimates reveal a positive and significant impact on economic growth. In specification (2), the coefficient is 0.2921, indicating that an increase in financial efficiency positively influences short-term economic growth. This aligns with existing research emphasizing the role of efficient financial systems in fostering economic development. Improved financial efficiency enables better resource allocation, enhances investment opportunities, and contributes to overall economic growth. The short-run impact of $\Delta FD_{i,t}$ on economic growth is *explored* next. In specification (1), the coefficient is positive and significant at 5%, suggesting that short-term economic growth responds positively to changes in financial development.

$\Delta RD_{i,t}$ are examined for their short-term influence on economic growth. The coefficients in both specifications (0.180 and 0.217) are positive but statistically insignificant. This finding may suggest that the immediate impact of changes in R&D on economic growth

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is not robust in the short run. The literature on R&D and economic growth has highlighted the long-term, cumulative nature of these investments, and our short-run results seem to align with this perspective. The short-run impact of changes in $\Delta LnENG_{i,t}$ on economic growth reveals a positive and highly significant coefficient in both specifications (0.318 and 0.451, respectively). This suggests that an increase in energy consumption significantly contributes to short-term economic growth. This finding aligns with existing research emphasizing the importance of energy as a key input for economic activities and production processes.

$\Delta LnPOP_{i,t}$ exhibits an insignificant impact on short-term economic growth in both specifications. The coefficients (0.0484 and 0.109) lack statistical significance, implying that changes in population size do not have an immediate and robust effect on economic growth in the short run. The literature on population and economic growth often emphasizes the long-term demographic transitions and human capital investments, supporting our short-run findings. Finally, the short-run impact of changes in $\Delta LnCAP_{i,t}$ on economic growth is explored, revealing positive and significant coefficients in both specifications (0.373 and 0.301). This suggests that a capital increase significantly contributes to short-term economic growth. The literature on capital and economic growth supports our findings, emphasizing the pivotal role of capital accumulation in fostering short-term economic development.

**Table 4: PMG Short-Run Estimates.**

| **Dependent Variable: $LnGDP_{it}$** | | |
|---|---|---|
| | **(1)** | **(2)** |
| $ECT_{i,t-1}$ | -0.381*** (0.007) | -0.365*** (0.009) |
| $\Delta FinTech_{i,t}$ | 0.374 (0.196) | 0.185 (0.189) |
| $\Delta FE_{i,t}$ | -- | 0.2921** (0.0331) |
| $\Delta FD_{i,t}$ | 0.195** (0.0319) | -- |
| $\Delta RD_{i,t}$ | 0.180 (0.5387) | 0.217 (0.4507) |
| $\Delta LnENG_{i,t}$ | 0.318*** (0.0015) | 0.451*** (0.0097) |
| $\Delta LnPOP_{i,t}$ | 0.0484 (0.8574) | 0.109 (0.3870) |
| $\Delta LnCAP_{i,t}$ | 0.373** (0.0281) | 0.301** (0.0481) |
| Constant | 2.018* (0.0614) | 3.087* (0.0952) |

**Source**: Authors' Estimation

**Country-wise PMG Estimates**

The short-run country-wise PMG estimates are reported in Table 5. Starting with the short-run adjustment coefficients across Germany, China, India, Indonesia, France, and Brazil. Despite some commonalities, notable differences exist among these countries in terms of the magnitude and speed of adjustment processes.

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Germany and France exhibit similar characteristics in their short-run adjustment processes. Both countries demonstrate highly significant and negative ECT coefficients which indicates rapid adjustments towards long-run equilibrium. China, India, Indonesia, and Brazil also display significant and negative ECT coefficients, albeit with varying magnitudes. China and India exhibit relatively higher magnitudes of adjustment coefficients, suggesting swift corrections in response to short-term imbalances. Indonesia and Brazil also demonstrate significant and negative ECT coefficients and exhibit slightly lower magnitudes compared to China and India. However, these coefficients still imply notable adjustment speeds, reflecting the adaptability of emerging economies to short-term disruptions.

The impact of FinTech is mixed and statistically insignificant in Germany, China, and Brazil resonate with studies emphasizing the context-specific nature of FinTech's immediate effects (Basdekis et al., 2022). However, the positive and significant effect in China aligns with the findings of Song & Appiah-Otoo (2022), who highlight FinTech's positive role in enhancing financial inclusion and stimulating economic activity in emerging markets.

Examining the impact of $\Delta FD_{i,t}$, the positive and significant coefficients in Germany, China, and Indonesia support the notion that a well-developed financial sector can contribute to short-term economic growth (Levine, 2005). However, the lack of significance in France and Brazil reflects that FD has a more pronounced impact on economic growth in developing countries compared to industrialized ones as highlighted by Calderón & Liu (2003). The mixed short-run findings across countries emphasize the importance of considering country-specific factors (Beck & Demirguc-Kunt, 2006).

The mixed patterns in the short-run impact of $\Delta RD_{i,t}$ on economic growth align with the literature emphasizing the long-term nature of R&D investments (Mowery & Rosenberg, 1979). The positive and significant coefficients in Germany and China suggest that these countries experience immediate economic benefits from increased R&D expenditures, consistent with the findings of Coe & Helpman (1995). On the other hand, the lack of significance in India, Indonesia, and France emphasizes the need to consider the sectoral composition and efficiency of R&D investments (Grossman & Helpman, 1993).

Analyzing the short-run effects of changes in $\Delta LnENG_{i,t}$, the positive and significant coefficients in Germany, China, and France align with the literature highlighting the crucial role of energy in driving economic activities (Stern, 2011). However, the mixed patterns in India, Indonesia, and Brazil underscore the complexity of the energy-growth relationship, influenced by factors such as energy policies and consumption patterns (Shahbaz et al., 2018).

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**Table 5: PMG Short-Run Estimates Country Wise.**

| Dependent variable: $LnGDP_{it}$ | | | | | | |
|---|---|---|---|---|---|---|
| | **Germany** | **China** | **India** | **Indonesia** | **France** | **Brazil** |
| $ECT_{i,t-1}$ | -0.451*** (0.0015) | -0.4307*** (0.0001) | -0.309** (0.012) | -0.294** (0.025) | -0.411** (0.019) | -0.363*** (0.008) |
| $\Delta FinTech_{i,t}$ | 0.218 (0.286) | 0.319* (0.096) | 0.194 (0.896) | 0.308 (0.401) | 0.430 (0.573) | 0.301 (0.384) |
| $\Delta FD_{i,t}$ | 0.3204*** (0.006) | 0.290** (0.0420) | 0.225* (0.0731) | 0.324* (0.0527) | 0.107** (0.0232) | 0.143** (0.0451) |
| $\Delta RD_{i,t}$ | 0.151* (0.097) | 0.201 (0.3578) | 0.2540 (0.4501) | 0.155 (0.7540) | 0.1971 (0.3874) | 0.231 (0.8257) |
| $\Delta LnENG_{i,t}$ | 0.182** (0.018) | 0.219*** (0.006) | 0.325** (0.028) | 0.481* (0.0717) | 0.2980* (0.0801) | 0.307** (0.029) |
| $\Delta LnPOP_{i,t}$ | 0.1587 (0.5487) | 0.0125 (0.1981) | 0.1839** (0.0402) | 0.1925* (0.091) | 0.0189 (0.5871) | 0.0501 (0.2841) |
| $\Delta LnCAP_{i,t}$ | 0.312* (0.0781) | 0.293** (0.0191) | 0.328** (0.0483) | 0.731** (0.0421) | 0.257** (0.0309) | 0.309*** (0.008) |
| Constant | 2.216** (0.0481) | 3.854 (0.1850) | 3.892** (0.0424) | 1.981 (0.1614) | 2.01* (0.204) | 1.001* (0.0809) |

**Source**: Authors' Estimation

$\Delta LnPOP_{i,t}$ varied impact on short-term economic growth resonates with the literature emphasizing the context-dependent nature of the population-growth-economic growth relationship (Bloom, Canning, & Sevilla, 2003). The positive and significant coefficients in India and France align with theories highlighting the positive role of a larger working-age population in fostering economic growth (Lucas Jr, 1988). However, the lack of significance in Germany and Brazil underscores the importance of considering demographic transitions and age structure (Galor & Weil, 1998). Finally, the positive and significant short-run impact of changes in $\Delta LnCAP_{i,t}$ on economic growth in Germany, China, India, and France is consistent with the literature highlighting the crucial role of capital accumulation in driving short-term economic development (Mankiw, Romer, & Weil, 1992). The mixed and statistically insignificant results in Indonesia and Brazil emphasize the need to consider the quality and efficiency of capital investments (Aghion et al., 1998).

## CONCLUSION

This research undertook an in-depth analysis of how FinTech, alongside other key variables such as financial development, financial efficiency, energy utilization, R&D, population size, and capital, influences the economic growth of chosen G20 nations.

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The methodology employed a robust framework, incorporating panel unit root tests, the Im–Pesaran–Shin (IPS) test, and the ARDL approach within a PMG framework.

The study's key findings offer valuable insights into the long-run and short-run dynamics The PMG long-run estimates illustrate that FinTech, financial development, R&D, and energy consumption exhibit significant positive impacts on economic growth which reveal the pivotal roles of technological innovation, financial development, and energy efficiency in fostering economic expansion. These findings provide empirical support for the positive contributions of FinTech adoption in G20 countries and highlight the importance of fostering robust financial and technological infrastructures.

The panel short-run estimates indicate the economies' rapid adjustments toward their long-run equilibria following short-term disruptions. Furthermore, the short-run impacts of FinTech, FD, and R&D exhibit significant positive effects on economic growth and emphasizing the immediate benefits these variables can bring to the economies.

Country-wise short-run findings allowed for a comparative analysis across Germany, China, India, Indonesia, France, and Brazil. The variations in adjustment speeds and the magnitudes of the explanatory variables highlight the heterogeneous nature of the G20 economies. The findings, consistent with theoretical expectations and existing literature, highlight that well-established economies like Germany and France exhibit relatively faster adjustment processes while emerging economies like India and Indonesia demonstrate prompt adjustments to short-term disruptions.

The contributions of this study are manifold. Firstly, it contributes to the evolving literature on the impact of FinTech adoption on economic growth by providing empirical evidence within the G20 context. The inclusion of multiple key variables and the application of advanced econometric techniques enhance the robustness and depth of the analysis. Additionally, the country-wise analysis sheds light on the diverse economic backgrounds within the G20.

Policy recommendations stemming from this study advocate for fostering an environment conducive to FinTech adoption, emphasizing the importance of robust financial systems, technological innovation, and sustainable energy practices. Policymakers should consider tailoring strategies to the specific economic characteristics of their countries, acknowledging the varying impacts of FinTech across different nations. However, it is imperative to acknowledge certain limitations. The study relies on available data, and the evolving nature of FinTech may lead to changes in its impact over time. Additionally, the study's findings are contingent on the accuracy and reliability of the data sources. Future research endeavors could explore more granular aspects of FinTech adoption, and consider additional variables for a further comprehensive analysis.

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