



Financial inclusion through digitalization and economic growth in Asia-Pacific countries



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ABSTRACT

Digital technology for financial inclusion tends to bring more benefits to people at the bottom of the economic pyramid across the Asia-Pacific region; therefore, financial inclusion is crucial for sustainable development and economic growth in this region. Digital financial services, based on technology-driven innovation, contribute to enhanced financial inclusion at affordable prices, which potentially reaches many new people who are unbanked or underbanked. This paper examines the impact of digital financial inclusion (DFI) on economic growth in 30 Asia-Pacific countries based on panel data for 2014, 2017, and 2021. A three-stage principal component analysis is used to develop the DFI index for the Asia-Pacific region, capturing both the digital and traditional aspects. We use fixed effect regression to examine the linear effect of DFI on economic growth, and results show a significant positive impact, contributing to the *Theory of Finance and Growth, System Theory, and Diffusion Theory of Innovation*. Given the different roles of DFI in different countries and the wide digital divide across the region, this paper employs a panel threshold regression model to identify any non-monotonic influence of DFI on economic growth. The results show a significant threshold effect of DFI, indicating the non-linear effect of financial inclusion on economic growth. The paper brings evidence-based policy implications to boost DFI to achieve inclusive growth.

1. Introduction

Financial inclusion, a remedy to financial exclusion, has become a widespread concept among policymakers, academics, and practitioners. It involves removing barriers to financial products and services, including credit, investment, savings, insurance, financial technology, and payments, for all economic participants (Abor, Issahaku, Amidu and Murinde, 2020). The goal is to establish a system that offers low-cost, fair, convenient, safe, quality, and sustainable financial services and products, ensuring access and usage by all individuals at all times. Financial inclusion, therefore, involves increasing individuals' access to formal financial services through formal bank accounts, thus contributing to poverty reduction and economic growth (Ozili, 2018).

Financial accessibility enables people to participate in economic activities, which is central to economic development. While financial inclusion is a policy priority for sustainable development, the economic literature on financial inclusion remains in its early stages (Ozili, 2022).

The *Global Findex Database 2017* (Demirguc-Kunt, Klapper, Singer, Ansar, & Hess, 2018) reflects the continued evolution of financial inclusion, driven by digital payments, government policies, and a new generation of financial services more widely accessible via mobile phones and the internet. According to Demirguc-Kunt, Klapper, Singer, and Ansar (2022), the proportion of adults making or receiving digital payments rapidly increased during the 5-year period from 2017 to 2021 by 13 % (from 44 % to 57 %), surpassing the growth in accounts ownership in developing countries. Mobile phones and the internet have created new prospects for delivering financial services, with even simple text-based mobile phones enabling mobile money accounts and smartphones facilitating transactions from financial institution accounts. However, the effectiveness of digital financial services depends on individuals' ability to access the necessary technology.

Digital financial services facilitated by recent FinTech innovation in the financial sector have been important drivers of financial inclusion in emerging markets and developing economies (Khera, Ng, Ogawa, &

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[Sahay, 2021](#)). FinTech advancements can play a vital role in contributing to growth and equity. Unlike traditional financial institutions, FinTech is better positioned to improve income distribution by introducing substantial changes, such as facilitating transaction services without leverage and offering low-cost, transparent, and accessible trading systems. This distinction highlights FinTech's ability to broaden financial access and promote growth and equity, a challenge that traditional financial services often struggle to address ([Zhang, Zhang, Wan, & Luo, 2020](#)). Thus, the digital economic model is considered important for inclusive finance.

Digital financial inclusion (DFI) broadly refers to digital access to and use of formal financial services by excluded and underserved populations. These services should be suited to customers' needs and delivered responsibly, at a cost both affordable to customers and sustainable for providers ([CGAP, 2015](#)). DFI focuses on leveraging Information and Communication Technology (ICT) to enhance financial inclusion subtly, blending digital finance with traditional financial inclusion efforts. This emerging phenomenon has significant policy implications ([Rekha, Rajamani, & Resmi, 2021](#)). The literature suggests that it can contribute to economic growth through ICT, providing excluded and underserved populations with access to formal financial services.

Inclusive finance has gradually developed from the availability of banks' physical outlets and credit services to a wide range of avenues, including payments, deposits, loans, insurance, credit services, and securities ([Liu, Luan, Wu, Zhang, & Hsu, 2021](#)). Nevertheless, according to [Demirguc-Kunt et al. \(2022\)](#), 1.4 billion adults globally lack access to formal financial services, depriving them of opportunities to improve their lives. Therefore, a pressing need exists for digital financial services alongside effective supervision to bridge the existing gaps in financial inclusion. DFI has a more promising communication space than traditional finance, resulting from various network-connection advantages ([Li, Wang, Liao, & Wang, 2022](#)). DFI reaches a broader range of people, facilitating more inclusiveness than traditional finance. Unlike traditional finance, which relies on physical outlets or branches, DFI relies on digital technology, taking advantage of the cost-efficient network effect, which fosters inclusive growth in remote areas, significantly affecting the economy, society, and people's lives.

Since the 1990s, the Asia-Pacific region has experienced a noteworthy socioeconomic transformation driven by strong and sustained economic growth ([ESCAP, U, 2018](#)). However, these rewards have not always benefited those in need. Several factors, both from the demand and supply side, have led to issues in financial accessibility in this region. The most common reasons, among others, relate to awareness, risks, knowledge, products, and processes ([Madan, 2020](#)). Specifically, women-owned businesses face these challenges driven by gender types, inadequate education opportunities, restricted mobility, and negative perceptions of women's leadership skills. As a result, many countries in this region have experienced enhanced inequalities. Interestingly, while Asia-Pacific countries are reported to lag behind Sub-Saharan Africa in terms of mobile banking adoption, they have made significant progress in traditional infrastructure, such as ATMs and bank branches ([Loukoianova, Yang and De, 2018](#)). Nevertheless, despite slower growth in mobile banking, several countries in the Asia-Pacific region, including Bangladesh, Indonesia, and Mongolia, have embraced digital financial services through branchless banking and mobile banking initiatives ([IMF, 2019](#)).

Meanwhile, the United Nations Sustainable Development Goals (SDGs) are seen as crucial for every country in the world ([Hoang, Nguyen, & Le, 2022](#)). The priorities of the 2030 agenda for SDGs envision a world free from poverty, hunger, disease, and violence, a world with universal literacy and equal access to quality education, healthcare, and social security ([Allen, Demirguc-Kunt, Klapper, & Peria, 2016](#)). The SDGs consist of 17 objectives, and financial inclusion is an enabler for seven of these goals ([Chitimira & Warikandwa, 2023](#); [United Nations, 2024](#)). Achieving the SDGs would be challenging without bringing

people into the banking system ([World Bank, 2018](#)). The financial sector shows a real relation to SDGs, even though financial inclusion and FinTech are not the main objectives. However, both play a crucial role in creating a better world in the future. Financial inclusion is a significant process toward achieving the SDGs, and FinTech is one of the best methods to accomplish these goals ([Hoang et al., 2022](#)). Digital technology, particularly digital financial services, plays a crucial role in enhancing financial inclusion and, consequently, contributing to the realization of the SDGs. Notably, new evidence shows that enhancing DFI creates the basis for inclusive economic growth ([UNSGSA, 2023](#)). Hence, national economies should concentrate on implementing policies for digital financial transition while sustaining financial inclusion ([Ozili, 2018](#)).

Digital technology has proven effective in improving financial inclusion ([Shen, Hueng, & Hu, 2021](#)). Consequently, this transition of focus from traditional financial inclusion to DFI has drawn attention in the academic literature. Nevertheless, a recent measure of national financial inclusion mostly focuses on traditional financial services ([Loukoianova, Yang and De, 2018](#)) and does not consider the role of digital finance ([Khera, Ng, Ogawa, & Sahay, 2022](#)). Existing studies have failed to capture the broader picture of financial inclusion. They mainly rely on a single measure of financial inclusion or access ([Sahay et al., 2015](#)). Many studies in the field of DFI also have considered only one indicator as a proxy for DFI (see [Daud and Ahmad, 2023](#); [Ozturk & Ullah, 2022](#)). Despite the fact that DFI has been examined in the literature, an index using all the possible indicators over the years, including recently updated data, has not been well developed. This paper develops a DFI index using a three-stage principal component analysis (PCA) for the Asia-Pacific region. As such, this study contributes to the existing literature on financial inclusion measurement.

While there is a widespread consensus in research that FinTech can significantly influence financial growth, its impact on sustainable economic development remains unclear ([Hoang et al., 2022](#)). Given the importance of financial inclusion, many studies have been undertaken to identify the impact of financial inclusion on economic growth. Nevertheless, DFI is a new concept, and as a result, studies on DFI and its effects on economic growth are lacking in the existing literature (see [Ahmad, Majeed, Khan, Sohaib, & Shehzad, 2021](#); [Shen, Hu, & Hueng, 2021](#)). Moreover, the relationship between DFI and economic growth over the years has not been explored due to data limitations ([Shen, Hu, & Hueng, 2021](#)). While there is considerable research on the influence of traditional financial inclusion on economic growth, the effects of DFI differ significantly from conventional financial inclusion, and only very few studies have investigated its influence on economic growth ([Liu et al., 2021](#)). Thus, there exists a vacuity in the existing literature on DFI and economic growth. This gives an impetus to examine the effect of DFI on economic growth in Asia-Pacific countries.

Although heterogeneity is a common problem in panel data, the classical fixed effect and random effect reflect only the heterogeneity in intercepts ([Wang, 2015](#)). However, the panel threshold model ([Hansen, 1999](#); [Hansen, 2000](#)) has noticeable implications for an economic policy, which describes the jumping character or structural breaks in the relationship between variables. Hence, this study introduces a novel perspective by examining the threshold effect of DFI on economic growth, making it the first study to explore the non-linear relationship between digital financial inclusiveness and economic growth in this region.

To address these gaps in the literature, this study brings an extended analysis of existing research to identify the influence of DFI on economic growth in the Asia-Pacific region from several theoretical perspectives. This study combines the *Theory of Finance and Growth*, *System Theory*, and *Diffusion Theory of Innovation* to comprehend the influence of inclusive finance on economic growth, how the advancement in financial inclusion through the existing system brings favorable outcomes to existing economic, financial, and social sub-systems, and to understand at what rate the technological advancement spread in the social system

in stimulating the economic outcomes. Thus, the overarching research question for this study is: *Does DFI affect economic growth in the Asia-Pacific region?*

In addressing this research question, the contribution of our study to existing literature is threefold. First, this study contributes to developing a comprehensive measure of the DFI index, capturing the broader picture of financial inclusion. Prior research has focused on traditional measures of financial inclusion or relying on a single measure, so we believe the construction of a comprehensive measurement of DFI for this region is an important tool for both researchers and policymakers. Second, using updated data, including the post-COVID-19 era, the paper examines the effect of DFI on economic growth in Asia-Pacific countries. Third, the paper investigates the existence of a non-linear relationship between DFI and economic growth, which leads to significant policy implications. The precise knowledge and understanding of the association between DFI and economic growth in the Asia-Pacific region can augment the theoretical system related to the growth of DFI, influencing economic growth and, hence, providing an explicit reference for future research in related fields. Following a discussion of the motivation, this paper aims to achieve two main objectives. The first objective is to develop the DFI index for the Asia-Pacific region, facilitating the comparison across the countries. The second objective is to examine the effect of DFI on economic growth, with both the linear and non-linear perspectives.

The remainder of the paper is structured as follows: **Section 2** presents the background exploiting the regulatory, reform, and policy issues and developments within the research context. **Section 3** presents the theoretical literature review. In particular, this section discusses the theoretical perspective based on the *Theory of Finance and Growth*, *System Theory*, and *Diffusion Theory of Innovation* to explain predictions and hypotheses explicitly outlining the link toward dependent and independent variables. **Section 4** brings the empirical literature review and hypotheses development. This section discusses the past literature and the development of hypotheses drawing on theory and empirical literature. **Section 5** brings the research design. **Section 6** presents the empirical results and discussions of findings, with theoretical, empirical and policy implications. Finally, **Section 7** presents the summary and conclusion outlining the implications, limitations, and avenues for future research.

2. Background

Since 2000, the term financial inclusion has gained global significance among policymakers, with much discussion on this topic within and among nations (APEC, 2011). Financial inclusion is a significant step toward promoting sustainable development and economic growth. Thus, the role of financial inclusion in poverty alleviation and inclusive development is widely recognized. The Asia-Pacific region has undergone accelerated development, including a reduction in the number of people who live in extreme poverty, ensuring improvements in food security, access to healthcare, education, water and sanitation, and energy, along with other fundamentals that facilitate socioeconomic developments (ESCAP, U, 2018). The Asia-Pacific region has had minimal use of formal finance; thus, a high level of informal finance has led these economies to strengthen their reform efforts that target financial inclusion (Jahan, De, Jamaludin, Sodsriwiboon, & Sullivan, 2019). Policymakers have executed different measures to increase access to financial services for financially excluded individuals, which has aided a fast expansion of financial inclusion over the past decades and nowadays. The Asia-Pacific region is heterogeneous in its approach to financial inclusion due to different income levels, structural changes, and technology adoption. Although the Asia-Pacific region has made noteworthy progress in financial inclusion over the past decades, disparities in access to financial services exist both among and within countries (ESCAP, U, 2022). Also, the gap between rich and poor, rural and urban populations, and men and women have been found to be the

highest in the world (Loukoianova, Yang and De, 2018).

Developing Asia has faced significant economic growth over the recent decades despite enduring challenges of continued poverty and increasing income inequality (ADB, 2021). The COVID-19 pandemic had a significant impact on vulnerable and disadvantaged groups, specifically casual workers, poor segments, and women. With the challenging pathway toward economic recovery, it is crucial to focus on more innovative approaches to financial inclusion. Most importantly, the pandemic has increased the significance of financial services accessibility, which supports economic recovery and resilience; therefore, the Asian Development Bank (ADB) and Asia-Pacific Financial Inclusion Forum (APFIF) have identified financial inclusion priorities to stimulate the Asia-Pacific region's economic recovery.

Many governments of this region have prioritized the digital economy to improve innovation and inclusion as a result of the pandemic. While some countries in this region are ahead of others in FinTech, the region lags behind significant areas, such as online purchases, electronic payments, mobile money, and mobile government transfers, while exhibiting the highest inequality in the use of FinTech, leading to significant gaps between rich and poor and rural and urban areas (Loukoianova, Yang and De, 2018). Therefore, digitalization has not yet benefited everyone equally. These gaps are remarkably apparent during times of crisis, such as epidemics and pandemics. Digitally connected and well-equipped countries, industries, companies, or individuals were able to deal with the pandemic, whereas the weakest organizations and the poorest people living in vulnerable situations were the hardest hit. Therefore, the pandemic has widened a vicious cycle of economic inequality and development gaps in this region (ESCAP, U, 2022).

With formal financial accessibility becoming crucial in improving the well-being of those communities at the bottom of the economic pyramid, bringing policy initiatives toward financial inclusion has become a priority for many governments. Governments across the Asia-Pacific region play a vital role in empowering the poor segment, enabling them to participate in digital financial ecosystems, enabling market-based solutions, and ensuring a regulatory environment (ESCAP, U, 2022). Moreover, the regulators and governments in these regions have undertaken several policy initiatives to increase financial accessibility despite the existing constraints. The approaches are both regulatory and financial to develop the financial infrastructure, such as creating secured transaction laws, collateral registries, credit bureaus, and payment and settlement systems (Madan, 2020). Many governments in developing economies face substantial financing gaps in the development of digital financial infrastructure, where facilitating them while ensuring safety, reliability, and affordability is crucial to achieving DFI.

Given the digital divide, policy priorities and regulatory reforms in this region, it is apparent that financial inclusion is a crucial concept to explore, with a special focus on its influence on economic outcomes in this region. Despite the importance of financial inclusion, few cross-country studies for the Asia-Pacific region are evident (Jahan et al., 2019; Loukoianova, Yang and De, 2018). The cross-country studies conducted have particularly focused on subregions or individual socio-economic characteristics and barriers (Allen et al., 2016; Shihadeh, 2018; Zins & Weill, 2016). Given the importance and significance highlighted in this section, we draw our attention to examining DFI on economic growth in the Asia-Pacific region to fill the empirical and theoretical gaps in the existing literature.

3. Theoretical literature review

Economists' ignorance of the financial sector's role in economic growth is a continuous argument in the literature; however, it is argued that the research that explains finance's role in economic growth will have policy implications and shape forthcoming policy-oriented research (Levine, 2005). The influence of financial inclusion on economic growth can be better explained by Levine's (2005) Theory of Finance and Growth. The theory explains that financial institutions or

intermediaries reduce the cost of acquiring and processing information, which results in improved resource allocation. Financial intermediaries can accelerate economic growth by improving information on firms, managers, and economic conditions. Moreover, this theory comprehends the effect of financial inclusion on economic growth. Financial institutions and FinTech players' decisions on financial accessibility can influence the level of financial inclusion because enhanced financial access will bring more people and firms into the formal financial system (Ozili, 2018; Ozili, Lay, & Syed, 2023). Consequently, deposits from existing and newly banked customers can be used by financial institutions to grant loans, which will be directed toward deficit units. This will accelerate production, investment, and consumption, increasing economic output and growth. The theory explains how financial inclusion boosts economic growth. Hence, we establish the relationship between financial inclusion and economic growth, following the *Theory of Finance and Growth*.

The *System Theory* of financial inclusion claims that financial inclusion effects are realized through various sections of the economic system. This implies that the indicators of financial inclusion will have a positive effect on the financial system, which enhances the performance of financial institutions, leading to the improvement of the economic system through economic growth (Ozili, 2020). According to System Theory, notable changes in one part of the system can substantially affect the expected financial inclusion outcomes. As such, under the System Theory perspective, the existing economic, financial, and social sub-systems in a particular country become the ultimate beneficiaries of financial inclusion. Hence, it is evident that the country's existing economic, financial, and social sub-systems will be beneficial when the financial inclusion efforts are expanded. This further justifies the relationship between financial inclusion indicators and economic growth. Following this theory, we considered financial inclusion indicators to develop the financial inclusion index and then examine its influence on economic growth. As such, both traditional and digital financial accessibility and usage indicators were considered to develop the financial inclusion index to capture the broad picture of financial inclusion and its effect on the existing sub-systems of a country.

The *Diffusion Theory of Innovation* aims to understand how, why and at what rate innovative ideas and technologies spread in a social system (Rogers, Singhal, & Quinlan, 2014). The theory justifies that the innovation of financial services and products through technological advancement at lower economic and social costs is an important matter (Daud and Ahmad, 2023). The technological advancement in mobile phones and internet access has improved the cost of providing banking and finance services, facilitating customized and tailored financial

products available at low cost and in convenient ways (Gulamhuseinwala, Hatch, Lloyd, Bull, & Chen, 2017). The increased adoption of internet-enabled phones in African countries has caused much speculation and optimism concerning its effects on financial inclusion (Evans, 2018). As such, the diffusion of the internet and mobile devices has been spurred in many regions where sensible levels of ICT stimulate the ranges and depths of economic activities, economic productivity, standards of living and access to social development factors, including health care, education, and good governance. In line with this theory, we considered the digital aspect in examining the level of financial inclusion in the Asia-Pacific region.

This paper develops the conceptual framework for this study, depicted in Fig. 1, based on the underlying theories discussed above to identify the independent and dependent variables, establish the relationship, and develop the hypotheses as follows.

4. Empirical literature review and hypotheses development

Digital Financial Inclusion, as a digital means, promotes information while effectively reducing transaction costs and expanding the scope of financial services and coverage through the application of internet technology (Liu et al., 2021). This is further strengthened with the aid of computer information processing, data communication, extensive data analysis, cloud computing, and an array of related technologies in the financial field. The focus of inclusive finance is to constantly improve the financial services availability, through strong development and improved economic infrastructure. This ensures extended financial assistance to the entire society, providing affordable financial services.

The G20 is committed to advancing global financial inclusion by implementing G20 high-level principles for DFI (Global Partnership for Financial Inclusion, 2020). These principles serve as catalysts for adopting digital approaches to achieve financial inclusion goals. The eight identified principles include Principle 1: Promote a digital approach to financial inclusion, Principle 2: Balance innovation and risk to achieve digital financial inclusion, Principle 3: Provide an enabling and proportionate legal and regulatory framework for digital financial inclusion, Principle 4: Expand the digital financial services infrastructure ecosystem, Principle 5: Establish responsible digital financial practices to protect consumers, Principle 6: Strengthen digital and financial literacy and awareness, Principle 7: Facilitate customer identification for digital financial services, Principle 8: Track digital financial inclusion progress.

As highlighted in the G20 Summit, the aim of inclusive growth is to narrow the gap among countries while spreading the bonuses of global

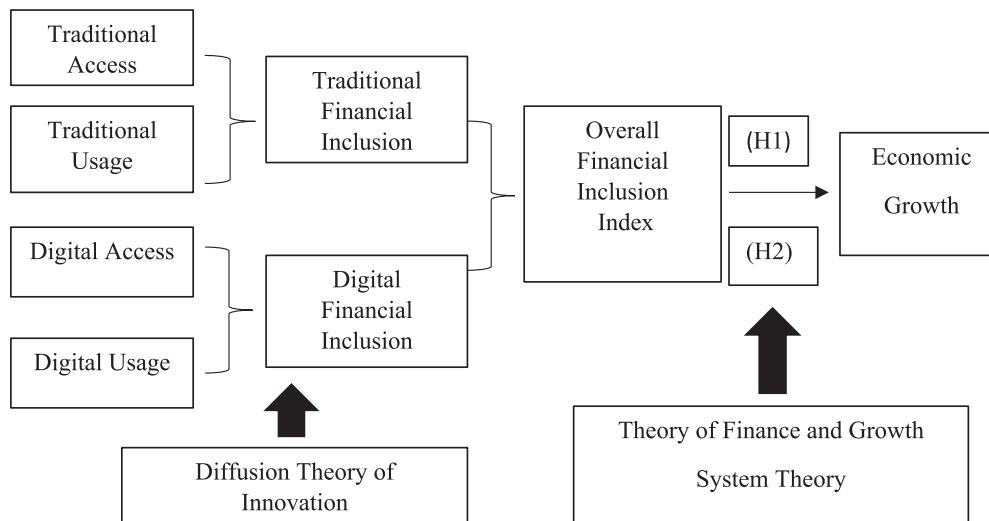


Fig. 1. Theoretical Framework.

economic growth. Nevertheless, despite the extensive literature on growth and inequality, there is a dearth of research on inclusive growth (Wan, Luo, & Zhang, 2017). An important dimension of inclusive growth is its connection to sustainable growth, which is allied to the concept of sustainable development. To mitigate the impact of climate change and various means of environmental degradation, policies should be included in the growth process that ensure sustainable development (Islam, 2016). This essentially emphasizes the need for economic growth to be both socially and environmentally sustainable. In line with this, it is important to identify how DFI relates to the pursuit of the SDGs.

Financial inclusion has helped the development in South Asian countries, as the banks play a leading role in the introduction of inclusive digital financial services such as mobile money, online accounts, electronic payments, insurance, and credits (Thathsarani, Wei, & Samaraweera, 2021). As FinTech has become one of the emerging technologies currently used by many developing countries, introducing FinTech apps supports attracting the younger generation. DFI has become a significant development approach in many economies (Ozturk & Ullah, 2022). Therefore, government and private organizations adopt innovative technologies in the financial sector. This accelerates the money circulation in the country while increasing investment and consumption performances, which drives a high rate of economic growth.

Daud and Ahmad, 2023 conducted their study of 84 countries since the global financial crisis period and found a positive and significant effect of financial inclusion and digital technology on a country's economic growth. Further, they highlighted that digital technology plays a role in complementing the effects of financial inclusion on economic growth, which implies that strengthening efforts need to be placed in improving the financial system via digital technology infrastructure.

Ozturk and Ullah (2022), in their study of 42 One Belt and Road Initiative (OBRI) countries, found that DFI increases economic growth but decreases environmental quality. They suggested that OBRI regions need to formulate policies to improve DFI to achieve economic performance and environmental sustainability. A study conducted by Liu et al. (2021) regarding China showed that the development of DFI has a significant contribution to economic growth. As per their study, DFI development affects economic growth through two important channels: promoting small and medium-sized enterprise entrepreneurship and stimulating residents' consumption. As per the empirical findings of Ahmad et al. (2021), DFI and human capital encouraged economic growth in China, where the Chinese Government should develop supporting strategies to expand DFI. Accordingly, they highlighted that it enables increased financial services penetration and eradicates barriers to access while maintaining profitability and economic growth.

Table 1
A summary of findings on digital financial inclusion and economic growth.

Author/s	Country(s)/ Sample	Data Sources and Sample Period	Methodology	Main Findings
Daud, and Ahmad, A. H. (2023)	84 Countries	FAS, IMF, and World Development Indicators Period: 2011–2017	<ul style="list-style-type: none"> Model: System Generalized Method of Moment. Dependent: GDP growth (annual GDP growth rate %). Independent: Financial inclusion proxied by deposit accounts with commercial banks per 1000 adults, digital technology infrastructure, initial income, investment, population growth rate, and trade openness. 	<ul style="list-style-type: none"> Financial inclusion and digital technology infrastructure do not have a positive effect on the economic growth of the countries; however, the quadratic term of financial inclusion has a significant and positive effect on GDP growth. Initial income and population growth rates have a negative and significant effect on economic growth. Investment and trade openness have a positive and significant effect on economic growth. ATMs per 100,000 adults and debit cards (% age 15+ years) have a significant and positive effect on economic growth. Internet usage by individuals, industrialization, energy consumption, and foreign direct investment are significant determinants of economic growth. Inflation has a significant negative effect on economic growth.
Ozturk and Ullah (2022)	42 OBRI countries	FAS, IMF, and World Bank Period: 2007–2019	<ul style="list-style-type: none"> Model: Ordinary least square (OLS), two-stage least squares (2SLS), generalized method of moments (GMM) approach. Dependent: GDP growth (annual GDP growth rate %). Independent: DFI proxied by ATMs per 100,000 adults and debit cards (% age 15+ years), internet usage by individuals, industrialization, energy consumption, foreign direct investment, inflation. Model: Panel threshold estimation, two-stage least square method. Dependent: Natural logarithm of GDP per capita (USD). Independent: Log DFI, physical capital stock per capita, Human capital level, industry structure, urbanization level. Model: fixed effect, panel-corrected standard errors mode, fixed effect robust regression, Driscoll-Kraay robust standard error method. Dependent: Log GDP per capita. Independent: Log DFI, Human capital, government expenditure on science and technology, inflation, trade openness, population growth rate. 	<ul style="list-style-type: none"> DFI has a significant and positive effect on the economic growth of China. Physical capital stock per capita, human capital level, industry structure, and urbanization level are significant determinants of China's economic growth. DFI positively and significantly affects China's economic growth. Human capital, inflation, and population growth rates are significant determinants of China's economic growth. Inflation and trade openness show a negative effect on the economic growth of China.
Ahmad et al. (2021)	30 China Provincial data	Website of the Statistics Bureau of the People's Republic of China, the statistical offices of provinces, autonomous regions, and municipalities, published social development bulletins, and the Peking University digital Finance research center. Period: 2011–2019	<ul style="list-style-type: none"> Model: Spatial Durbin Model. Dependent: GDP per capita. Independent: Inflation, government expenditure, education, unemployment, population growth rate, urbanization level, Gini index. 	<ul style="list-style-type: none"> DFI affects economic growth positively and significantly. Government expenditure, population growth rate, urbanization level and Gini index are significant determinants of economic growth. Inflation does not have an effect on economic growth. Education and unemployment negatively affect economic growth.
Shen, Hu, & Hueng, 2021)	31 China Provinces	China statistical yearbook and Peking university DFI index of China Period: 2011–2018		
Shen, Hu, & Hueng, 2021)	86 Countries	FAS, IMF, and World Bank. Period: 2017		

Similarly, policymakers can use financial technology providers to deliver digital financial services, enabling financial institutions to provide services at low cost and in remote locations, which will advance economic growth.

However, there exists a vacuity in the existing literature for clearly investigating the relationship between DFI and economic growth (Ahmad et al., 2021). Furthermore, one of the most important constraints is that researchers have used traditional financial inclusion proxies, such as commercial bank branches per 100,000 adult population, the number of ATMs in 1000 km², and the measure of credit and deposits as a percentage of gross domestic product (GDP). Concentrating merely on financial inclusion through traditional measures might not provide a holistic picture in addressing the objective of sustainable economic growth. As shown in the limited literature, the important new digital financial services are still absent from the traditional financial inclusion index; therefore, this paper explores the impact of DFI on economic growth in Asia-Pacific countries with a new measurement of the DFI index. The summary information of the past studies conducted on DFI and economic growth to bring further understanding of the literature is shown in Table 1.

The established theoretical backgrounds in Section 3 support the empirical literature that infers the nexus between DFI and economic growth. Followed by the theories and empirical literature highlighted above, we developed two main hypotheses for this study based on the previous literature.

4.1. Linear relationship between digital financial inclusion and economic growth

The System Theory of financial inclusion identifies the role of a country's existing economic, financial, and social systems in fostering financial inclusion, highlighting a macro perspective on financial inclusion. Interestingly, this theory considers how financial inclusion outcomes are affected by the interrelationship among the sub-systems that financial inclusion relies on (Ozili, 2020). Moreover, the theoretical models illustrate that financial instruments, markets, and institutions come up to mitigate the effects of information and transaction costs (Levine, 2005). The finance-growth nexus confirms that financial systems may affect saving rates, investment decisions, and technological innovation, leading to long-run growth rates. Drawing on the Diffusion Theory of Innovation, FinTech innovations have been found to enable financial services accessibility through mobile devices for many unbanked populations worldwide (Senyo & Osabutey, 2020). In line with these theories, the existing studies show that financial inclusion is related to economic growth (Ozili et al., 2023). Moreover, the empirical literature identifies some studies that examined the relationship between DFI and economic growth. Daud and Ahmad, 2023 studied 42 OBRI countries from 2007 to 2019 and discovered that DFI increases economic growth. They found that digital technology played a role in the effect of financial inclusion on economic growth. Moreover, Ahmad et al. (2021) found that China's swift growth of DFI in the last several years has intensely improved the accessibility and affordability of financial services and served formerly excluded people from the financial system, positively contributing to higher economic growth. Therefore, we propose the first hypothesis:

Hypothesis 1. Digital financial inclusion linearly affects economic growth.

4.2. Non-linear relationship between digital financial inclusion and economic growth

The empirical analysis initially adopts a threshold regression model for static panels introduced by Hansen (1999). This determines the exogenous threshold level that splits the overall regression. However, despite many potential applications, there is a dearth of statistical theory of threshold estimation (Hansen, 2000). However, using the panel

threshold regression model, several studies have examined the non-linear relationship between financial inclusion and economic growth. A study by Karim, Nizam, Law, and Hassan (2022) of 60 countries showed that financial inclusion had a non-monotonic influence on economic growth, highlighting that a low level of financial inclusion substantially stimulates economic growth, while a high level of financial inclusion does at a decreasing rate. Similarly, Nizam, Karim, Sarmidi, and Rahman (2021) identified a threshold effect of financial inclusion on the nexus between financial inclusion and economic growth in developed and developing countries. Hence, we propose the next hypothesis:

Hypothesis 2. A non-linear relationship exists between digital financial inclusion and economic growth.

5. Research design

5.1. Data and sources of data

As per Khera et al. (2021) and Shen, Hu, and Hueng (2021), the indicators (see Appendix Table A1) have been identified to construct the DFI index – the independent variable. The index consists of four dimensions: traditional access, traditional usage, digital access, and digital usage. The data relating to the traditional financial access dimension were obtained from the 2022 Financial Access Survey (*Financial Access Survey*, 2022) of the IMF, and indicators for the traditional usage dimension were obtained from the *Global Findex Database*, (2021). Digital financial access-related measures were obtained from the *International Telecommunications Union*, (2024) and Digital financial usage-related measures were obtained from the *Global Findex Database*, (2021). The GDP per capita- the dependent variable, and selected macroeconomic variables used to control the possible factors that affect economic growth were obtained from *World Development Indicators*, (2022). The study uses control variables such as the population growth rate, gross capital formation, tertiary education rate, unemployment rate, and inflation rate, following Kim, Yu, and Hassan (2018) and Shen, Hu, and Hueng (2021). The rule of law following Chomen (2022) was obtained from *Worldwide Governance Indicators*, 2022.

We used GDP Per Capita (constant 2015 US\$) in the natural logarithm as the proxy variable to measure the economic growth, which eliminates the differences in economic growth caused by different population sizes (Liu et al., 2021). We used 16 indicators covering traditional access, traditional usage, digital access, and digital usage to construct the DFI index, as shown in Fig. 2. Data on the population aged 15–64 years were used to calculate the population growth and used in natural logarithms. Gross capital formation (at constant prices), in natural logarithms, was used as a proxy for capital formation. To measure tertiary education, we used the percentage of tertiary school enrollment. The GDP deflator (annual %) was used as a proxy for the inflation rate, and the rule of law is an estimate of governance, which ranges from -2.5 (weak) to 2.5 (strong). Table 2 provides a summary of the variables used for this paper.

Countries for the study – East and North-East Asia, North and Central Asia, South-East Asia, South and South-West Asia, and the Pacific – were selected based on the United Nations Economic and Social Commission for Asia and Pacific (UNESCAP; see Appendix Table A2; *United Nations Economic and Social Commission for Asia and Pacific*, 2024.). A total of 60 countries are listed in the UNESCAP country classification for the Asia-Pacific region. The number of countries selected for this study was limited by data availability. Specifically, data related to the DFI indicators in the Findex database is unavailable for many Pacific islands. Some countries, such as Bhutan and the Maldives, were excluded from the sample due to the unavailability of data for all the years under consideration. Some countries were removed due to the unavailability of data for the control variables selected in the study. A sample of 30 countries was selected, representing all the five subregions. Table 3

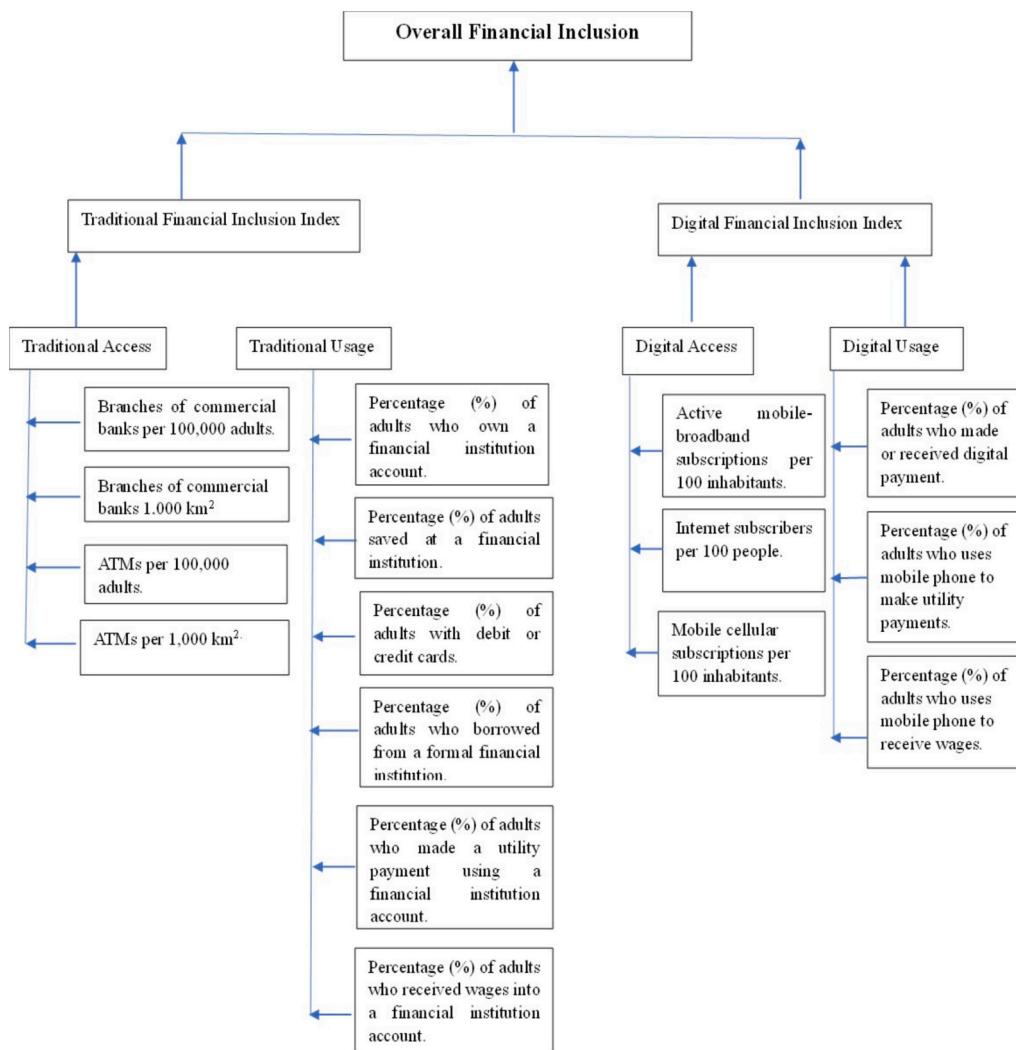
**Fig. 2.** Financial Inclusion Dimensions.

Table 2
Variables and proxies.

Categories	Variables	Proxies Used
Dependent variable	Economic growth	GDP per capita (constant 2015 US\$)
Independent variable	DFI index	DFI index computed by authors
Control variables	Population growth rate Gross capital formation Tertiary education rate Unemployment rate Inflation rate Rule of law Trade openness	The growth rate of the population aged 15–64 years Gross capital formation (at constant prices) School enrollment, tertiary (% gross) Unemployment, total (% of the total labor force) (modeled ILO estimate) Inflation, GDP deflator (annual %) The rule of law: estimate Trade (% of GDP) Foreign direct investment, net inflows (% of GDP) General government final consumption expenditure (% of GDP)
Additional control variables	Government expenditure Gross domestic savings Instrument variable	Gross domestic savings (% of GDP) Percentage (%) of the population who has access to internet

Table 3
Sample selection.

Total countries in the Asia-Pacific region	60 countries
Countries not available due to limited data	27 countries
Countries with only one year of data	3 countries
Sample countries selected for the study	30 countries

outlines the total population and selection of the sample for this study.

5.2. Methodology

5.2.1. Financial inclusion indexing strategy

This section discusses the development of the DFI index. The existing literature related to financial inclusion measurement has focused on a single measure of financial inclusion using different indicators representing traditional financial inclusion dimensions. Moreover, recent studies have developed comprehensive measures considering various aspects of financial access and usage by households and firms. However, these measures have not captured the role of technology in financial services (Khera et al., 2022). Because mobile money operators and FinTech companies are playing a vital role at different phases across countries, including the banks that have started adopting technology in delivering financial services, capturing and quantifying access and usage of digital financial services is found to be important. Though some

studies have quantified the extent of DFI by taking relevant indicators (Cámará & Tuesta, 2014; Loukoianova, Yang and De, 2018), those measures have captured a single aspect, overlooking the comprehensive picture of multiple aspects.

This study focuses on constructing a comprehensive financial inclusion index, incorporating digital access and usage measures. The study contributes to a new measurement of the financial inclusion index by developing a DFI index for 30 Asia-Pacific countries for 2014, 2017, and 2021. As traditional financial inclusion has some weaknesses, the conventional financial inclusion index is assumed to be inadequate in measuring actual financial inclusion. Hence, the present study will use both sources of indicators, including the digital financial aspects that include the financial technology dimensions, as a new demand-side indicator and a supply-side indicator in constructing a new financial inclusion index.

Following the previous literature (Khera et al., 2022; Nizam, Karim, Rahman, & Sarmidi, 2020), a three-stage PCA is employed to determine each indicator's weight and then develop the index. The first stage computes the access and usage sub-indices. The second stage computes the traditional and DFI indices. Accordingly, in the third stage, a weighted combination of these forms a comprehensive measure of overall financial inclusion; here onwards, referred to as the *DFI index*. The indicators used to make up the indices are depicted in Fig. 2.

The multidimensional index of DFI (IDFI) is developed as follows:

$$\text{IDFI} = \sum_{i=1}^k W_i X_i \quad (1)$$

where W_i is the factor loading and X_i is the respective dimension of the financial inclusion. Following a three-stage PCA analysis, the eigenvalues generated from the analysis are considered to identify an appropriate principal component to generate the respective dimension. Accordingly, the principal components with the larger proportion(s) of the variation (eigenvalue greater than 1) in eigenvalues are selected as the weights in generating the sub-dimensions and the overall financial inclusion index, respectively.

5.2.2. Empirical model

Using the new DFI index computed, the study aims to find its impact on economic growth across 30 countries in the Asia-Pacific region during the years 2014, 2017, and 2021. The empirical linkage between DFI and economic growth can be written as shown below.

$$\ln\text{GDPPC}_{i,t} = \beta_0 + \beta_1 \text{IDFI}_{i,t} + \sum_{k=1}^n \delta_k X_{i,t,k} + \varepsilon_{i,t} \quad (2)$$

where, $\ln\text{GDPPC}_{i,t}$ is the natural logarithm of real gross domestic product per capita, $\text{IDFI}_{i,t}$ is the index of DFI (in percentages). $X_{i,t}$ indicate the vector of control variables and $\varepsilon_{i,t}$ is the error term. Based on the previous literature, we controlled the variables that affect economic growth, such as population growth, gross capital formation, tertiary education rate, unemployment, inflation rate, and rule of law. The panel data consisting of 30 countries during the years 2014, 2017, and 2021 are used to identify the influence of DFI on economic growth. The fixed effect regression with a robust error of heteroskedasticity and autocorrelation is performed for the data.

This study employs a panel threshold regression model to examine if a non-linear relationship between DFI and economic growth exists. The panel threshold model shows the non-monotonic influence of DFI on economic growth. This assumes that financial inclusion has a threshold value that leads to promising economic growth in countries (Raouf, 2022). To examine if a non-linear relationship exists between financial inclusion and economic growth in 30 selected Asia-Pacific countries, we use the panel threshold regression model as follows:

$$\begin{aligned} \ln\text{GDPPC}_{i,t} = & \alpha_0 + \beta_1 \text{IDFI}_{i,t} I(\text{IDFI}_{i,t} \leq \gamma) + \beta_2 \text{IDFI}_{i,t} I(\text{IDFI}_{i,t} \\ & > \gamma) + \sum_{k=1}^n \delta_k Z_{i,t,k} + \varepsilon_{i,t} \end{aligned} \quad (3)$$

where $\text{IDFI}_{i,t}$ is the DFI index (threshold variable); γ is the threshold parameter that divides the equation into two regimes with coefficients β_1 and β_2 . $Z_{i,t,k}$ represent the vector of control variables; $I(\cdot)$ is the indicator function that takes the value "1" if the condition in parenthesis is met and "0" otherwise. α_0 is the constant and $\varepsilon_{i,t}$ is the error term.

6. Empirical results and discussion

6.1. Construction of index of digital financial inclusion

We first discuss the DFI index computed through PCA analysis – the first objective. In developing the index, the indicators of financial inclusion were normalized, so the values range from "0" to "1". Using data for the six indices for years 2014, 2017, and 2021, we conducted the PCA for the 30 countries. Following the first stage of PCA, using the respective indicators, we indexed digital access, digital usage, traditional access, traditional usage sub-indices. The second stage includes generating traditional and DFI indices. Finally, in the third stage, the overall financial inclusion index was generated using the two indices developed in the second stage. The results of PCA can be found in Appendix – Table A4-A10.

Using the DFI constructed, the country-wise DFI index in the Asia-Pacific region is presented in Fig. 3. When the financial inclusion index is closer to "0", it reflects financial exclusion, and when it is closer to "1", it reflects a high level of financial inclusion. Singapore, Korea, Japan, Australia, and New Zealand are financially inclusive countries, while Pakistan, Laos, Myanmar, and Tajikistan are financially exclusive countries, as shown in Fig. 3.

We analyzed the trend of DFI and traditional financial inclusion over 3 years in selected countries in our sample under high-income, upper-middle-income and lower-middle-income countries, based on World Bank country classification. Country classification is based on gross national income (GNI) per capita calculated using the World Bank Atlas method. Lower-middle-income economies are those with a GNI per capita between \$1136 and \$4465; upper-middle-income economies are those with a GNI per capita between \$4466 and \$13,845; and high-income economies are those with a GNI per capita of \$13,846 or more. The financial inclusion trends for high-income, upper-middle-income, and lower-middle-income countries are shown in Figs. 4, 5, and 6, respectively. For the high-income and upper-middle-income categories, the countries with high GDP per capita in our sample were selected for the visual depiction. The countries at the bottom level with lower GDP per capita in our sample were selected to represent the lower-middle-income countries. DFI is at a higher level in high-income countries, while traditional financial inclusion tends to decrease over time, as shown in Fig. 4. However, these countries do not show a significant increase over time in DFI except in Japan. DFI in upper-middle-income countries, as per Fig. 5, shows a substantial upward trend over time compared to high-income countries. Traditional financial inclusion does not show a clear change over time. It shows an increasing trend in China and Kazakhstan, while Turkey shows a declining trend over time. In contrast, a low level of DFI and traditional financial inclusion is found in lower-middle-income countries, as shown in Fig. 6. Yet, it shows a slight upward trend in DFI over time. Declining traditional financial inclusion does not mean that people are excluded from the financial system. Instead, that is replaced with financial inclusion through digitalization. DFI shifts people from traditional financial systems toward digital financial systems while bringing previously unbanked and underbanked people to the formal financial system.

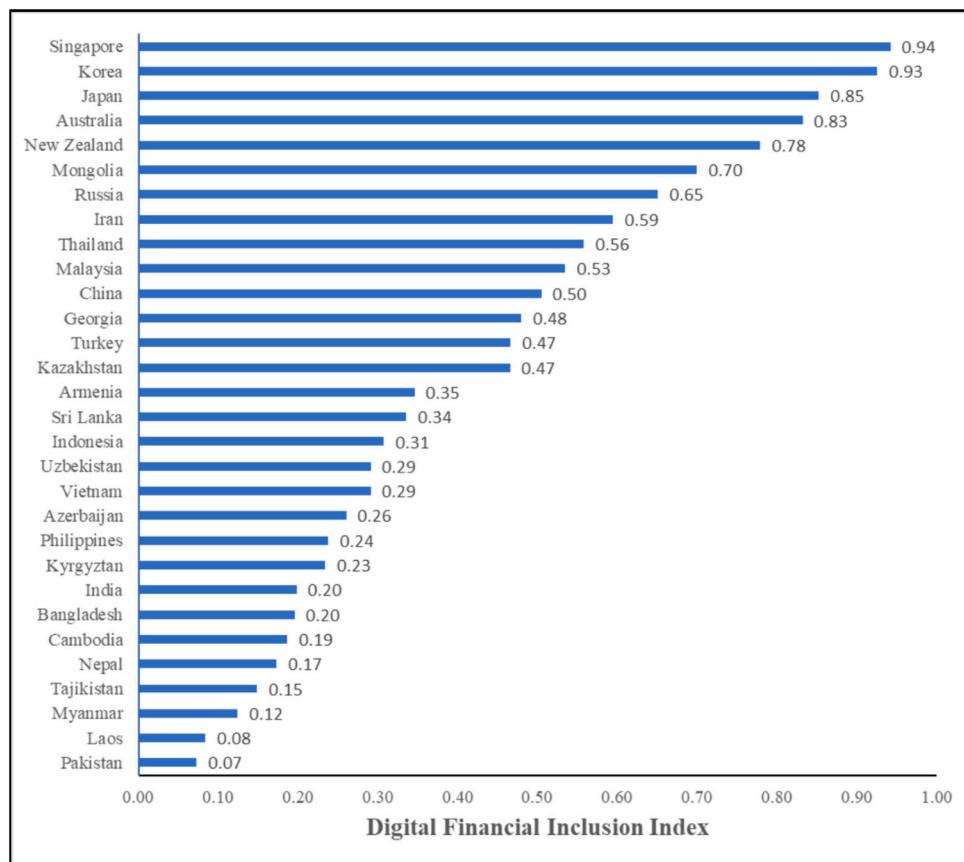


Fig. 3. Digital Financial Inclusion Index, 30 countries.

6.2. Model estimation

We plot economic growth against the DFI of 30 Asia-Pacific countries to see, visually, if financial inclusion and economic growth are linearly related, as shown in Fig. 7. The upward-sloping line shows a positive relationship between financial inclusion and economic growth, which states that the higher the level of financial inclusion is, the higher the economic growth of the respective country.

The impact of DFI on economic growth in 30 Asia-Pacific countries using the constructed DFI index is presented in Table 4. The corresponding equation is:

$$\begin{aligned} \ln GDPPC_{i,t} = & \alpha_0 + \beta_1 IDFI_{i,t} + \beta_2 \ln PopGrowth_{i,t} + \beta_3 \ln GrossCap_{i,t} \\ & + \beta_4 Education_{i,t} + \beta_5 Unemployment_{i,t} + \beta_6 Rule of Law_{i,t} \\ & + \beta_7 Inflation_{i,t} + \epsilon_{i,t} \end{aligned} \quad (4)$$

Performing the Hausman test, the fixed effect (FE) regression is preferred over the random effect (RE). As such, the estimation results of FE regression are presented in column (1) of Table 4. The DFI index was taken in percentage to estimate the impact of DFI on economic growth. As can be seen from the table, financial inclusion has a significant and positive effect on economic growth. The population growth shows a significant negative effect on economic growth. While Gross capital formation, tertiary education rate, and the rule of law show significant positive effects, unemployment and inflation show insignificant effects on economic growth.

The Asia-Pacific region is said to have the broadest digital divide in the world (ESCAP, U, 2022) among and within countries. In the East Asia region, countries such as China, Japan, and the Republic of Korea are sophisticated, while the small Pacific Island are likely to be the least connected, followed by countries in South and South-West Asia. Among

the subregions, ASEAN is the most divided, where Singapore is the most superior, while Myanmar lags significantly behind. However, the COVID-19 pandemic has brought a global shock to the socioeconomic system while significantly affecting the quality of people's lives, coupled with millions of deaths and destroyed livelihood. But on the other hand, this has also driven the countries to accelerate digital adoption at an unprecedented pace. It is evident that one of the most significant developments in finance over the last decade is technology-driven innovation. Therefore, we assume that DFI is crucial to a country's economic growth. As such, the positive and significant effect of DFI on economic growth confirms that DFI influences economic growth in the Asia-Pacific region.

The findings of the linear regression in this study are consistent with the past studies conducted by Ozturk and Ullah (2022), who found a positive and significant effect of DFI on economic growth using 42 OBRI countries. Moreover, findings of studies conducted in China by Ahmad et al. (2021) and Liu et al. (2021) also found a positive and significant impact of DFI on economic growth. Thus, the findings of our study are consistent. Theoretically, the findings support the Theory of Finance and Growth. Because shift toward DFI can be enhanced by the decisions of financial institution and Fintech players on financial accessibility which will bring more people into the formal financial system (Ozili, 2018; Ozili et al., 2023). This is evidenced by the upward trends of DFI shown in the high-income, upper-middle-income and lower-middle-income countries over the years 2014–2021 (refer to Figs. 4–6). These trends justify that FinTech innovation facilitates financial services accessibility (Senyo & Osabutey, 2020) and usage through mobile services and the internet for the unbanked population in this region. This paper further demonstrates that financial intermediaries can accelerate economic growth by improving information on firms, managers, and economic conditions through enhanced DFI (Levine, 2005; Ozili et al., 2023).

Moreover, the findings demonstrate that the existing systems of a

High-income Countries

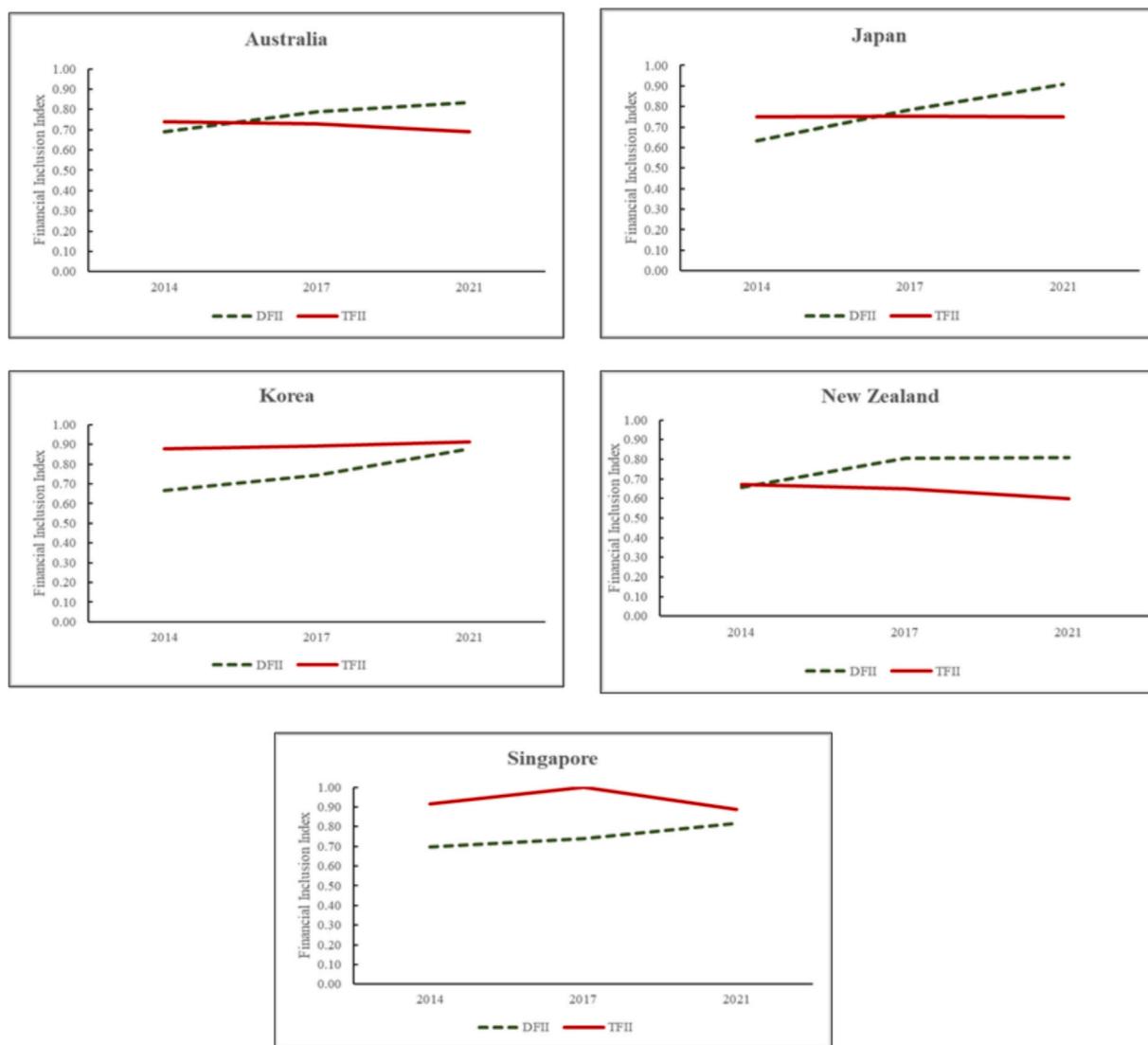


Fig. 4. Financial Inclusion Trends in High-income Countries – 2014, 2017, and 2021.

country, including economic, finance, and social subsystems, will be beneficial when the financial inclusion efforts are expanded, given the significant and positive effect of DFI on economic growth. Therefore, our findings contribute to the System Theory. As discussed in section 2 of this paper, despite the digital divide in this region following the COVID-19 pandemic, the digital adoption of these countries has accelerated at an unprecedented rate, which has contributed to enhanced financial inclusion and, thus, boosted economic growth.

The findings more clearly contribute to the Diffusion Theory of Innovation, which justifies the rate of spreading innovative ideas and technologies in a social system (Rogers et al., 2014). Our analysis of financial inclusion trends has clearly identified how the DFI has grown over the years in selected countries. This confirms technological advancement in mobile phones and internet access that enable banks to provide banking and financial services at a low and convenient cost (Daud and Ahmad, 2023; Gulamhuseinwala et al., 2017), which stimulate economic productivity and quality of life with access to health care, education, and good governance in this region. As a result, the findings help accept our first hypothesis: DFI linearly affects economic growth.

In this paper, we employed the panel threshold regression model to assess if DFI has a threshold effect on economic growth because the linear model does not capture it. This examines the optimum level or minimum turning point of DFI that brings positive economic growth and assumes a non-linear relationship between financial inclusion and economic growth (Nizam et al., 2020; Raouf, 2022).

The panel threshold regression model has been extensively used in financial and macroeconomic fields (Wang, 2015). Nizam et al. (2020) considered developed and developing countries and found a non-linear relationship between financial inclusion and economic growth. Khera et al. (2022) also examined the impact of inclusive finance on economic growth using a dynamic panel threshold estimation technique and concluded that a threshold effect existed in the nexus between financial inclusion and economic growth. Their findings highlight that the positive effect of finance on growth is more noticeable in low-income than in high-income countries.

Table 4, column (2), shows the panel threshold regression model estimation results. The results show that the threshold effect of DFI is high in regimes with low DFI, while it is positive but substantially low in regimes with high DFI. However, the impact of DFI on economic growth

Upper middle-income Countries

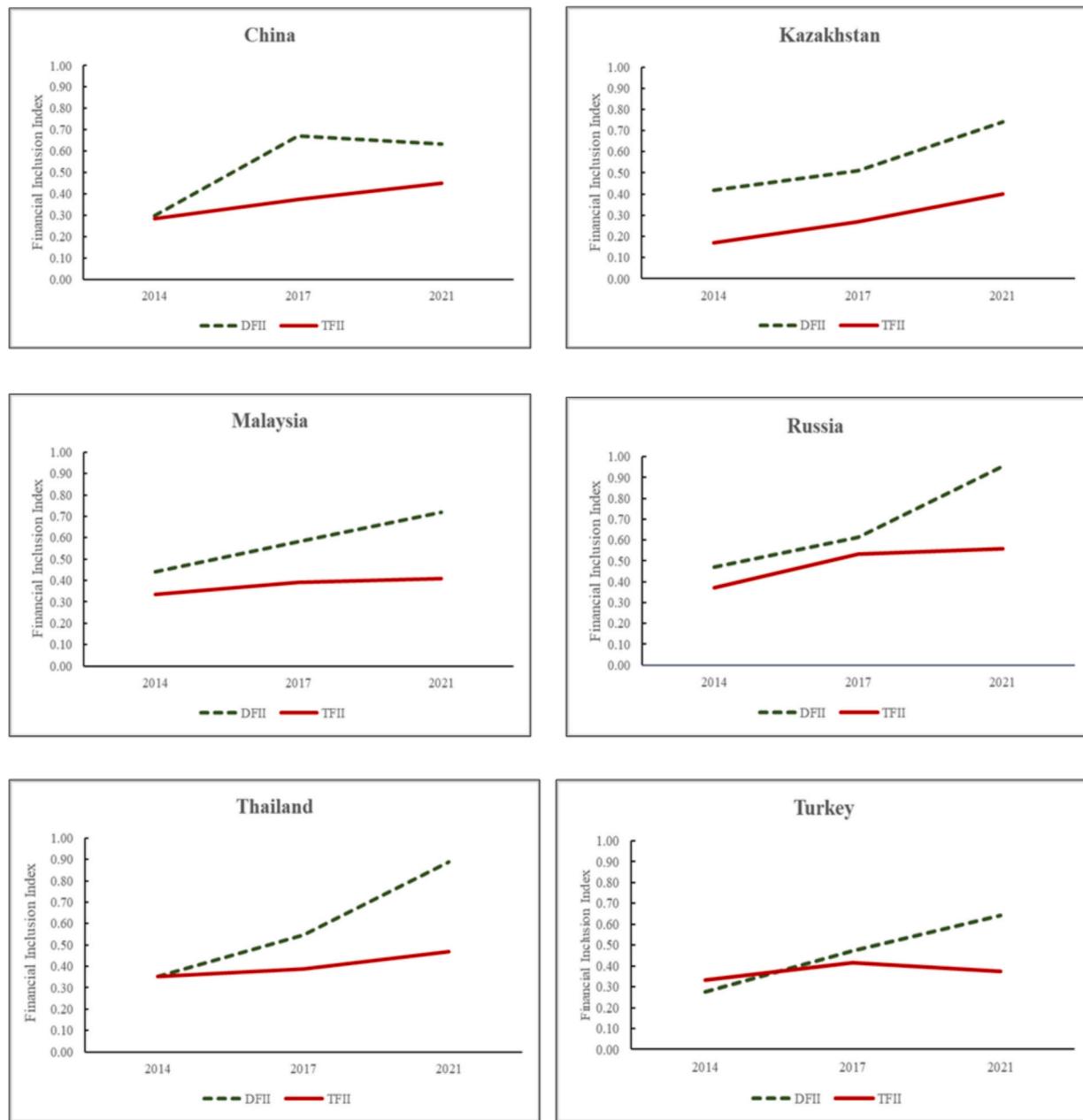


Fig. 5. Financial Inclusion Trends in Upper-middle-income Countries – 2014, 2017, and 2021.

in regimes with both low and high financial inclusion is significant. As such, the advancement in DFI has a non-linear inverted U-shaped impact on economic growth. With constant increases in DFI, economic growth increases significantly; however, when the level of DFI exceeds 71.87 %, economic growth increases at a reduced rate. The result verifies the different impacts of DFI under various levels and shows the gradual changing of marginal effect. Accordingly, at the early stages, the level of DFI contributes to the improvement of economic growth at an increasing rate. However, when the level of DFI reaches a certain level – the optimum level – the marginal effect of DFI on economic growth starts to decline. This shows the structural break in the relationship between DFI and economic growth in Asia-Pacific countries. In line with this, the development of DFI increases economic growth in countries with high DFI while showing a significant and substantial increasing effect of DFI

on economic growth in countries with low DFI compared to economies with high levels of DFIs, which confirms noticeable implications for an economic policy (Hansen, 1999; Hansen, 2000). Moreover, empirically, the non-linear relationship between DFI and economic growth in the Asia-Pacific region identified in this paper is consistent with past studies conducted by Karim et al. (2022) and Nizam et al. (2020).

Economic growth does not happen overnight: It is an extended journey. Nevertheless, if the uptake of the digital financial solution is high in a country, it can make progress fast. For instance, if a person lives in a rural area and must spend much time traveling to a banking agent, the travel is likely to reduce the efficiency and productivity of that person. Instead, digitalization is more likely to reduce cost and increase efficiency, enabling them to engage in productive work over commuting for a bank agent or a financial institution. This can facilitate small

Lower middle-income countries

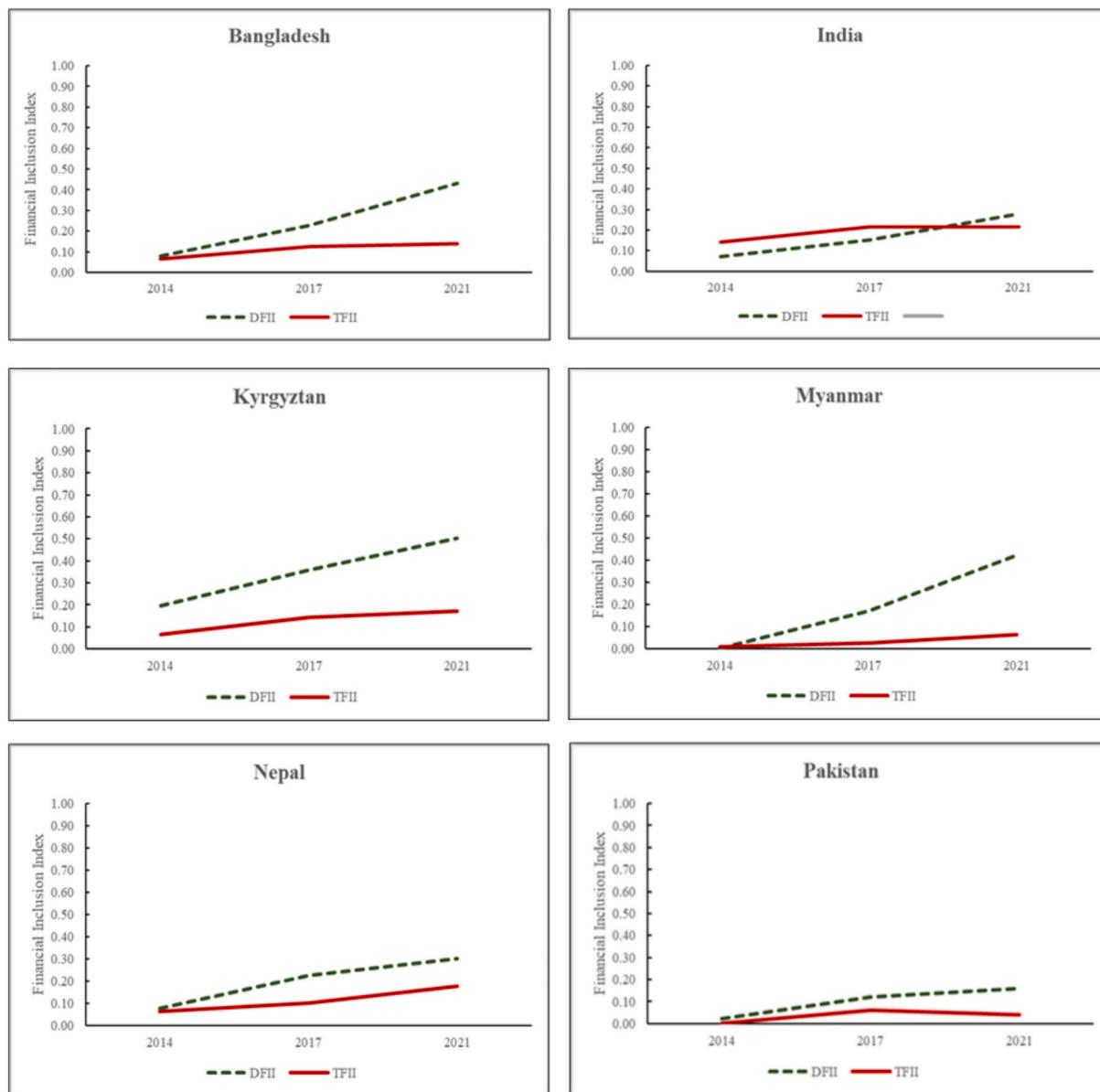


Fig. 6. Financial Inclusion Trends in Lower middle-income Countries – 2014, 2017, and 2021.

businesses to expand their business, having enhanced access to credit. So, a small farmer can get loans to buy the required seeds, fertilizer, and other accessories to improve the yield, which will enhance the income. On the other hand, a much broader customer base of individuals and businesses will create new business prospects for banks, telecommunication companies, and FinTech companies. It is apparent that finance digitalization is an effort taken over many years; however, the quicker they are established, the faster the benefits will come, leading to higher growth, greater innovation, and more inclusion (Manyika, Lund, Singer, White, & Berry, 2016).

As per the McKinsey Global Institute, digital finance could increase the level of GDP of emerging economies by a total of 6 % (\$23.7 trillion) by 2025. This requires an increase in digital payments over the next 10 years at a similar rate to that achieved by the top quartile of developed economies over the long term (Manyika et al., 2016). The potential impact on GDP for countries depends on the starting point; as such, lower-income countries have the largest potential with low level of

financial inclusion (Fig. 6) and digital payments today. Middle-income countries can potentially improve GDP by a reasonable amount with their higher level of financial inclusion (Fig. 5) and digital payments. However, when more investment is made in digitalization in high-income countries, they may fail to achieve the expected return enhancement, as explained in the theory of the “digitalization paradox” (Gebauer, Fleisch, Lamprecht, & Wortmann, 2020). This confirms the non-monotonic influence of DFI on economic growth in the Asia-Pacific region. Consequently, the second hypothesis of the study, that a non-linear relationship exists between DFI and economic growth, can be accepted.

6.3. Robustness test

We used various methods to examine the robustness and endogeneity of the models.

As we take log GDP per capita as the dependent variable, missing

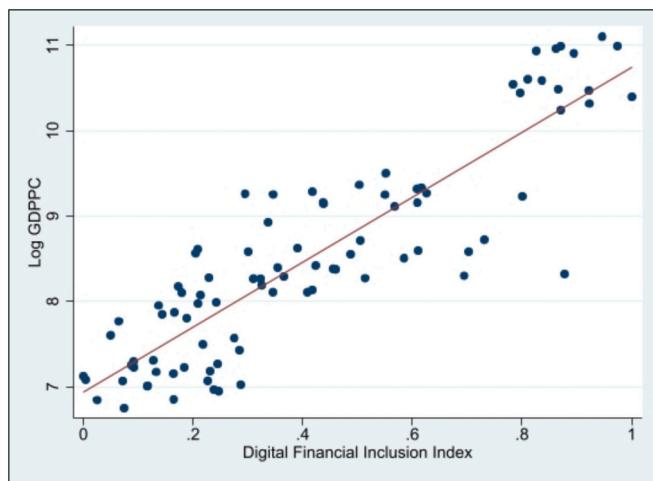


Fig. 7. Digital Financial Inclusion vs. Economic Growth.

Table 4
Estimation results of fixed effect and panel threshold regression model.

Variables	Linear	Non-Linear
	(FE Regression)	(Threshold regression)
	(1)	(2)
DFI index	0.005*** (0.001)	
DFI index (<71.87)		0.007*** (0.001)
DFI index (>71.87)		0.004*** (0.001)
Population growth rate	-3.470** (1.330)	-4.004** (1.969)
Gross capital formation	0.146** (0.057)	0.189*** (0.045)
Tertiary education rate	0.005** (0.002)	0.003** (0.002)
Unemployment	0.003 (0.011)	0.004 (0.009)
Rule of law	0.001** (0.000)	0.001** (0.001)
Inflation	0.004 (0.003)	0.005** (0.002)
Constant	6.940*** (1.897)	6.275** (1.894)
N	90	90
R-sq	0.660	0.750
Adj. R-sq	0.631	0.573

Notes. The standard errors are in parentheses.

*, ** and *** denote significance at the 10 %, 5 %, and 1 % levels, respectively. The F statistic for threshold model test results is 31.34, with a p-value of 0.01; therefore, the null hypothesis of no threshold effect can be rejected at the 1 % significance level (See Appendix Table A11).

variables can affect the regression results. This paper uses population growth, gross capital formation, inflation, tertiary education rate, unemployment rate, and the rule of law as the control variables. Considering that other variables may affect economic growth; the paper re-examines the baseline model, adding more control variables. The results in column (1) of Table 5 show that the empirical results remain unchanged after adding more control variables. This ensures that financial inclusion significantly influences economic growth in Asia-Pacific countries.

Next, we use internet penetration as an instrumental variable for the two-stage least square analysis (2SLS). In selecting a valid instrumental variable, it is essential to satisfy both the correlation and homogeneity conditions (Liu et al., 2021). To examine whether DFI and economic growth nexus are driven by simultaneity bias, an instrumental variable

Table 5
Robustness and endogeneity test results.

	Adding more control variables	2SLS
	(1)	(2)
DFI index	0.005*** (0.001)	0.034*** (0.011)
Population growth	-5.843** (2.264)	5.087 (12.05)
Gross capital formation	0.151** (0.061)	0.043 (0.026)
Tertiary education	0.003* (0.002)	0.002 (0.006)
Unemployment	0.005 (0.011)	-0.009 (0.019)
Rule of law	0.001** (0.001)	0.002 (0.002)
Inflation	0.004 (0.003)	-0.009 (0.012)
Trade openness	0.001 (0.001)	
Foreign direct investment	-0.005 (-0.004)	
Government expenditure	-0.010 (-0.008)	
Gross domestic savings	0.001 (0.002)	
Constant	8.567** (2.432)	2.516 (8.576)
N	90	90
R-Sq	0.683	0.833
Adj. R-sq	0.639	0.819
LM-Statistics		18.67
Wald-Statistics		491.53

Notes. The standard errors are in parentheses.

*, ** and *** denote significance at the 10 %, 5 %, and 1 % levels, respectively.

that explains cross-country differences in DFI is a necessity (Khera et al., 2021). DFI depends on the internet, so these are highly correlated. This serves as the basis for selecting internet penetration as an instrumental variable. Moreover, internet penetration is driven by national policies on infrastructure and hence considered a valid instrumental variable. As shown in column (2) of Table 5, the instrumental variable results ensure that DFI significantly contributes to economic growth at a 1 % significance level. The Cragg-Donald Wald F-test for weak instrumental variables is 18.67, which is higher than the critical value of 16.38 under 10 % bias, implying no under-identification of instrumental variables and weak instrumental variables.

7. Summary and conclusion

7.1. Main conclusion

In this paper, we examined the influence of DFI on economic growth in the Asia-Pacific region, both from linear and non-linear perspectives. This was motivated by the limited research previously conducted on the relationship between DFI and economic growth, in particular in this region and also due to the lack of use of comprehensive financial inclusion measurement capturing the broader picture of financial inclusion, including the digital aspect. Given the importance of understanding broader financial inclusion and its influence on the economic growth of countries in this region, it is essential to capture the extent to which the people are digitally embraced and included in the financial system of this region and how it affects economic outcomes. To address these gaps, the study focused on three main theories, namely the *Theory of Finance and Growth*, the *System Theory*, and the *Diffusion Theory of Innovation*.

We presented over-time trends of digital and traditional financial inclusion over 3 years in selected high-income, upper-middle-income, and lower-middle-income countries using the newly developed DFI index. It shows an upward trend in terms of DFI, regardless of the level of

DFI in each country. In the empirical analysis, we used FE and panel threshold estimation techniques to examine the linear and non-linear nexus between DFI and economic growth using country panel data from the years 2014, 2017, and 2021. The baseline results have confirmed that DFI significantly promotes economic growth in Asia-Pacific countries. The development of DFI advances economic growth in high-income and upper-middle-income countries. However, though DFI is low in low-income countries, the increasing effect of DFI has a significant contribution to economic growth compared to high-inclusive countries. Our panel threshold regression model statistically proves this, which shows that DFI has different roles under low-inclusive and high-inclusive regimes in enhancing economic growth.

Moreover, this paper assessed the robustness, adding more control variables to the baseline model and using two-stage least square regression. Both methods ensure robustness, with the main independent variable remaining unchanged when more variables were added and 2SLS satisfying the statistical requirement, as explained in the previous section.

7.2. Policy recommendations

In addition to the theoretical contribution, this study brings practical implications. The study identified a substantial increase in DFI, indicating that people are likely to embrace the digital economy despite the digital divide in this region. Therefore, DFI is essentially a crucial aspect of overall financial inclusion in this region. The findings ensure that the reinforcement of DFI through the development of digital technology affects financial inclusion and then enhances the economic growth of a country. Therefore, regulators, financial intermediaries, FinTech companies, and service providers need to take policy initiatives to upgrade the digital infrastructure while enhancing the avenues for financial accessibility. This study brings several policy implications, as follows.

7.2.1. Re-evaluate and outline the financial inclusion strategies focusing more on leveraging digital technology

From a macro perspective, countries should prioritize leveraging digital technology as a part of their financial inclusion policy to pursue a higher level of financial inclusion. In this, the stakeholders need to be cooperative in building a coherent blueprint considering pathways to build up digital technology while adequately assessing the income levels and resources of the economy. In doing so, considering demand-side factors such as the digital and financial literacy of the economic participant is incredibly important.

7.2.2. Support innovation and infrastructure development

Countries need to focus on building the infrastructure that facilitates digital finance to increase digital access while strengthening the digital identification and hassle-free account opening process. This should be coupled with regulatory approaches to ensure adequate risk management with effective supervision so that people become more confident and comfortable using digital financial services, which will increase DFI.

7.2.3. Ensure increased engagement of commercial banks and financial institutions in digital financial initiatives

Because the results show that the development of DFI has a significant role in promoting economic growth in the Asia-Pacific region, traditional financial institutions and commercial banks must be encouraged to engage in digital financial initiatives through FinTech developments. This requires smart product design and good incentives because people will adopt digital finance only if they prefer new to existing options. Therefore, it is recommended to launch affordable, user-friendly products that require a minimal behavioral change compared to traditional measures to attract customers.

7.2.4. Reinforce broader business activities

In the long term, the benefits of digital finance would be much larger,

given the low cost and increased convenience of transactions. Digital technology can reinforce broader and more innovative business activities because it is also a part of the basic infrastructure of an economy. Digital payments facilitate transactions in small amounts. Thus, it creates many business avenues that are based on small payments; therefore, suitable infrastructure and accessibility are required to promote digital-enabled finance. Policies need to be devised to ensure a high level of internet access and availability of mobile phones and internet coverage to ensure smooth and uninterrupted access to digital financial facilities.

7.2.5. Strengthen the digital wage payment system to ensure increased account ownership and usage

The initiatives need to be placed to shift toward digital wage payments from cash to improve payroll service efficiency and workers' financial inclusion. This will increase account ownership and usage. Also, the workers can access financial services for various uses, such as paying bills, making purchases, sending money abroad, and building a credit history and savings, which ensures enhanced usage of digital finance.

7.2.6. Increase women's financial autonomy through enhanced digital financial services

Advanced digital financial services can increase women's financial autonomy so that they can have more control over their earnings and more access to other financial services. This can lead them to spend more on nutrition, education, and health. The wage digitalization of garment factories in Bangladesh, digital payments to enhance logistics and payments for small and medium enterprises in Indonesia, use of artificial intelligence, computing, and risk management technologies to make the loan approval process faster in My Bank in China (UNSGSA, 2023) are finer examples of the initiatives available to increase DFI, and thus economic growth.

These financial innovations ensure the pursuit of economic growth, contributing mainly to SDG 4: Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all. The success stories of certain countries can be replicated in other countries in the Asia-Pacific region to achieve sustainable development through DFI.

7.3. Limitations and future research

The current study has various limitations. The study only considers limited countries due to the data unavailability for many countries. Moreover, the data related to financial inclusion are only available in gaps, so it limits the analysis of long-run relationships. Regardless of the data limitation, the empirical findings of this study can help future researchers in conducting these estimations for other regions, expanding the number of countries. The index can be used to examine the spatial effect of DFI. Moreover, using the developed DFI, future researchers can analyze the impact of DFI on variables such as income inequality and financial stability.

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Declaration of competing interest

The authors report no potential conflict of interest.

Data availability

Data will be made available on request.

Appendix

Table A1

Variables and Sources.

Independent Variables			
Traditional Financial Inclusion Index	Data Source	Digital Financial Inclusion Index	Data Source
Access to bank infrastructure	FAS, 2022	Access to digital infrastructure	International Telecomm Union (ITU), 2024
Automated Teller Machines (ATMs) per 100,000 adults		Mobile broadband subscription per 100 people	
Branches of commercial banks per 100,000 adults		Mobile-cellular subscriptions per 100 inhabitants	
ATMs per 1000 km ²			
Branches of commercial banks per 1000 km ²		Internet subscribers per 100 people	
Usage of traditional financial services	Global Findex Database, 2021	Usage of digital financial services	Global Findex Database, 2021
Percentage (%) of adults who own a financial institution account		Percentage (%) of adults who made or received digital payment	
Percentage (%) of adults Saved at a financial institution		Percentage (%) of adults who uses mobile phone to make utility payments	
Percentage (%) of adults with debit or credit cards		Percentage (%) of adults who uses mobile phone to receive wages	
Percentage (%) of adults borrowed from a formal financial institution			
Percentage (%) of adults who made a utility payment using a financial institution account.			
Percentage (%) of adults who received wages into a financial institution account.			
Dependent Variable		Control variables	
GDP Per capita	World Development Indicators (WDI), 2022	Inflation Rate	World Development Indicators (WDI), 2022
		Population Growth Rate	
		Gross Capital Formation	
		Tertiary Education Rate	
		Unemployment Rate	
		The rule of law	Worldwide Governance Indicators (WGI), 2022

Source: Financial Access Survey, Findex Database, International Telecommunication Union, World Development Indicators, and Worldwide Governance Indicators.

Table A2

Country Classification, Asia, and the Pacific Region.

Sub-Region	Countries
East and North-East Asia	China, Republic of Korea, Japan, Mongolia
North and Central Asia	Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Russia, Tajikistan, Uzbekistan
South-East Asia	Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, Vietnam
South and South-West Asia	Bangladesh, India, Iran, Nepal, Pakistan, Sri Lanka, Türkiye
Pacific	Australia, New Zealand

Source: United Nations Economic and Social Commission for Asia and Pacific.

Table A3

Descriptive Statistics of Variables.

Variable	Observations	Mean	Std. dev	Min	Max
Digital Financial Inclusion Index	90	0.426	0.276	0.000	1.000
GDP Per Capita*	90	8.524	1.210	6.749	11.100
Population Growth (%) *	90	0.697	0.006	0.667	0.710
Gross Capital Formation*	90	24.311	2.264	19.206	29.508
Inflation Rate (%)	90	6.708	7.390	-1.285	56.320
Tertiary Education Rate (%)	90	47.410	29.581	8.103	118.611
Unemployment Rate (%)	90	5.424	3.541	0.140	17.440
Rule of Law	90	-0.137	0.906	-1.456	2.004

* In logarithm values.

A.1. Principal Component Analysis Results

Table A4
Results of PCA for Digital Access.

Number of Observations = 90				
Number of Components = 3 = 3				
Rho = 1.000				
Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	2.076	1.417	0.692	0.692
Comp2	0.659	0.395	0.220	0.912
Comp3	0.264	.	0.088	1.000
Principal components (eigenvectors)				
Variable	Comp1	Comp2	Comp3	Unexplained
Internet Subscribers	0.577	-0.580	0.575	0
Mobile broadband subscription	0.635	-0.126	-0.763	0
Mobile cellular subscription	0.515	0.805	0.295	0

Table A5
Results of PCA for Digital Usage.

Number of Observations = 90				
Number of Components = 3				
Rho = 1.000				
Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	1.974	1.262	0.658	0.658
Comp2	0.713	0.400	0.238	0.896
Comp3	0.313	.	0.104	1.000
Principal components (eigenvectors)				
Variable	Comp1	Comp2	Comp3	Unexplained
Made or received digital payments	0.578	-0.574	0.580	0
Use mobile phone to make utility payments	0.640	-0.121	-0.759	0
Use mobile phones to receive wages	0.506	0.810	0.298	0

Table A6
Results of PCA for Traditional Access.

Number of Observations = 90				
Number of Components = 4				
Rho = 1.000				
Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	2.008	0.690	0.502	0.502
Comp2	1.317	0.663	0.329	0.831
Comp3	0.654	0.633	0.164	0.995
Comp4	0.021	.	0.005	1.000
Principal components (eigenvectors)				
Variable	Comp1	Comp2	Comp3	Comp4
Branches per Km ²	0.688	-0.067	0.228	0.686
Branches Per 100,000 adults	-0.100	0.711	0.694	-0.061
ATMs per 1000 km2.	0.702	0.011	0.027	-0.712
ATMs per 100,000 adults.	0.156	0.700	-0.683	0.139

Table A7
Results of PCA for Traditional Usage.

Number of Observations = 90							
Number of Components = 6							
Rho = 1.000							
Component	Eigenvalue	Difference	Proportion	Cumulative			
Comp1	5.127	4.817	0.855	0.855			
Comp2	0.311	0.046	0.051	0.906			
Comp3	0.265	0.114	0.044	0.950			
Comp4	0.150	0.057	0.025	0.976			
Comp5	0.093	0.039	0.015	0.991			
Comp6	0.054	.	0.009	1.000			
Principal components (eigenvectors)							
Variable	Comp 1	Comp 2	Comp 3	Comp 4	Comp 5	Comp 6	Unexplained
Owns a financial institution account	0.409	-0.512	0.267	-0.190	0.550	0.401	0
Saved at a financial institution	0.396	0.295	0.734	0.363	-0.289	0.052	0
Owns a debit or credit card	0.427	-0.249	0.026	-0.215	-0.023	-0.842	0
Borrowed from a formal financial institution	0.392	0.732	-0.186	-0.445	0.266	0.083	0
Made a utility payment using a financial institution account	0.407	0.020	-0.503	0.731	0.218	-0.007	0
Received wages into a financial institution account.	0.418	-0.230	-0.319	-0.232	-0.704	0.348	0

Table A8
Results of PCA for Traditional Financial Inclusion Index.

Number of Observations = 90				
Number of Components = 2				
Rho = 1.000				
Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	1.741	1.483	0.871	0.871
Comp2	0.259	.	0.129	1.000
Principal components (eigenvectors)				
Variable	Comp1	Comp2	Unexplained	
Traditional Access	0.7071	0.7071	0	
Traditional Usage	0.7071	-0.7071	0	

Table A9
Results of PCA for Digital Financial Inclusion Index.

Number of Observations = 90				
Number of Components = 2				
Rho = 1.000				
Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	1.652	1.305	0.826	0.826
Comp2	0.347	.	0.174	1.000
Principal components (eigenvectors)				
Variable	Comp1	Comp2	Unexplained	
Digital Access	0.7071	0.7071	0	
Digital Usage	0.7071	-0.7071	0	

Table A10

Results of PCA for Comprehensive Financial Inclusion Index

Number of Observations = 90				
Number of Components = 2				
Rho = 1.000				
Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	1.844	1.689	0.922	0.922
Comp2	0.156	.	0.078	1.000
Principal components (eigenvectors)				
Variable	Comp1	Comp2	Unexplained	
Digital Financial Inclusion Index	0.7071	0.7071	0	
Traditional Financial Inclusion Index	0.7071	-0.7071	0	

Table A11

Threshold Effect Test Results.

Model	Threshold		Lower		Upper	
Th-1	71.87		66.78		74.10	
Threshold	RSS	MSE	F-stat	Prob	Crit10	Crit5
Single	0.154	0.002	31.34	0.01	16.57	20.69
					31.19	

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