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Financial inclusion, digital technology, and economic growth: Further evidence

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ABSTRACT

This paper examines the effects of financial inclusion and digital technology on economic growth. We also investigate the possibility of using digital technology to improve financial inclusion overall and bridge the financial inclusion gender gap. Through dynamic panel data estimation for 84 countries from 2011 to 2017, we find evidence that digital technology would complement the effect of financial inclusion on economic growth through increased usage of financial services as well as bridging the financial inclusion and gender gap. The empirical results are robust to the inclusion of various control variables and changes in specification.

1. Introduction

Implemented in 2015, the UN Sustainable Development Goals (SDGs) are a collaborative agenda aimed to transform the people and planet to enjoy prosperity, peace, and partnership. The objectives include eradicating poverty and reducing income inequality. Financial inclusion— providing easy access to financial services at a relatively affordable rate—has been seen as one path toward achieving the SDGs. Financial market inclusivity means more opportunities for participants in managing their money (savings and investment) for future earnings, as well as greater business opportunities for firms.

The positive effect of financial development has become a stylized fact within the academic literature on the nexus of financial development and economic growth (Benhabib and Spiegel, 2000; Christopoulos and Tsionas, 2004; Levine, 2005; Liang and Teng, 2006; Hassan et al., 2011), with some empirical studies suggesting an inverted-U effect (Law et al., 2013; Law and Singh, 2014). In particular, the spillover effect of developed financial institutions and systems would benefit a country up to the point at which mobilization of the capital in the economy would stimulate consumption, investment, and import/export activities, creating economic

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growth. Too much growth in financial development with too little supervision through monetary and financial stability policy, however, could create an overheated market or even a bubble, leading to a high level of indebtedness among both households and firms.[1]

Nevertheless, a well-developed financial system does not guarantee total inclusion. Evidence shows 1.7 billion adults worldwide are "unbanked"—that is, they lack access to traditional financial services (Demirguc-Kunt et al., 2017). A growing amount of empirical research that supports the premise of the positive effect of financial inclusion on development has shown that "access" to financial services (e.g., savings and credit) leads to reducing inequality, boosts consumption and investment, and to a lesser extent, enhances a country's economic development (Galor and Zeira, 1993; Aghion and Bolton, 1997; Beck et al., 2007; Dupas and Robinson, 2013; Sahay et al., 2015). Although financial inclusion has been defined in various dimensions—namely, usage of, access to, and barriers to accessing financial services, it remains unclear which approach the banks and the central bank should focus on in order to speed up financial inclusion initiatives. In Mexico, for example, the financial access dimension could be proxied by the number of automated teller machines (ATMs) and bank branches because it is important to reach the low-income client population (Bruhn and Love, 2014). The emergence of a fourth industrial revolution and the growth in the digital technology integration, however, could change the focus of financial inclusion landscape. Should the number of ATMs and bank branches be increased to reach more of the unbanked population? We thus highlight the importance of identifying the proper channel of financial inclusion with the support of digital technology in terms of potential to affect a country's economic growth.

Several factors contribute to households' level of inclusion in the financial system. Individual characteristics affect household behavior in the financial market. Being richer, more financially literate, and older are all qualities associated with financial inclusion, as is being male (Fungáčová and Weill, 2015; Kostov et al., 2015; Allen et al., 2016). In contrast, being poor, young, less financially literate, and/or female increases the probability that an individual will be excluded from the financial market. In addition, specific laws, regulations, and procedures imposed on certain groups of people (e.g., women) have hindered their participation in the financial system (Demirguc-Kunt et al., 2013).[2] The gender gap is particularly large in South Asia, where only 37% of women have bank accounts (Sahay et al., 2015). Meanwhile, a recent study by Kabakova and Plaksenkov (2018) that uses a qualitative comparative (fuzzy-set Qualitative Comparative) analysis suggests that a stable economic ecosystem plays an important role in initiating financial market participation. In particular, the health of the financial market, economic, political, social, and technological spheres is among the most important components of the ecosystem. Interestingly, Kabakova and Plaksenkov find that the combination of social and economic factors does not improve the financial inclusion in absence of political and technological advancement. We further investigate this issue by providing deeper analysis on the effect of digital technology on financial inclusion, extending our exploration into the realms of gender inequality and economic disruptions (or uncertainty).

This paper aims to clarify to what extent financial inclusion could improve a country's economic growth in the presence of digital technology. In addition, we investigate the role of digital technology in bridging the financial inclusion gender gap. Our analysis will benefit central banks in formulating strategies to expedite financial inclusion without affecting a country's financial stability. With countries' diverse characteristics in terms of regulation, infrastructure, culture, and norms, as well as varying financial literacy levels, is there any evidence to support the idea that digital technology would boost the effect of financial inclusion on a country's economic growth? Investigating this issue could lead to the creation of policies that support digital technology as an enabling factor as well as ecosystems that facilitate the relationship between financial inclusion and economic growth.

To investigate this issue, we collect data for 84 countries from 2011 to 2017. Because the period is so short, our analysis uses dynamic panel estimation, a system GMM (generalized method of moments) estimator earlier proposed by Holtz-Eakin et al. (1988). This method has the advantage of mitigating the endogeneity and simultaneity problem that arises in panel data estimation. Our study adds value to the literature on the financial inclusion–led growth nexus by taking into consideration the role of digital technology.

We find that the effect of financial inclusion on growth is not straightforward. The effect of financial inclusion via the usage dimension only presents if it has achieved certain "productive capacity" or economies of scale. In addition, digital technology needs to achieve a certain level of development before it benefits the economy. We also find that digital technology plays some role in the effect of financial inclusion on economic growth, indicating the importance of using digital technology to improve financial inclusion and, to a lesser extent, economic growth. In other words, leveraging technology would bridge the gender gap, which consequently would improve economic growth. Our study remains limited by lack of available data on financial law and regulation with regard to gender, analysis on the effect of financial law, and regulation on financial inclusion gender gap. In addition, we conduct several dimensions of robustness tests to confirm the empirical results of the effects of financial inclusion and digital technology on economic growth, segregating by level of income and country level of institutional quality, as well by using the non-linear dynamic panel data approach. All results are robust.

The paper is structured as follows: The next section reviews the data and methodology; Section 3 presents the empirical results; and Section 4 concludes.

[1] This scenario could be linked to the 2008 economic crisis that erupted in United States in response to subprime mortgage and financial deregulation. The impact of financial inclusion on growth and stability is documented in Dabla-Norris et al. (2015) and Mehrotra and Yetman (2015).

[2] In particular, differential treatment under either law or customs excludes women from financial services, eliminating or reducing their autonomy to use or manage their own accounts (International Financial Corporation Annual Report, 2011; World Bank, 2015).

2. Review of literature

2.1. Financial development and economic growth

Many prior studies have explored the link between financial development and economic growth Hasan et al. (2009), Aggarwal and Goodell (2010), and Minea and Villieu (2010). Seminal work by Schumpeter (1934) and King and Levine (1993) support the premise of financial development improving growth via efficient allocation of resources. A well-developed financial system that includes financial intermediaries and a stock market would benefit the economy by responding to firm and household financing initiatives of new venture, enhanced liquidity and thus influence economic growth (Beck et al., 2007; Bruhn and Love, 2014). Benhabib and Spiegel (2000), Christopoulos and Tsionas (2004), Levine (2005), Liang and Teng (2006), Hassan et al. (2011), and Boukhatem (2016) explain how financial development could alleviate poverty. In particular, expanding access of microfinance products at affordable cost to low-income individuals has become a tool for financing entrepreneurs that could foster the creation and survival rates of informal businesses, which in turn increases employment, alleviates poverty, reduces income inequality and eventually improving overall economic growth (Beck et al., 2007; Claessens and Perotti, 2007; Bruhn and Love, 2014; Boukhatem, 2016).

The dynamic role of finance has been seen as fuel to spark the economy's instability, for instance, the explosion of the 2008 subprime lending crisis in the United States. The quality of lending activities, limiting excessive leverage and risk-taking activities, were among the key highlights for policy maker and financial institution players to mitigate the risk of financial bubbles in the economy (Beck et al., 2014; Law and Singh, 2014; Arcand et al., 2015) of which has led to research in finding the optimal level of financial development. In addition, institutional quality and governance should be held up to a certain level, complementing the effect of financial development on economic growth (Law et al., 2013). Recent evidence suggests that the financial system's stability (through improving bank balance sheets) not only could prevent banking crises but also facilitate the positive effect of finance and growth relationship (Demetriades et al., 2023).

2.2. Financial inclusion and economic growth

In light of the established relationship between financial development and economic growth, both households and firms need access to finance in order to benefit the economy. Broader access available in a well-developed financial system could be linked with greater financial inclusion. Levine (2005) suggested that access to financial services can increase economic growth by properly distributing capital and risk across different groups. In this sense, access to financial services can improve the living standard, especially for low-income groups, because it could be accessed at a low and affordable cost, which leads to more output production and high growth at the macro level. A well-developed financial system, which includes financial intermediaries and a stock market, would benefit the economy by responding to firms' and households' financing initiatives of new ventures and enhanced liquidity, and thus influence economic growth (Beck et al., 2007; Bruhn and Love, 2014; Lenka and Sharma, 2017). Easy access to financial services products such as deposit, credit and insurance could raise funds in financial markets and encourage more investments; additionally, accepting higher risk generates more output and employment. This could lead to improvements in the distribution of income and thus stimulate the country's economic growth (Claessens and Perotti, 2007). Honohan (2008) argues that the usage (depth) of financial products would provide a more significant effect than access to such products.

Financial inclusion is found to reduce poverty and lower overall income inequality (Honohan, 2008; Sharma, 2016; Park and Mercado, 2018). Neaime and Gaysset (2018) examine the extent of the impact of financial inclusion on inequality, poverty, and financial stability. Using the number of banks or ATMs per 100,000 adults as the measurement of financial inclusion, Neaime and Gaysset (2018) that financial inclusion reduced income inequality and improved financial stability in the Middle East and North Africa from 2002 to 2015. Other studies find a positive effect of financial inclusion on macro growth (Kim et al., 2018; Sethi and Acharya, 2018). Furthermore, examining the gender dimension, Swamy (2014) finds that financial inclusion has a strong impact on the income of poor women.[3] As such, we could conclude a positive effect of financial inclusion on growth and stability. The challenge, however, is to identify the effective channel to gain access and utilization of financial products, which we highlight in the objective of this paper. Barajas et al. (2013) find that the effect of finance–growth nexus is heterogeneous across regions, across income levels, and between oil and non-oil exporters, with low-income countries suffering from shallow financial systems. In addition, across the overall population, different income levels can lead to disproportionate benefits from financial inclusion (Demirgüc-Kunt and Klapper, 2013).

As such, various approaches and strategies have been formulated and implemented to improve financial inclusion through financial services products. Enabler is needed to improve the financial inclusion. Kabakova and Plaksenkov (2018) analyze the ecosystem of 43 countries and consider three combinations of factors that would affect or complement financial inclusion: high socio-demographic and political factors in the absence of economic development; high social, technological, and economic factors in the absence of political development; and political and economic factors in the absence of social and technological development. They find that both the absence of social and economic factors in the presence of political and technological development and the absence of socio-demographic, technological, and political development factors lead to financial exclusion.

[3] Substantial literature suggests that recipient gender matters in credit programs. In addition, women are more likely to use resources efficiently to improve family well-being (Handa and Davis, 2006; Rawling and Rubio, 2005). Data from the Global Findex Database in 2017, however, shows that women are still less likely than men to own a financial account.

2.3. Digital technology and financial inclusion

A stable developed financial market and support from technological spheres could build an ecosystem that can enhance financial inclusivity. This has been summed up as the role of financial innovation and technology enhancement in the new financial ecosystem. The financial system has experienced dynamic change in recent years with the help of a technological revolution in finance and banking system, stimulated by web-based and mobile banking transactions. The web-based and mobile banking transactions driven by digital technology have been seen as offering benefits as well as threats to a country's economic growth. High market penetration among internet and mobile phone customers has linked the relationship between digital banking (finance) and financial inclusion, in that devices or technology would improve access to financial services particularly for underserved and excluded populations (e.g., poor people and women). Furthermore, digital banking platforms would possibly improve access to credit and deposits, allow more efficient allocation of credit, facilitate financial transfer, and finally boost financial inclusion (Andrianaivo and Kpodar, 2011).

The digital banking platforms or digital transformation would only be realized with adequate internet infrastructure. Pradhan et al. (2016) found bidirectional causality between internet penetration rates and economic growth. Similarly, using 61 countries as a sample, Shamim (2007) suggested that better telecommunication infrastructure leads to higher and longer- running economic growth. Using African countries as a sample, Andrianaivo and Kpodar (2011) suggested that an affordable communication cost would lead to higher use of the telephone industry and financial inclusion could be improved through technology due to the relatively low cost of mobile phones and internet subscriptions. In this sense, active access to financial services products can be attained. However, inadequate digital infrastructure in certain countries could limit the role of digital technology in improving access to financial services products. In addition, shifting from cash transactions to account-based transactions would improve speed, security, and transparency,

Table 1
Descriptive statistics, 2011–2017.

Variables	Mean	Std. deviation	Min.	Max.	No of sample	Definition
GROWTH; Growth rate of GDP per capita	2.26	2.83	-9.44	13.04	84	Annual percentage growth rate
Initial income	24.83	2.04	19.02	29.43	84	Lagged levels of GDP per capita in constant 2010 US dollars (in natural log)
Capital stock	25.16	8.27	11.37	67.91	84	Gross capital formation as percentage of GDP
Population growth	1.29	1.29	-0.82	7.06	84	Annual percentage growth rate
Trade	90.35	41.41	0.20	325.86	84	Total exports plus imports as percentage of GDP
FI; Deposits	6.84	0.97	3.99	8.89	84	Deposit accounts with commercial banks per 1000 adults (in natural log)
FI; ATM	3.89	1.19	-2.39	5.67	84	ATMs per 100,000 adults (in natural log).
DIGITAL; Digital technology	6.70	2.83	0.00	14.00	84	Number of secure internet servers (in natural log)
Account-female	49.95	28.75	2.61	100	69	Account ownership at a financial institution or with a mobile-money-service provider, female (percentage of population age 15+)
Account-male	56.70	27.02	3.60	100	69	Account ownership at a financial institution or with a mobile-money-service provider, male (percentage of population age 15+)
Control of corruption	-0.05	0.90	-1.59	2.31	84	Perception of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests
Government effectiveness	0.08	0.88	-2.06	2.24	84	Perception of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies
Regulatory quality	0.01	0.87	-2.12	1.74	84	Perception of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development
Rule of law	-0.03	0.90	-1.90	2.10	84	Perception of the extent to which agents have confidence in and abide by the rules of society—in particular, the quality of contract enforcement, property rights, the police, and the courts—as well as the likelihood of crime and violence
Voice and accountability	0.01	0.87	-2.12	1.74	84	Perception of the extent to which a country's citizens are able to participate in selecting their government, as well as freedom of expression, freedom of association, and a free media
World Uncertainty Index	0.24	0.21	0	1.82	62	Country-level indices computed by counting the frequency of the world uncertainty and normalized by total number of words and rescaled by multiplying by 1000.

This table reports descriptive statistics of all variables. ATM stands for automated teller machine. Data for GDP, initial income, capital stock, population growth, and trade are obtained from WDI, World Bank. Deposit, ATM, digital technology, account-female and account-male data are taken from the IMF Financial Access Survey. All variables are from 2011 to 2017 based on data availability. For analysis that involves data on account-female and account-male variables, 69 countries have the data available. We also include the quality of institution variable in the analysis, which is control of corruption, government effectiveness, regulatory quality, rule of law, and voice and accountability. All quality of institution variable is a country's score on the aggregate indicator, in units of a standard normal distribution (i.e., ranging from approximately –2.5–2.5). A high number on the World Uncertainty Index represents higher uncertainty, and vice versa.

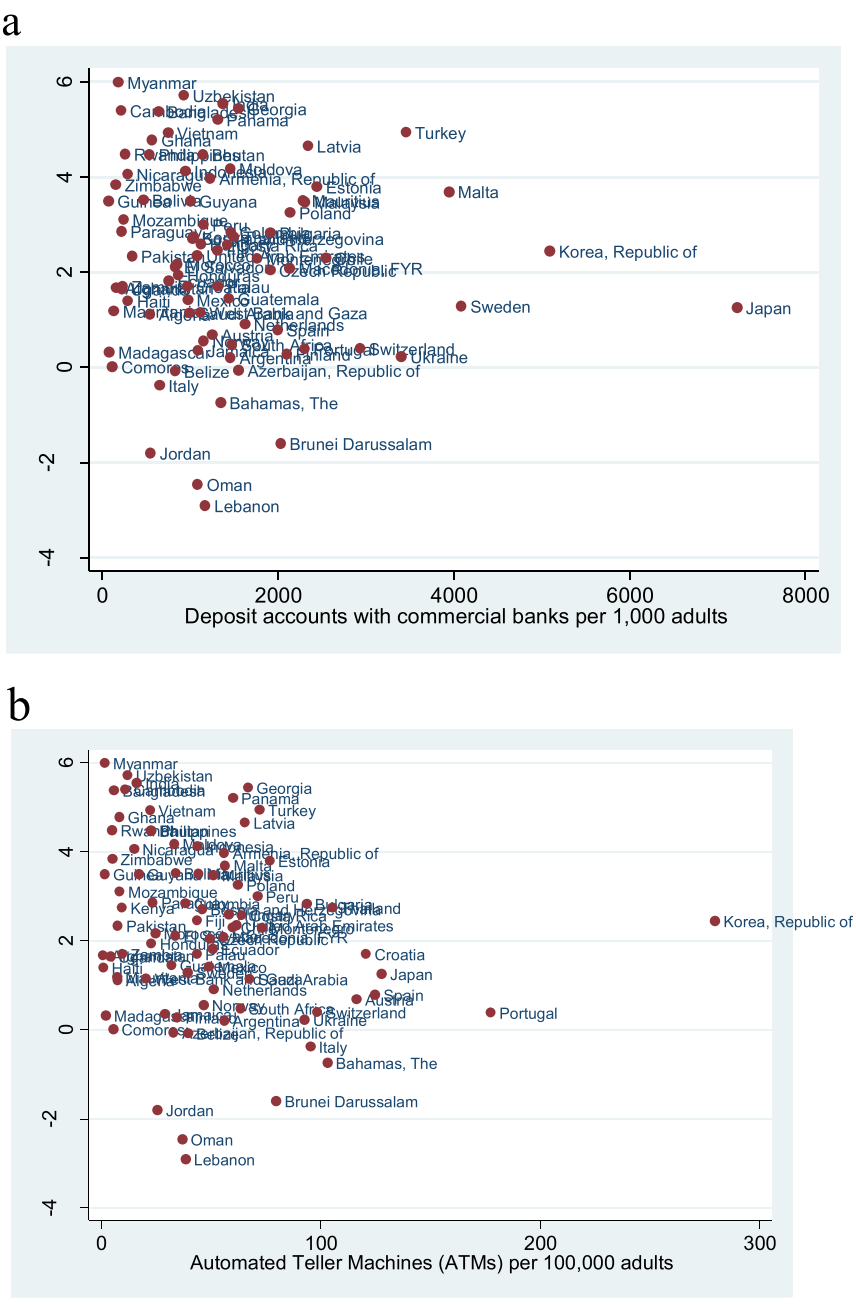


Fig. 1. a: Financial inclusion versus GDP per capita growth (average 2011–2017). Note: Author's calculation. b: Financial inclusion versus GDP per capita growth (average 2011–2017). Notes: Author's calculation.

as well as allowing customers to track their payment history (Demirguc-Kunt et al., 2017).

Women who have access to financial inclusion are better able to control their earnings, manage their money (savings or investment), and thus escape the poverty cycle. Even though women's participation in the financial markets is associated with greater economic development (Duflo, 2012; Morawczynski and Pickens, 2009; Swamy, 2014), developing economies have a steady 9%-point gender gap in account ownership (Demirguc-Kunt et al., 2017). Both legal discrimination against woman and gender norms may explain cross-country variation in access to financial inclusion (Demirguc-Kunt et al., 2013). The literature focused on the role of digital technology in financial inclusion, in terms of both growth and in narrowing the gender gap, remains limited, however, and thus serves as one of the motivations for this paper.

Geopolitical uncertainty and a tense trade atmosphere may cause economic disruptions that could affect access to financial inclusion and digital technology. The impact of financial development on stability and output volatility have been discussed extensively

Table 2
Results on GMM-system estimation on the role of financial inclusion on country economic growth.

Growth rate of GDP per capita	*FI* =deposit		*FI* =ATM	
	Model 2(a)	Model 2(b)	Model 2(c)	Model 2(d)
Initial income	-2.482(1.006)***	-2.789(1.014)***	-2.495(1.00)***	-2.706(1.078)***
Capital stock	0.140(0.024)***	0.137(0.02)***	0.142(0.024)***	0.146(0.024)***
Population growth	-1.480(0.340)***	-1.500(0.34)***	-1.480(0.336)***	-1.478(0.326)***
Trade	0.032(0.012)***	0.031(0.01)***	0.034(0.120)***	0.036(0.012)***
FI	0.022(0.481)	-5.611(3.05)*	0.112(0.349)	0.096(0.721)
FI^2		0.446(0.25)*		0.027(0.159)
Constant	59.13(23.883)***	84.215(23.979)***	58.999(24.327)***	63.718(25.875)***
No. of countries	84	84	84	84
AR(2) test (*p*-value)	0.22	0.22	0.22	0.22
Sargan test (*p*-value)	0.16	0.15	0.22	0.19

This table shows regression results for the effect of financial inclusion on country economic growth for the period 2011–2017 for 84 countries. In addition, we use two variables—namely, deposits for Model 2(a) and Model 2(b) and ATMs for Model 2(c) and Model 2(d)—as a proxy for financial inclusion. We include the quadratic term of both indicators in Model 2(b) and Model 2(d).
The value in parentheses refers to the standard error.
*** $p < 0.01$
* $p < 0.10$.

in the literature by Bernanke and Gertler (1989), Raddatz (2006), and Caglayan et al. (2013), among others. Segal et al. (2015) classified uncertainty into two types: good uncertainty and bad uncertainty. Good uncertainty predicts growth in future consumption, investment, and output, whereas bad uncertainty forecasts a decline in growth and depresses asset prices. On the other hand, a recent study by Baum et al. (2021) for 89 countries found that uncertainty represented by unexpected inflation significantly undermines the health of the financial system. Yet evidence on the impact of uncertainty on financial inclusion–led growth is relatively scarce, highlighting the contribution of this paper.

2.4. Institutional quality and financial inclusion

Hypothetically, weak institutions, weak property rights, ineffective rule of law, and corruption would adversely affect financial sector development (Wei and Sievers, 1999; Barth et al., 2004; Beck et al., 2007; Cooray and Schneider, 2018). The financial sector allocates limited economic resources through financial activities and contributes to economic growth (Graff, 2003). Strengthening institutional quality and governance framework would contribute to the positive effect of financial development in emerging countries, thus stimulating economic growth (Anwar and Cooray, 2012; Law and Azman-Saini, 2012; Khan et al., 2020). Institutions are important in shaping the financial development of a country through constitutions, laws, standards of conduct and social interaction (North, 1990). Extensive empirical studies have found that financial development on growth depends on institutional quality (Demetriades and Law, 2006; Law et al., 2013; Slesman et al., 2019; Khalid and Shafiullah, 2021).

A well-developed financial system should provide easy access to financial services at a relatively affordable rate (financial inclusion) which ultimately helps to foster financial sector development and economic growth (Chen and Yuan, 2021; Lenka, 2022). A country's characteristics may influence the level of financial inclusion, which include high-quality institutions, efficient legal rules, strong contract enforcement, political stability, and the income level of a country (Honohan, 2008; Demirgüc-Kunt et al., 2015; Allen et al., 2016). Looking back to the ecosystem to be established, the quality of institutions matters in the financial inclusion agenda. Better quality institutions are highly correlated with financial access (Honohan, 2008; Nkoa and Song, 2020).

Madestam (2014) and Allen et al. (2016) both investigate the effect of institutional quality on financial inclusion in the context of formal and informal credits. Both studies find that institutional quality is associated with a positive effect on financial inclusion, and weak legal institutions increase the popularity of informal credit. No study has been conducted in the presence of digital technology in the growth model, however, and our paper fills in this gap in the literature.

3. Empirical methodology and data

This paper adapts the standard growth model in literature to investigate the effect of financial inclusion on economic growth in the context of digital technology:

$$GROWTH_{it} = \beta_1 FI_{it} + \beta_2 DIGITAL_{it} + \beta_3 (FI_{it} \quad x \quad DIGITAL_{it}) + \beta_4 X_{it} + \mu_i + \theta_t + \varepsilon_{it} \tag{1}$$

where *GROWTH* is the economic growth rate, proxied by growth rate of gross domestic product (GDP) per capita; $i = 1, ..N$ represents the country in the sample; and $t = 1, ..T$ represents the time index. *FI* is the country's level of financial inclusion represented by two indicators: deposit accounts with commercial banks and ATMs per 100,000 adults. This is to capture the usability and accessibility dimensions in financial inclusion. In addition, *DIGITAL* is digital technology measured by the number of secured internet servers. The expected sign of *FI* and *DIGITAL* is positive where the financial inclusion and advancement in technology would lead to the improvement of country economic growth. The interaction of $(FI * DIGITAL)$ variable would capture the contingency effect of digital

technology on the effect of financial inclusion on country's economic growth. β_3 captures the contingency effect of digital technology on the finance–growth relationship. *DIGITAL* could improve the effect of *FI* on economic growth if the signs of β_1 and β_3 are positive. The other explanatory variable, X_{it}, includes the initial income, investment to GDP ratio, population growth rates, and trade to GDP ratio. The initial income is considered an endogenous variable (GDPfrom the previous period), while μ_i, θ_t, and ε_{it} represent the country-specific effect, time effect, and white noise error term, respectively. Investment and population are considered to be the factor inputs in production.

To further analyze the role of digital technology in bridging the financial inclusion gender gap on country growth, Eq. 1 includes a variable for the gender gap, *Gender Gap*, and an interaction variable $(Gender\ Gap * DIGITAL)$. *Gender Gap* is represented by difference between female and male account ownership at a financial institution. This paper also considers an uncertainty factor, *Global*, represented by the World Uncertainty Index (GUI). Our focus is on the interaction variables between uncertainty factors on digital technology, $(Global * DIGITAL)$, and financial inclusion, $(Global * FI)$.

For robustness, we analyze the effect of financial inclusion, digital technology, and economic growth based on income level, institutional quality, and alternative estimators—namely, threshold regression. We divide our sample into high-income and non-high-income countries based on World Bank Classification. Institutional quality is represented by control of corruption, government effectiveness, regulatory control, rule of law, and voice and accountability indicator.

This paper uses the system generalized method of moments (GMM) estimator proposed by Holtz-Eakin et al. (1988). The system GMM estimator controls for the potential endogeneity of all explanatory variables by using the instrumental variable. To use these additional instruments, we need the identifying assumption that the first difference of the explanatory variables is not correlated with the explanatory variables; the correlation is supposed to be constant over time. Blundell and Bond (1998) showed that if the moment conditions are valid, in Monte Carlo simulations the system GMM estimators perform better than the first-difference GMM estimator. We can test the validity of the moment conditions by using the conventional test of overidentifying restrictions proposed by Sargan (1958), testing the null hypothesis to see that the error term is not second-order serially correlated.

The advantage of the system GMM method is that it removes the unobserved time-invariant, country-specific effect by taking first differences. As such, it eliminates bias by omitting variables that are constant over time (Bond et al., 2001). In addition, the use of instrumental variables allows the parameter to be estimated consistently, which could eliminate the potential endogeneity problem as well as the presence of measurement errors. For robustness of the empirical findings, we use dynamic panel threshold regression method by Kremer et al. (2013) where this method was employed to test for the existence of threshold estimates of the growth model. Kremer et al. (2013) is an extension of Hansen's (1999) original static panel threshold estimation and Caner and Hansen's (2004) cross-sectional instrumental variable (IV) threshold model, where the GMM-type estimator is used to manage endogeneity. The threshold regression model is as follows:

$$GROWTH_{it} = \mu_i + \beta_1 FI_{it} I(FI_{it} \leq \lambda) + \delta_1 I(FI_{it} \leq \lambda) + \beta_2 FI_{it} I(FI_{it} > \lambda) + \gamma X_{it} + \theta_t + \varepsilon_{it} \quad (2)$$

where *FI* is the threshold variable and λ is the unknown threshold parameter. This allows the effect of financial inclusion on a country's economic growth to differ depending on whether financial inclusion or digital technology is below or above some unknown level of λ. The impact of finance growth is captured by β_1 and β_2 for low and high regimes, respectively. This method allows for a difference in regime intercept (δ_1).

Eq. 2 is estimated using the least squares method for a fixed threshold λ, where the endogenous variables are replaced by the predicted values in the reduced form regression. The estimator of the threshold value λ with the smallest sum of squared residuals is selected. Data are collected from the World Development Indicator (WDI) and International Monetary Fund (IMF) Financial Access Survey. The sample covers the period from 2011 to 2017 for 84 countries due to data availability. For robustness, financialization is represented by an alternative indicator measured by ATMs per 100,000 adults, which may represent financialization from the context of financial inclusion from the IMF Financial Access Survey. We use data from the World Uncertainty Index (WUI) for uncertainty measures.

4. Results and discussion

Table 1 presents the descriptive statistics and the measurements of the variables used in this study. We used the number of deposit accounts with commercial banks per 1000 adults and number of ATMs per 100,000 adults to measure accessibility and financial inclusion. Digital technology is measured by the number of secured internet servers in a country. The mean growth rate of GDP per capita is 2.26%, with a standard deviation of 2.83. Other explanatory growth variables—namely, capital stock and population growth—recorded a small variation with standard deviation of 8.27 and 1.29, respectively, compared with a trade variable that shows a double-digit standard deviation of 41.41. Meanwhile the natural logarithm of deposit and ATMs gathered from the IMF Financial Access Survey shows a mean of 6.84 and 3.89, respectively, with standard deviation of 0.97 and 1.19. With natural logarithm of the number of secure internet servers used as a proxy for digital technology, the mean is 6.702.

To examine the financial inclusion gender gap issue, we use variables for female and male account ownership at a financial institution or with a mobile-money-service provider. Based on the data, the minimum of account ownership is 2.61% and 3.60% for female and male, respectively, while the maximum of account ownership is 100 across countries in the sample.

To explore the relationship between financial inclusion and country economic growth scenario in our sample, we average the data from 2011 to 2017 and present the scatter plot in Fig. 1a and Fig. 1b for both proxies—deposit accounts and ATMs. In terms of financial inclusion from a usability dimension (average number of deposit accounts with commercial banks), most country data is scattered

Table 3
Results on GMM-system estimation on the digital technology and financial inclusion on economic growth.

Growth rate of GDP per capita	*FI* =deposit			*FI* =ATM		
	Model 3(a)	Model 3(b)	Model 3(c)	Model 3(d)	Model 3(e)	Model 3(f)
Initial income	-2.825(1.042)***	-1.879(1.037)*	-3.295(1.304)***	-2.692(1.026)***	-2.077(1.041)**	-3.085(1.187)***
Capital stock	0.139(0.023)***	0.157(0.022)***	0.138(0.022)***	0.140(0.024)***	0.159(0.022)***	0.145(0.023)***
Population growth	-1.503(0.325)***	-1.558(0.311)***	-1.557(0.350)***	-1.493(0.328)***	-1.484(0.313)***	-1.380(0.322)***
Trade	0.035(0.012)	0.033(0.011)***	0.032(0.011)***	0.036(0.012)***	0.032(0.011)***	0.033(0.011)***
FI	-0.789(0.472)	0.326(0.476)	-1.245(0.779)	0.013(0.350)	0.579(0.400)	-0.190(0.598)
DIGITAL	0.089(0.063)	-0.767(0.348)**	-2.173(0.865)***	0.067(0.064)	-0.777(0.345)**	-0.664(0.317)**
DIGITAL ^2		0.049(0.019)**			0.049(0.019)**	
*FI** *DIGITAL*			0.324(0.121)***			0.200(0.083)**
Constant	67.431(24.884)***	44.166(24.545)*	87.240(30.995)***	63.583(24.831)***	49.334(25.005)**	73.881(28.729)**
AR(2) test (*p*-value)	0.22	0.21	0.22	0.23	0.22	0.22
Sargan test (*p*-value)	0.20	0.13	0.21	0.24	0.19	0.22

This table shows regression results on the effect of digital technology, financial inclusion on country economic growth for the period 2011–2017 for 84 countries. In addition, we use two variables—deposits for Model 3(a), Model 3(b), and Model 3(c); and ATMs for Model 3(d), Model 3(d), and Model 3(f)—as proxies for financial inclusion. We include the quadratic term of digital technology in Model 3(b) and 3(e). We also include the interaction term of digital technology and financial inclusion in Model 3(c) and Model 3(f).
The value in parentheses refers to the standard error.
*** p <0.01
** p < 0.05
* p < 0.10.

Table 4
Results on GMM-system estimation on the role of financial inclusion on country economic growth.

Growth rate of GDP per capita	*FI* =deposit		*FI* =ATM	
	Model 4(a)	Model 4(b)	Model 4(c)	Model 4(d)
Initial income	-0.815(1.076)	-0.606(1.038)	-0.528(0.830)	-0.333(0.822)
Capital stock	0.169(0.039)***	0.170(0.041)***	0.162(0.035)***	0.161(0.037)***
Population growth	-1.269(0.163)***	-1.355(0.169)***	-1.329(0.164)***	-1.407(0.171)***
Trade	0.034(0.013)***	0.032(0.012)***	0.040(0.011)***	0.038(0.011)***
FI	0.252(0.559)	0.228(0.611)	-0.089(0.408)	-0.120(0.439)
Gender gap	0.008(0.021)	-0.136(0.086)*	0.015(0.021)	-0.139(0.0812)*
DIGITAL	-0.012(0.083)	0.051(0.104)	0.011(0.082)	0.079(0.098)
*Gender gap** *DIGITAL*		-0.018(0.010)*		-0.020(0.010)**
Constant	15.188(25.569)	9.742(24.464)	9.559(20.069)	4.426(19.776)
No. of countries	69	69	69	69
AR(2) test (*p*-value)	0.35	0.34	0.34	0.34
Sargan test (*p*-value)	0.12	0.11	0.17	0.15

This table shows regression results for the effect of digital technology, financial inclusion on country economic growth for the period 2011–2017 for 69 countries. In addition, we used two variables—deposits and ATMs—as a proxy for financial inclusion. In addition, we added the gender gap variable and the interaction term of digital technology and gender gap in Model 4(b) and Model 4(d).
The value in parentheses refers to the standard error.
*** p <0.01
** p < 0.05
* p < 0.10.

between 2000 to 4000 deposit accounts and 0–6% of GDP growth. Korea, Japan, and Sweden recorded a greater number of deposit accounts and had 0–2.5% GDP growth, while Malta and Turkey had a moderate number (about 4000) of deposit accounts with GDP growth between 3% and 5%. As such, no consensus emerged on the relationship between the financial inclusion proxy in terms of usability with the level of a country's economic growth.

Meanwhile, Fig. 1b plots the number of ATMs versus country growth rate in order to examine financial inclusion in terms of accessibility. Korea recorded the highest average of ATMs per 100,000 adults, at more than 250, with GDP growth of more than 2%. Nations with a lower number of ATMs (less than 100)—including Lebanon, Oman, Jordan, and Brunei Darussalam—are associated with negative per capita GDP growth. In contrast, more than half of the sample countries center around 0–150 ATMs per 100,000 people and range between 0% and 6% of GDP per capita growth rate. Thus, we can draw no conclusions based on the scatterplot and suggest further empirical analysis of the effect of financial inclusion on country economic growth, as well as to what extent digital technology could influence the role of financial inclusion on economic growth.

We conducted preliminary analysis to check for the possible existence of outliers. Using the Cook's distance outlier detection method, we excluded countries with outlier variables and thus proceed with 84 countries. Appendix 1 lists all the countries in our sample.

Table 5
Results on GMM-system estimation on the role of uncertainty in financial inclusion and digital technology.

Growth rate of GDP per capita	*FI*=deposit		*FI* =ATM		*FI* =deposit	*FI* =ATM
	Model 5(a)	Model 5(b)	Model 5(c)	Model 5(d)	Model 5(e)	Model 5(f)
Initial income	0.341(0.348)	0.336(0.343)	0.285(0.329)	0.283(0.326)	0.315(0.339)	0.211(0.321)
Capital stock	0.137(0.034)***	0.119(0.038)***	0.142(0.036)***	0.121(0.040)***	0.125(0.036)***	0.130(0.038)***
Population growth	-1.143(0.273)***	-1.085(0.270)***	-1.060(0.228)***	-1.021(0.226)***	-1.123(0.282)***	-1.046(0.237)***
Trade	0.028(0.009)***	0.026(0.009)***	0.031(0.009)***	0.029(0.009)***	0.026(0.009)***	0.028(0.009)***
FI	-1.254(0.372)***	-0.886(0.430)**	-1.004(0.471)**	-0.767(0.426)*	-1.222(0.377)	-0.996(0.467)**
Global	-0.489(0.317)	6.531(3.164)***	-0.390(0.303)	3.374(1.161)***	1.047(1.080)	1.522(1.074)
DIGITAL	-0.114(0.074)	-0.111(0.071)	-0.098(0.073)	-0.092(0.068)	-0.060(0.065)	-0.024(0.065)
Global FI*		-1.027(0.464)***		-1.108(0.348)***		
*Global*DIGITAL*					-0.203(0.134)	-0.255(0.137)*
Constant	-1.058(9.267)	-2.982(9.482)	-5.312(8.348)	-5.604(8.252)	-0.592(9.149)	-3.539(8.243)
No. of countries	63	63	63	63	63	63
AR(2) test (*p*-value)	0.960	0.984	0.885	0.993	0.965	0.903
Sargan test (*p*-value)	0.030	0.034	0.093	0.108	0.039	0.118

This table shows regression results for the role of uncertainty on the effect of digital technology, financial inclusion to country economic growth for the period 2011–2017 for 63 countries. In addition, we use the World Uncertainty Index as a proxy for uncertainty.
The value in parentheses refers to the standard error.
*** p <0.01
** p < 0.05
* p < 0.10.

5. Baseline results

5.1. The role of financial inclusion on country economic growth

Table 2 shows our results from the baseline model. It shows our estimates for the effect of financial inclusion on country economic growth based on two proxies of financial inclusion, deposits and number of ATMs, which cover the infrastructure that has been established would support the financial market via improvements and access dimensions, respectively. Model 2(a) and Model 2(c) display the results of variable of interest for deposit and ATMs as a proxy of financial inclusion with other explanatory variables of the conventional growth model.

Both estimates show a positive coefficient for the financial inclusion variable, but neither is statistically significant at conventional significance levels.[4] This result stands in contrast to literature that found a positive effect of financial inclusion on economic growth (Kim et al., 2017; Sethi and Acharya, 2018). In light of the argument that financial inclusion would affect the economy, however, we then proceed to investigate the potential of achieving a certain level of financial inclusion before a country would experience positive economic growth. This is based on the fact that having access and usage (deposit) do not necessarily translate to the benefit of the financial inclusion on growth if the access or account does not mobilize the savings effectively. In addition, it should be "high enough" to create an impact on economic growth through financial inclusion (utilization of financial services) in both business and household transactions. Model 2(b) shows that the quadratic term of the deposit variable is positive and significant at the 10% significance level, while the original variable of deposit accounts turns negative and significant at least at the 10% significance level. Model 2(d) using the ATMs variable shows an insignificant effect on country economic growth for both variables (original ATMs and quadratic term of ATMs). This finding implies that the usage dimension of financial inclusion would possibly have some positive effect on country growth after achieving a certain level. In other words, the deposit account would be the possible channel of financial inclusion to impact the country's economic growth.

Intuitively, the usage of financial services would not impact economic growth if there is no significant inclusion of the society in the financial system. Financial inclusion is the continuity process from financial development, where with high and active participation of society in maximum capacity of usage, poverty and income inequality could be reduced. An increase in the number of deposit account holders (maximizing usage) would generate a significant increase in country economic growth but on the other hand, inactive deposit account holders would not boost the country's sustainable growth. The process of financial inclusion would start with the take-up action (opening a deposit account) by individuals. In other words, people must put forth active effort to reach a level of financial product usage in order to reach the point of boosting economic growth. Financing products for youth, women, and people with disabilities as well as private pension schemes were among the new financial products demanded by households, while microfinancing solutions for small and medium-sized enterprises (SMEs) would benefit firms.

Other control variables—initial income, capital stock, population growth, and trade—show the correct signs and are significant at least at a 5% significance level. In addition, Model 2(a) through Model 2(d) could not reject the null of no second-order serial correlation with at least a 5% significance level. Besides that, the *p*-values reported by the AR and Sargan test could not reject the null

[4] For robustness, following Pradhan et al., 2021b, we use banking branch penetration, measured as the commercial bank branches per 100,000 adults, as a proxy of financial inclusion. The results do not vary sensibly and are attached in Appendix 2.

Table 6
Results on GMM-system estimation on the role of digital technology on the effect of financial inclusion on country economic growth (non-high-income countries).

Growth rate of GDP per capita	*FI*=deposit		*FI* =ATM		*FI* =deposit		*FI* =ATM	
	Model 6(a)	Model 6(b)	Model 6(c)	Model 6(d)	Model 6(e)	Model 6(f)	Model 6(g)	Model 6(h)
Initial income	-8.649(2.230)***	-9.149(2.255)***	-4.889(1.860)***	-5.170(1.892)***	-10.852(3.524)***	-9.864(3.218)***	-8.603(2.943)***	-9.108(2.934)***
Capital stock	0.164(0.021)***	0.167(0.021)***	0.154(0.022)***	0.154(0.022)***	0.162(0.021)***	0.180(0.020)***	0.151(0.022)***	0.163(0.021)***
Population growth	-1.483(0.140)***	-1.485(0.148)***	-1.404(0.233)***	-1.384(0.243)***	-1.423(0.144)***	-1.392(0.145)***	-1.382(0.234)***	-1.375(0.210_***
Trade	0.002(0.013)	0.004(0.013)	0.014(0.012)***	0.010(0.012)	-0.012(0.016)	-0.022(0.017)	0.000(0.014)	-0.013(0.016)
FI	1.877(0.467)***	4.960(3.889)	-0.149(0.191)	0.287(0.162)*	1.968(0.474)***	2.130(0.516)***	-0.200(0.194)	-0.037(0.240)
FI^2		-0.243(0.309)		-0.107(0.031)***				
DIGITAL					0.090(0.109)	-0.728(0.355)***	0.180(0.092)**	-0.394(0.299)
DIGITAL^2						0.057(0.021)***		0.042(0.018)***
Constant	199.797(53.007)***	202.027(58.198)	119.694(44.892)***	126.482(45.714)	253.489(85.152)***	231.128(78.157)***	210.570(71.552)***	224.939(71.546)***
AR(2) test (*p*-value)	0.21	0.21	0.20	0.20	0.21	0.21	0.22	0.21
Sargan test (*p*-value)	0.19	0.17	0.15	0.14	0.22	0.21	0.23	0.27

This table shows regression results for the effect of digital technology, financial inclusion on country economic growth for non-high-income countries over the period from 2011 f to 2017 for 69 countries. In addition, we use two variables—deposits and ATMs—as a proxy for financial inclusion. We include the quadratic term of financial inclusion in Model 6(b) and 6(d). The country classification is based on World Bank Country Classification, June 2018.
The value in parentheses refers to the standard error.
*** p <0.01
** p < 0.05
* p < 0.10.

Table 7
Results of GMM-system estimation on digital technology's role in the effect of financial inclusion on country economic growth (non-high-income countries).

Growth rate of GDP per capita	*FI* =deposit	*FI* =ATM
	Model 7(a)	Model 7(b)
Initial income	-9.662(3.312)***	-9.458(3.221)***
Capital stock	0.166(0.020)***	0.151(0.022)***
Population growth	-1.449(0.163)***	-1.353(0.230)***
Trade	-0.013(0.017)	-0.004(0.014)
FI	1.144(0.626)*	0.204(0.203)
DIGITAL	-1.153(0.633)*	0.392(0.138)***
*FI** *DIGITAL*	0.187(0.092)**	-0.068(0.028)***
Constant	230.038(80.293)***	230.551(78.247)***
AR(2) test (*p*-value)	0.22	0.22
Sargan test (*p*-value)	0.21	0.21

This table shows regression results for the interaction term of digital technology and financial inclusion on country economic growth for non-high-income countries over the period from 2011 f to 2017 for 69 countries. The country classification is based on World Bank Country Classification, June 2018.
The value in parentheses refers to the standard error.
*** p <0.01
** p < 0.05
* p < 0.10.

hypothesis of no over-identifying restriction for the estimation. This result means that the system GMM estimator does not indicate a serious problem with the validity of these instrumental variables.

As a conclusion of the baseline analysis, we find that deposits accounts (the usage dimension of financial inclusion) play a substantial role in improving a country's economic growth. However, the growth rate of deposit accounts needs to be upheld until it becomes a responsible usage before the country will benefit from business entity and household. Lack of deposit accounts could lead to small opportunity for business to recourse to loans, thus expanding the business, creating job opportunities, and reducing inequality, while households would benefit through consumption smoothing, investment opportunities, and saving for a buffer to protect against unforeseen shocks.

5.2. The role of digital technology on country economic growth

During the last 10 years, we have seen vast developments in technology and communication, which have forced the financial and banking system to change in order to remain relevant. Integration of financial services and technology, including mobile devices, have been seen as mechanisms to enhance financial inclusion (Andrianaivo and Kpodar, 2011). According to the Global Findex Database in 2017, 69% of adults have had account. In addition, 52% of adults (equivalent to 76% of account owners) either made or received at least one digital payment in 2017, suggesting that digital payment of financial services or digital financial inclusion is on rise. This shift makes it possible to reach the unbanked customer and sources of business to the internet provider as well as the fintech company. High levels of customer penetration of mobile and internet subscription indicates the need to see the role of digital technology in boosting financial inclusion, and finally economic growth.

Table 3 shows the results that explore the role of digital technology on country growth and its role on the effect of financial inclusion on country economic growth. In Model 3(a) and Model 3(d), we test the role of digital technology on financial inclusion–led growth model. With the consideration of two proxies of financial inclusion, both estimates show an insignificant effect of digital technology on a country's economic growth. In addition, by considering the quadratic function of digital technology on economic growth in Model 3(b) and Model 3(e), the quadratic term of digital technology variable shows a positive and significant effect on economic growth at the 5% significance level. In particular, the coefficient of initial variable of digital technology turns negative and significant in affecting country growth. This would possibly imply evidence of a non-linear relationship, which might suggest the possible existence of tipping-point of digital technology level (achievement) before it could affect country growth. In other words, countries need to achieve a certain level of digital technology development before digital technology can benefit the overall economy. Low digital technology penetration would not affect the economy. When more households, businesses, and government organizations are equipped with digital technology support, the country benefits via the enhancement of productivity and efficiency. In the context of African countries, a study performed by Andrianaivo and Kpodar (2011) reveals that affordable communications costs lead to higher use of telephones, thus lowering the unit production cost for a phone. Consequently, customers benefit from a cheaper price. This dynamic could extend to digital financial inclusion, where mobile phone and internet subscription at a lower cost and active access to financial services products would benefit a country's economy.

For all the estimates, the financial inclusion variable is consistent with the insignificant effect. In addition, Model 3(c) and Model 3 (f) were estimated by including the interaction between the digital technology and financial inclusion variables. This is to look on the potential effect of digital technology in complementing the effect of financial inclusion on a country's economic growth.

Table 8
Results of GMM-system estimation on digital technology's role in the effect of financial inclusion on country economic growth.

Growth rate of GDP per capita	*FI* =deposit					*FI* = ATM				
	Model 8(a)	Model 8(b)	Model 8(c)	Model 8(d)	Model 8(e)	Model 8(f)	Model 8(g)	Model 8(h)	Model 8(i)	Model 8(j)
Initial income	-2.901(1.152)**	-2.018(0.819)***	-2.883(0.940)***	-2.665(1.009)***	-3.085(0.995)***	-2.732(1.110)***	-1.680(0.798)***	-2.506(0.905)***	-2.513(0.987)***	-2.906(0.951)***
Capital stock	0.135(0.024)***	0.131(0.021)***	0.132(0.023)***	0.138(0.023)***	0.133(0.022)***	0.134(0.024)***	0.137(0.023)***	0.136(0.024)***	0.140(0.024)***	0.140(0.024)***
Population growth	-1.514(0.333)****	-1.274(0.288)***	-1.407(0.299)***	-1.441(0.318)***	-1.442(0.278)***	-1.516(0.340)***	-1.252(0.286)***	-1.355(0.299)***	-1.422(0.320)***	-1.413(0.272)***
Trade	0.033(0.012)***	0.028(0.011)***	0.032(0.011)***	0.030(0.012)***	0.029(0.011)***	0.034(0.012)***	-0.602(0.436)	0.032(0.011)***	0.032(0.012)***	0.032(0.011)***
FI	-0.031(0.489)	-0.968(0.485)**	-0.496(0.498)	-0.433(0.518)	-0.563(0.553)	0.033(0.338)	-0.602(0.436)	-0.323(0.394)	-0.178(0.374)	-0.160(0.537)
DIGITAL	0.076(0.066)	0.023(0.060)	0.057(0.061)	0.075(0.062)	0.126(0.063)**	0.057(0.067)	-0.00(0.061)	0.029(0.065)	0.052(0.064)	0.077(0.066)
Control of corruption	0.006(0.015)					0.005(0.014)				
Government effectiveness		0.070(0.018)***					0.064(0.019)***			
Regulatory quality			0.056(0.019)***					0.055(0.018)***		
Rule of Law				0.027(0.014)*					0.025(0.013)*	
Voice and accountability					0.051(0.022)**					0.041(0.022)*
Constant	69.166(27.360)**	50.708(19.850)***	69.354(22.531)***	64.990(24.094)***	75.105(23.445)***	64.731(27.024)***	37.912(19.356)**	57.720(21.772)	58.911(23.896)***	67.711(22.772)***
AR(2) test (*p*-value)	0.22	0.21	0.23	0.21	0.22	0.23	0.20	0.22	0.22	0.23
Sargan test (*p*-value)	0.23	0.30	0.35	0.26	0.24	0.25	0.29	0.37	0.29	0.27

In this robustness test, we include the institutional quality indicator of control of corruption, government effectiveness, regulatory quality, rule of law, and voice and accountability. In Model 8(a) to 8(e), we employ deposits as a financial inclusion indicator; Model 8(f) to 8(j) use ATMs as a financial inclusion indicator.
The value in parentheses refers to the standard error.
*** p <0.01
** p < 0.05
* p < 0.10.

Table 9
Robustness test on non-linear relationship.

Growth rate of GDP per capita	Threshold variable *FI*=Deposit	Threshold variable *FI*=ATM	Threshold variable = *DIGITAL*
	Model 9(a)	Model 9(b)	Model 9(c)
Threshold estimates, $\widehat{\lambda}$	7.563	1.490	6.878
95% confidence interval	[7.563, 7.564]	[1.469,3.094]	[3.850, 9.409]
Impact of FI $(\widehat{\beta_1})$	-0.784(0.711)	-0.851(0.530)	
Impact of FI $\widehat{\beta_2}$	5.778(2.457)***	-1.013(0.6578)	
Impact of DIGITAL $(\widehat{\beta_1})$			-0.53(0.44)
Impact of DIGITAL $\widehat{\beta_2}$			0.17(0.27)
Impact of covariates			
Initial income $_{it-1}$	-1.791(2.047)	-0.268(1.998)	2.771(5.777)
Capital stock $_{it}$	0.066(0.033)***	0.080(0.035)***	0.083(0.039)***
Population growth $_{it}$	-0.650(0.229)***	-0.717(0.237)***	-1.279(0.216)***
Trade $_{it}$	0.032(0.013)***	0.029(0.013)***	0.034(0.018)***
$\widehat{\delta_1}$	53.359(19.589)***	-1.013(0.658)***	6.379(2.036)***

This table shows the panel threshold results on the effect of financial inclusion and digital technology on country economic growth. Model 9(a) and Model 9(b) represent the use of deposit and ATM variables as a proxy of financial inclusion variable respectively in the context of non-linear. While model 9(c) captures the effect of digital technology in the context of non-linear. This estimate tries to establish any cut-end-point of the interest variable if exist. ** $p < 0.05$, * $p < 0.10$.
*** $p < 0.01$

By including the interaction term of digital technology and financial inclusion in the model, we find that the coefficient of the interaction term shows a positive and significant effect on economic growth.[5] This result implies that digital technology plays a role in the effect of financial inclusion on economic growth for both financial inclusion channels. These dynamic underscores the importance of leveraging digital technology to improve the usage and access or financial inclusion, to a lesser extent economic growth. Digital technology offers easy access to financial services products, which in turn spurs the effect towards responsible usage of financial services products. A shift toward digital banking benefits consumers in terms of speed, security, transparency, and access to payment history (Demirguc-Kunt et al., 2017). Internet connection and mobile phone or devices would thus be the key to the financial inclusion initiative. Switching human behavior from conventional to digital banking is not an easy task, however.

Although two-thirds of the world's unbanked adults have a mobile phone, 1 billion adults who have a financial account still pay utilities bills in cash (Demirgüç-Kunt et al., 2017). Bhutan and Vietnam are among countries that experienced this phenomenon. At the beginning, people should be offered incentives to switch from cash to digital. A utility provider, for instance, should offer a good affordable digital alternative to encourage people to move from cash to digital payments. In addition, internet providers should engage people in rural area as well as people with special needs. Technology could play a role whereby the private sector could develop e-commerce payment solutions. With economies of scale, the cost of internet payment would be very low. The ability to leverage technology is driving the usage, to a lesser extent, inclusion, and economic growth. A secure, affordable, and convenient non-bank payment provider platform would speed up reaching the scale, efficiency.

Other control variables show the correct signs and are significant at least at a 5% significance level. In addition, the main model could not reject the null of no second-order serial correlation at least at a 5% significance level. Besides that, the *p*-values reported by the Sargan test could not reject the null hypothesis of no over-identifying restriction for the estimation. This result shows that the system GMM estimator does not indicate a serious problem with the validity of these instrumental variables. Thus, one could conclude that utilization of digital technology would complement the effect of financial inclusion on country economic growth. In addition, the gender gap issue has risen to prominence among developing economies. The growth in financial account ownership since 2011 has not benefited all individuals equally—women still are less likely than men to have an account (Demirgüç-Kunt et al., 2017).

For an in-depth analysis of the extent to which digital technology could bridge the financial inclusion gender gap, we empirically test the effect of the financial inclusion gender gap on country economic growth via the two channels (deposits and ATMs). Table 4 reveals the results. Model 4(a) and Model 4(b) examine the financial inclusion gender gap variable and the growth model. Consistent with the earlier findings, the financial inclusion and digital technology variables show an insignificant effect on a country's economic growth, implying that both variables depend on other factors to affect economic growth. In particular, the financial inclusion gender gap also shows an insignificant effect on country growth. By adding in the interaction variable of gender gap and digital technology for Model 4 (b) and Model 4 (d), the coefficient of interaction variable shows a negatively significant effect (at least 10% significance) on a country's economic growth. This result implies that the effect of financial inclusion gender gap on economic growth depends on digital technology. In other words, digital technology has some role in bridging the gender gap. Because a low level of digital technology penetration would not affect the economy (findings in Table 3), however, the negative effect of gender gap still holds.

The *p*-value for the model estimation reports that the estimates could not reject the null of no second-order serial correlation. The

[5] An additional proxy of digital technology has also been used to measure the robustness of the results. Following Pradhan et al. (2021a) that use fixed broadband subscriptions in representing digital technology, the estimation results confirm the role of digital technology in the effect of financial inclusion on economic growth. The estimation results are attached in Appendix 3.

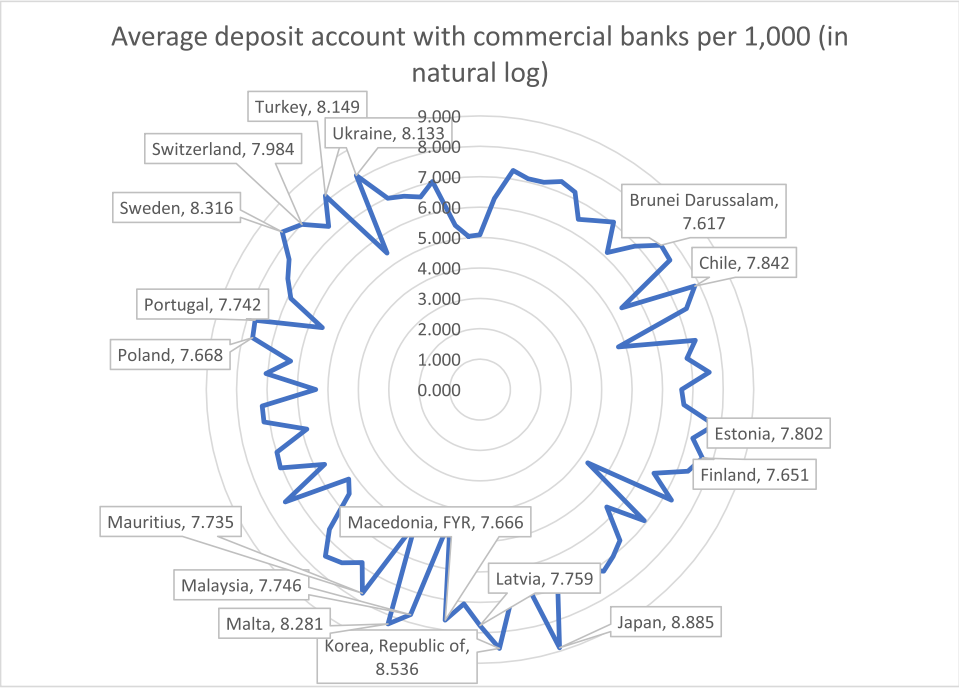


Fig. 2. Individual country's financial inclusion that exceeds the threshold level.

Sargan test also could not reject the null hypothesis, suggesting that a valid specification without an overidentifying problem exists in the estimated model. The gender gap arises worldwide because of both legal restrictions and customs, compounded by low literacy among women. In fact, research conducted by the World Bank Groups Women finds that in 155 of the 173 economies, at least one law impedes women's opportunity to access economic opportunities (World Bank, 2015). Furthermore, specific permission may be needed or additional documentation demanded by the financial services provider for women to hold accounts. As such, legal issues must be addressed in order to mitigate this financial access barrier, enabling women to open accounts and more easily conduct transactions. Amending regulations and removing legal restrictions would complement technology in improving women's economic empowerment. Some initial initiatives that could mitigate the financial inclusion gender bias include using mobile technology to open an account, save or invest, and conduct business transactions for female-owned businesses.

We further analyze the effect of uncertainty on financial inclusion-growth in Table 5. As with our other models, Models 5(d) and 5 (f) could not reject the null of no second-order serial correlation and the null hypothesis of the Sargan test, suggesting that a valid specification without an over-identifying problem exists in the estimated model. In addition, both models show a negative and significant effect of the financial inclusion variable at least at a 10% significance level, while the effect of digital technology remains insignificant. In Model 5(d), the uncertainty variable shows a positive and significant effect on a country's economic growth. This result may relate to findings by Segal et al. (2015), where this phenomenon could be associated with good uncertainty via the enhancement of investment. By adding the interaction variable of uncertainty and financial inclusion indicator, however, we find the coefficient of interaction variable shows a negatively significant effect (at the 1% significance level) on a country's economic growth. This result implies that the effect of financial inclusion on economic growth depends on the level of uncertainty in the economy. In other words, there exists some role of good uncertainty in improving the financial inclusion. However, the "not enough" of responsible usage the negative effect of financial inclusion still holds.

6. Robustness checks

We present the results of several robustness tests to confirm that the effects of financial inclusion, digital technology, and economic growth are robust to different income groups, different levels of institutional quality, and different alternatives estimates—namely, the threshold estimates. This is based on the argument by Barajas et al. (2013), who find that the finance–growth nexus is indeed heterogeneous across regions, across income levels, and between oil and non-oil exporters, with low-income countries suffer from shallow financial systems. As such, this section presents the estimation results for the financial inclusion–led growth model in the context of income level and institutional quality.

6.1. Different income groups

We start our robustness test by splitting the sample of countries in the study. The sample is segregated by level of income: high-

income and non-high-income countries, based on the World Bank Country Classification as of June 2018. Because of the limitation of the method of estimates (which is robust for a sample size greater than 50), we proceed the estimation with non-high-income countries group, as shown in Table 6. Current literature shows that different income levels can lead to disproportionate benefits of financial inclusion across the population (Demirgüc-Kunt and Klapper, 2013). In particular, these studies show evidence that differences in income across countries and among individuals within countries influence the level of financial inclusion.

Results in Model 6(a) to 6(d) estimate the link between financial inclusion and country economic growth (see Table 6). The results in Model 6(a) and Model 6(c) show a significant positive effect (at the 1% significance level) of financial inclusion—namely the deposit variable—while the other proxy of financial inclusion (ATMs) was insignificant for country economic growth. This indicates that financial inclusion via deposit accounts is positively and directly impacting economic growth for non-high-income countries. Because the effect of ATM on economic growth was insignificant, this result establishes that deposit (or access) would be the strong (significant at the 1% level) channel to improve economic growth in non-high-income-countries. In addition, the quadratic term of financial inclusion, shown in Model 6(b) and Model 6(d), is insignificant for deposits, suggesting that the linear effect holds. The quadratic term for ATMs shows a negative effect at the 1% significance level on non-high-income countries growth. The initial ATM variable is associated with a positive effect on country growth, although at a slightly at weaker significance level. This result implies that the effect of ATMs in boosting economic growth is not as strong as that of deposit accounts. In addition, too many ATMs would not benefit a country's economic growth, as they might be inefficient and costly.

Meanwhile, in Model 6(e) to Model 6(h), we include the digital technology variables and the quadratic term of digital technology. However, we find that digital technology does not affect growth for non-high-income countries via the deposit channel, although the deposit variable remains positive in affecting economic growth. However, digital technology positively affects a country's economic growth, as shown in Model 5(g). Meanwhile, the quadratic term of digital technology is found to have a positive effect, where the initial digital technology variable remains negatively significant in affecting the economic growth of non-high-income countries. The results are consistent with the results in Model 3(b) and 3(e), suggesting that the relationship of digital technology with economic growth is robust across different levels of country income.

We also analyze the role of digital technology in the effect of financial inclusion on economic growth in non-high-income countries. Table 7 presents the results. Model 7(a) adds an interaction variable of the deposit variable and digital technology. With inclusion of this interaction term, the coefficient of interaction variable shows a positive and significant sign. This result implies that digital technology plays some role in effecting financial inclusion that creates economic growth in non-high-income countries. In brief, the results indicate the importance of leveraging digital technology to improve the usage of financial inclusion, and economic growth in the context of non-high-income countries.

Meanwhile, looking from the context of access which we use ATMs as a proxy in Model 7(b), the initial financial inclusion is insignificant while the digital technology affecting country economic growth is positive and significant (at the 1% level). The interaction between digital technology and ATMs, however, resulted in a negative effect on country economic growth. This finding implies that the digital technology would play a role in the effect of ATMs on economic growth for non-high-income-countries.

Overall, the results are consistent with the baseline analysis, suggesting that deposits (or access) would be the main channel to boost a country's economic growth. Digital technology needs to achieve a certain level before the effect "spills over" into economic growth. In addition, digital technology would complement the effect of financial inclusion via deposits on country economic growth. As such, this finding suggests that digital financial inclusion would boost economic growth.

6.2. *Institutional quality*

We continue our robustness check by considering governance quality in the financial-led growth model. Hypothetically, weak institutions would adversely affect financial sector development (Wei and Sievers, 1999; Barth et al., 2004; Beck et al., 2007; and Cooray and Schneider, 2018), which would ultimately affect a country's economic growth. Table 8 shows the results. The governance variables are represented by control of corruption, government effectiveness, regulatory quality, rule of law, and voice and accountability indicators. Model 8(a) to 8(e) use deposits as the financial inclusion variable, while the rest use ATMs as the financial inclusion variable. Consistent with the previous finding, the financial inclusion and digital technology variable would not have a significant direct effect on economic growth. In addition, in line with the theory that good governance led to better growth as a results of efficient resources allocation, the institutional quality variable contributes positively and significantly to a country's economic growth, with almost all of our model except 8(a) and 8(f) significant at least at the 5% significance level.

6.3. *Panel threshold estimates*

The analysis proceeds with threshold estimates of our model. Based on our earlier findings, there is a possibility of non-linear relationship of the financial inclusion–growth model, as in Beck et al. (2014) and Law and Singh (2014), which found that credit expansion affects per capita output growth up to a point. Relying on the estimation results of Model 1(b), which shows the quadratic term of deposit to be significantly positive (at the 10% significance level), we estimate the model using a dynamic panel threshold method (see Table 9). Model 9(a) and Model 9(b) present the growth model estimates based on two proxies of financial inclusion: deposits and ATMs. Model 9(c) shows the results of the growth model, in the context of non-linear of the digital technology variable. Consistent with the results in Model 1(b), the coefficient of deposit variable shows a significant positive sign at the 1% significance level, suggesting that a threshold level (point) for financial inclusion exists that needs to be reached before financial inclusion can positively affect a country's economic growth. The estimate of the threshold point is 7.56, equivalent to 1915 deposit accounts with

commercial banks per 1000 adults. In addition, the 95% confidence interval indicates that level of deposit should range between 7.563 and 7.564. Our findings in Model 9(b) are shown to be insignificant, as were our earlier estimates of Model 1(d). In addition, the digital technology variable in Model 9(c) show an insignificant effect of growth. Other control variables—capital stock, population growth, and trade—show the correct signs and are significant at least at the 1% level. In summary, the impact of financial inclusion which is baseline results, are robust to panel threshold estimates.

Taking the average data of deposit accounts with commercial banks per 1000 adults (in natural log), we find that quite a number of countries (17 out of 84) achieve or exceed the threshold level of financial inclusion—namely, the deposit variable—placing them among the nations that potentially experience the positive effect of financial inclusion. These 17 countries are Brunei Darussalam, Chile, Estonia, Finland, Japan, the Republic of Korea, Latvia, Malta, Malaysia, Macedonia, Mauritius, Poland, Portugal, Sweden, Switzerland, Turkey, and the Ukraine.

7. Conclusion

Extant literature focuses on the effect of financial inclusion on a country's economic growth. Limited studies exist that highlight the role of digital technology in financial inclusion–led growth. To catalyze the development of digital banking and the fintech ecosystem, this study explores the benefit of leveraging technology in improving financial inclusion and to bridge the financial inclusion gender gap. We use a robust dynamic panel data estimation that includes 84 countries, covering the period from 2011 to 2017. We find that the usage dimension of financial inclusion plays a greater role in improving a country's economic growth. However, it needs to be upheld until it becomes a responsible usage before benefits the country via business entity and household. In addition, it indicates the importance of leveraging digital technology to improve financial inclusion and, to a lesser extent, economic growth. The findings indicate that the effect of financial inclusion gender gap on a country's economic growth depends on digital technology. Leveraging technology to bridge the gender gap, however, needs to start with reforming laws and removing legal restrictions to improve women's empowerment in the economy. Building confidence among financial service providers is crucial for the development and growth of new digital financial products to promote financial inclusion. Simultaneously, a strong and enforceable consumer protection framework remains a priority to ensure the well-being of consumers. In addition, we conducted several dimensions of tests to confirm the robustness of the empirical results on financial inclusion, digital technology, and economic growth. Those results suggest our findings are robust to the inclusion of various control variables and changes in specification by employing the non-linear dynamic panel data approach. Further investigations could encompass the realm of enhancing the efficiency and stability of the financial sector as the financial sector embraces digital technology.

CRediT authorship contribution statement

Irwan Trinugroho: Conceptualization, Supervision, Validation, Writing – review & editing. **Abd Halim Ahmad:** Conceptualization, Formal analysis, Methodology, Project administration, Software, Writing – original draft. **Siti Nurazira Mohd Daud:** Conceptualization, Data curation, Formal analysis, Methodology, Software, Writing – original draft.

Data availability

Data will be made available on request.

Appendix 1. List of countries

Afghanistan, Algeria, Argentina, Armenia, Austria, Azerbaijan, Bahamas, Bangladesh, Belize, Bhutan, Bolivia, Bosnia and Herzegovina, Brunei Darussalam, Bulgaria, Cambodia, Chile, Colombia, Comoros, Costa Rica, Croatia, Czech Republic, Ecuador, El Salvador, Estonia, Fiji, Finland, Georgia, Ghana, Guatemala, Guinea, Guyana, Haiti, Honduras, Hungary, India, Indonesia, Italy, Jamaica, Japan, Jordan, Kenya, the Republic of Korea, Latvia, Lebanon, Macedonia, Madagascar, Malaysia, Malta, Mauritania, Mauritius, Mexico, Moldova, Montenegro, Morocco, Mozambique, Myanmar, the Netherlands, Nicaragua, Norway, Oman, Pakistan, Palau, Panama, Paraguay, Peru, the Philippines, Poland, Portugal, Rwanda, Saudi Arabia, South Africa, Spain, Sweden, Switzerland, Thailand. Turkey, Uganda, Ukraine, United Arab Emirates, Uzbekistan, Vietnam, West Bank and Gaza, Zambia, Zimbabwe.

Appendix 2. Results on GMM-system estimation on the role of financial inclusion on economic growth: additional proxy

Growth rate of GDP per capita	*FI* =commercial bank branches	
	Model 2(i)	Model 2(ii)
Initial income	-2.223(1.091)**	-3.242(1.278)***
Capital stock	0.143(0.024)***	0.150(0.024)***
Population growth	-1.445(0.352)***	-1.605(0.370)***
Trade	0.029(0.014)**	0.027(0.014)*

(*continued on next page*)

(*continued*)

Growth rate of GDP per capita	*FI* =commercial bank branches	
	Model 2(i)	Model 2(ii)
FI	0.015(0.052)	0.102(0.096)
FI^2		-0.001(0.001)
Constant	53.077(27.325)**	77.911(32.149)***
No. of countries	80	80
AR(2) test (*p*-value)	0.28	0.25
Sargan test (*p*-value)	0.11	0.14

This table shows regression results for the effect of financial inclusion on country economic growth for the period 2011–2017 for 80 countries (excludes Azerbaijan, Lebanon, Macedonia and Palau due to data unavailability). In addition, we use one additional variable of financial inclusion—namely, commercial bank branches in Model 2(i) and Model 2(ii) for the linear and quadratic term respectively. ***p <0.01, ** p < 0.05, and * p < 0.10. The value in parentheses refers to the standard error.

Appendix 3. Results on GMM-system estimation on the digital technology and financial inclusion on economic growth: additional proxy

Growth rate of GDP per capita	*FI* = commercial bank branches		
	Model 3(i)	Model 3(ii)	Model 3(iii)
Initial income	-8.027(2.300)***	-7.014(2.184)***	-8.088(2.232)***
Capital stock	0.133(0.026) ***	0.135(0.026)***	0.125(0.025)***
Population growth	-1.505(0.378) ***	-1.630(0.362)***	-1.411(0.363)***
Trade	0.011(0.014)	0.010(0.014)	0.007(0.014)
FI	0.025(0.055)	0.041(0.057)	-0.092(0.164)
DIGITAL	0.272(0.142)*	0.048(0.125)	0.124(0.164)
DIGITAL ^2		0.005(0.004)	
FI * *DIGITAL*			0.008(0.004)**
Constant	196.291(56.546) ***	172.148(53.874)***	199.783(55.111)***
AR(2) test (*p*-value)	0.27	0.25	0.28
Sargan test (*p*-value)	0.30	0.26	0.33

This table shows regression results for the effect of digital technology, financial inclusion on country economic growth for the period 2011–2017 for 80 countries (excludes Azerbaijan, Lebanon, Macedonia and Palau due to data unavailability). In addition, we use one additional variable of digital technology—namely, fixed broadband subscriptions (per 100 people) in Model 3(i) and Model 3(ii) for the linear and quadratic term respectively. We also include the interaction term of digital technology and financial inclusion in Model 3(iii).***p <0.01, ** p < 0.05, and * p < 0.10. The value in parentheses refers to the standard error.

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