DRIVING FINANCIAL INCLUSION: THE ROLE OF FINANCIAL DEVELOPMENT AND FINANCIAL TECHNOLOGY IN G20 ECONOMIES

Berto Usman[1], Kamaludin[2], and Willy Abdillah[3]

Abstract

This study aimed to examine the influence of financial development and financial technology (fintech) on financial inclusion in G20 member countries. The study explored how traditional financial instruments, such as credit cards, debit cards, and ATMs, as well as fintech services, contribute to improving access to formal financial services. Additionally, the study analyzed the impact of economic conditions, particularly inflation, on cashless transactions, as an indicator of financial inclusion. Using a multi-year panel dataset covering G20 economies from 2012 to 2023, the research applied panel-data regression models with country and year fixed effects, controlling for macroeconomic variables such as inflation, market capitalization, and bank branch density. The results revealed that the use of credit cards and electronic payments is positively associated with enhanced financial inclusion. Conversely, the number

[1] Berto Usman, Ph.D is an Associate Professor of Finance and has been at the Department of Management, University of Bengkulu - Indonesia since 2012. He obtained his Ph.D. (Accounting & Finance) from the Department of Economics and Management, University of Padua - Italy; and earned a degree of M.Sc. in Finance at Universitas Gadjah Mada. He was also a research associate at the Department of Accounting, University of Exeter - England. Currently, Berto is responsible for teaching at the undergraduate and postgraduate programs at the University of Bengkulu. His research interests lie at the intersection between the fields of accounting and finance; voluntary disclosure, corporate social responsibility (CSR), corporate governance, corporate finance, capital markets, and digital business. Email: berto.usman@unib.ac.id

[2] Prof. Dr. Kamaludin, S.E., M.M is a Professor in Financial and Strategic Management and currently serves as the Vice Rector of academic affair, University of Bengkulu, Indonesia. He earned his bachelor's degree in economics from the University of Bengkulu, his master's degree in management from Brawijaya University, and his Doctorate in Financial Management from Padjadjaran University. In addition to being active in teaching and research, Prof. Kamaludin has extensive experience in higher education management, having served as Rector of Dehasen University, Head of the Doctoral Program in Management Science, and Vice Dean for Academic Affairs at the Faculty of Economics and Business, University of Bengkulu. His research areas include corporate finance, governance, and organizational strategy, with publications in several reputable international journals such as Pertanika Journal of Social Sciences and Humanities, Contaduría y Administración, and International Journal of Business and Globalisation. He also serves as an assessor for LAMEMBA and BAN-PT, a member of regional government investment advisory teams, and a research reviewer for LPDP, making him one of Indonesia's leading scholars in management and financial policy.

[3] Prof. Dr. Willy Abdillah, S.E., M.Sc. is a Professor of MIS and researcher at the Department of Management, Faculty of Economics and Business, University of Bengkulu. He earned his bachelor's degree in economics from the University of Bengkulu and both his Master of Science and Doctoral degrees in Management from Gadjah Mada University. His main areas of expertise include management information systems, organizational behavior, and strategic and technology management. Prof. Willy is widely recognized as a prolific academic with numerous national and international publications in the fields of management, information technology, and organizational behavior. He also serves as an editor and reviewer for several reputable journals such as the Journal of Global Entrepreneurship Research, International Journal of Economics and Management, and Journal of Asia Business Studies. In addition to teaching and research at undergraduate, master's, and doctoral levels, he has served as Head of Department and Vice Dean for Academic Affairs at the Faculty of Economics and Business, University of Bengkulu, and remains active in professional and academic organizations such as ISEI Bengkulu and BKSP.

of ATMs shows a significant negative effect, indicating that the availability of traditional banking infrastructure encourages the continued use of cash, thereby hindering the adoption of cashless transactions. On the other hand, fintech, including e-money accounts, is found to have a highly significant influence on increasing cashless transactions, highlighting the critical role of financial technology in expanding access to formal financial systems. Furthermore, inflation has a significantly negative impact on financial inclusion, as high inflation reduces purchasing power and diminishes trust in formal financial systems. These findings underscore the importance of supporting fintech, reducing reliance on physical banking infrastructure, and maintaining stable macroeconomic policies to promote financial inclusion in G20 member countries. This study provides clear policy implications regarding the necessity of advancing digital financial services to achieve broader financial inclusion.

Keywords: Financial Development, Financial Inclusion, Financial Technology (Fintech), G20 Countries, Fintech

INTRODUCTION

In recent decades, the development of the financial sector has become a primary focus in global economic discourse, particularly concerning its role in driving economic growth and alleviating poverty. Financial development, which involves enhancing the quality and quantity of financial institutions and instruments, has often been linked to financial inclusion—efforts to ensure access to financial services for all segments of society. This study aims to explore the relationship between financial development and financial inclusion as well as the financial development and financial inclusion nexus.

Financial development is often measured through indicators such as banking penetration, capital market depth, and the availability and diversity of financial products offered to the public. According to Levine (2005), mature financial development can reduce transaction and information costs, improve resource allocation, and support overall economic growth. Meanwhile, financial inclusion refers to broader access to affordable and secure financial services, which, as noted by Sarma and Pais (2011), can help reduce inequality and accelerate economic growth. Meanwhile, financial technology, encompassing all forms of innovation in how people transact and how companies deliver financial services, has emerged as a critical factor influencing the dynamics between financial development and financial inclusion. Fintech applications, such as mobile banking, digital payments, and blockchain technology, have the potential to transform the traditional financial landscape by providing faster, cheaper, and more accessible services to previously underserved segments of the population.

Previous studies have shown that financial technology enhances financial inclusion by simplifying processes and reducing transaction costs, enabling more people, especially those in remote areas or without bank accounts, to access financial services (Demirgüç-Kunt et al., 2018). In this context, fintech acts not only as a tool but also as a catalyst for transforming the financial sector. However, despite its potential, the penetration and effectiveness of fintech vary significantly across different economic and social contexts. For example, Ozili (2018) found that the effectiveness of fintech in promoting financial inclusion heavily depends on supportive regulations, adequate technological infrastructure, and the financial literacy levels of users. Therefore, it is essential to evaluate the role of fintech on financial inclusion, particularly to understand the conditions under which fintech can provide maximum contributions.

Taking these aspects into account, this study seeks to address the following research questions: How does financial development associate with financial inclusion? Is the presence

of financial technology positively associated with financial inclusion? Furthermore, the research focuses on investigation within the G20 countries. Selecting G20 countries as the research setting for studying the impact of financial development and fintech on financial inclusion offers several advantages. First, the G20 represents more than 80% of global GDP and includes both advanced and developing economies, providing significant diversity in financial systems (IMF, 2020). This diversity enables a comprehensive analysis of how financial development and financial inclusion operate across different economic contexts. Second, these countries often have more complete and systematic financial data, which is crucial for quantitative research requiring consistent and reliable data (World Bank, 2019). Third, policy decisions made in G20 countries often serve as global benchmarks, making findings from these countries highly relevant to global policymaking (Bank for International Settlements, 2018). Lastly, as hubs of innovation, the G20 countries are at the forefront of developing and implementing fintech solutions, making them ideal settings for exploring the effects of technology on financial inclusion (Demirgüç-Kunt et al., 2018). By employing this approach, the study aims to generate insights that significantly contribute to economic literature and influence financial policy worldwide.

This study makes three key contributions. First, it provides empirical evidence on the role of financial development and financial technology in fostering financial inclusion, emphasizing the traditional and non-traditional implications of financial development. Second, it introduces a novel perspective by employing a nontraditional approach, investigating financial development as indicated by the impact of financial technology on financial inclusion, thereby advancing the application of financial development theory in finance research. Finally, it offers actionable insights for enhancing the functionality as well as the effectiveness of financial development and financial technology on financial inclusion. A deeper understanding of this topic is expected to not only enrich the academic literature but also provide practical insights for policymakers and practitioners in the financial sector. This is crucial for optimizing strategies and policies that leverage financial technology to enhance financial inclusion, ultimately supporting various sustainable development goals, including poverty reduction and improving societal well-being.

The remainder of this paper is organized as follows: Section 2 reviews the relevant literature and outlines the development of the research hypotheses. Section 3 details the research design, including data collection methods, variable measurements, and econometric modeling. Section 4 presents the empirical results and discussion along with their implications. Section 5 provides a summary of the findings, limitations, and the scope for future research.

LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

Financial Development Theory

The theory of financial development emphasizes the critical role of evolving financial systems in driving economic growth and reducing borrowing and lending costs. It explores how financial intermediation, particularly within the banking sector, becomes more efficient as economies grow, with increased competition and specialization among banks lowering intermediation costs (Sussman et al., 1993; Tirole 1994). A study by Sussman et al. (1993) used a spatial model of monopolistic competition, highlighting the importance of "gross markups"—the difference between borrowing and lending rates—and how proximity between banks and firms improves credit accessibility and risk management. Empirical evidence shows that wealthier economies typically exhibit lower financial markups, reflecting more efficient systems. This underlines the significance of fostering competitive and efficient financial institutions to channel resources effectively, promoting economic development and providing actionable insights for policymakers (Sussman et al., 1993; Benchimol & Bozou, 2024).

Moreover, according to Bazhal (2016) financial development theory is also significantly associated with ideas developed by Joseph Schumpeter, an Austrian economist, in the early 20th century. Schumpeter argued that innovation is the primary driving force behind economic growth, and financial institutions play a crucial role in supporting this innovation by providing access to capital for entrepreneurs and companies seeking to implement new technologies or more efficient business processes (Ülgen, 2015). In his seminal work, *The Theory of Economic Development*, published in 1911, Schumpeter explained that financial development entails the establishment and utilization of financial institutions that can allocate resources to the most productive areas, which is essential for economic development. He emphasized that without an efficient financial system, entrepreneurs would struggle to obtain the necessary capital for innovation. According to Schumpeter, financial development is not only focused on economic growth but also on how financial institutions can contribute to financial inclusion by providing financial services to groups underserved by traditional financial systems (Bazhal, 2016). This includes innovations in financial services that extend their reach to broader segments of society, such as the introduction of financial technologies that simplify access to financial services (Ülgen, 2015). In contemporary literature, many economists have expanded and adapted Schumpeter's theory to further explain the relationship between financial development and economic growth. Researchers such as Levine (2005), Demirgüç-Kunt & Levine (2009) and Demirgüç-Kunt et al. (2018), have conducted empirical studies supporting the notion that financial development is positively correlated with economic growth and a more equitable distribution of wealth.

Hypothesis Development

The Relationship between Financial Development and Financial Inclusion

The relationship between financial development and financial inclusion has been the subject of intensive analysis in economic literature, focusing primarily on how improvements in a country's financial system can expand access to financial services for all societal segments (Bist, 2017). Financial development, which involves enhancements in the availability and diversity of financial institutions and instruments, plays a crucial role in facilitating access to more inclusive financial services (Gizaw et al., 2024). Research by Sarma and Pais (2011) has highlighted that financial development can significantly enhance financial inclusion by extending outreach and reducing the costs of financial services, enabling more individuals and businesses to access essential financial resources (Sarma & Pais, 2011). The study of Guru and Yadav (2019) further investigated the relationship between financial development and economic growth in BRICS countries (Brazil, Russia, India, China, and South Africa) from 1993 to 2014, using banking sector and stock market development indicators. Their findings revealed that indicators such as the size of financial intermediaries, credit-to-deposit ratio, domestic credit to the private sector, and the value of shares traded, significantly contribute to economic growth, while banking and stock market development are shown to be complementary in fostering growth. Moreover, the depth and efficiency of financial markets, measured through variables such as the credit-to-GDP ratio, have been found to have a positive relationship with financial inclusion. Beck, Demirgüç-Kunt, and Levine (2007) previously identified that deeper financial markets provide more opportunities and are more effective in allocating financial resources, directly supporting small enterprises and individual consumers in gaining access to financial services.

Recent studies in the literature also show that advancements in financial technology (fintech) have revolutionized the relationship between financial development and financial inclusion. Technologies such as mobile banking, digital payments, and peer-to-peer lending platforms have created new pathways for financial inclusion by lowering barriers to accessing

financial services. According to the World Bank's Global Findex Database 2017, compiled by Demirgüç-Kunt et al. (2018), fintech usage has significantly contributed to reaching previously underserved groups, demonstrating the potential of fintech to strengthen the connection between financial development and financial inclusion (Demirgüç-Kunt et al., 2018). An empirical study by Elgharib (2024) also pointed out the impact of financial inclusion and financial development on financial stability in eight MENA countries. Utilizing panel data and indicators derived from the IMF and World Bank, their findings reveal that financial inclusion positively influences financial stability, with financial development acting as a moderating factor in strengthening this relationship.

Additionally, supportive regulations that promote financial innovation are essential for advancing financial inclusion. Ozili (2018) emphasized that policies encouraging fintech innovation can provide an adequate framework for financial institutions to experiment with, and implement, new, more inclusive financial solutions, which in turn reinforces the relationship between financial development and financial inclusion. Consequently, financial development, supported by fintech innovation and progressive regulations, collectively plays a vital role in expanding financial inclusion. This leads to a deeper understanding that financial development not only enhances economic stability and efficiency but also actively promotes financial inclusion by integrating more individuals into the formal financial system. Based on the arguments above, the first hypothesis is formulated as follows.

H1: *Financial development is positively associated with financial inclusion.*

The Relationship between Financial Technology and Financial Inclusion

Financial technology has accelerated the process of inclusion by delivering financial services to segments of the population previously unreachable by conventional banking systems. This creates a synergy between financial development and financial inclusion that is stronger and more inclusive. According to research by Demirgüç-Kunt et al. (2018), fintech enables more innovative and efficient financial services, such as mobile banking, peer-to-peer lending, and microfinance through digital platforms, all of which significantly reduce the cost and complexity of financial transactions. These findings suggest that fintech can effectively connect individuals who previously lacked access to financial services with the formal financial system, thereby expanding the reach of financial inclusion (Demirgüç-Kunt et al., 2018). Additionally, research by Ozili (2018) supports the view that financial technology can reduce traditional barriers to accessing financial services by providing alternative methods for transactions and savings, as well as assisting in improving personal financial management. This indicates that fintech not only facilitates financial inclusion but also supports its sustainability in the long term (Ozili, 2018).

Financial inclusion has also been closely associated with poverty alleviation and plays a pivotal role in promoting financial stability through financial technology (Lal, 2018; Vuković et al., 2024). Research indicates that banks operating under Islamic principles are more resilient during financial crises and contribute significantly to maintaining financial stability (Ahamed & Mallick, 2019; Bourkhis & Nabi, 2013). Additionally, findings from Danisman and Tarazi (2020) have highlighted that financial inclusion positively influences banking stability, particularly through the use of digital accounts and payment systems. This effect is notably driven by individuals in rural areas, young people without access to traditional financial services, and the unemployed, as supported by the studies of Vo et al. (2021) and Ashoer et al., (2024), which noted that enhancing financial inclusion levels not only bolsters bank stability but also improves adaptability and resilience.

Previous studies have also shown that the emergence of fintech has significantly expanded access to financial services, particularly for underserved populations, as noted by Girma and Huseynov (2024). Leveraging innovations such as mobile banking and digital

payments, fintech companies have been instrumental in addressing the needs of unbanked and underbanked communities, especially in developing regions (Rehman et al., 2024; Rouse et al., 2023). In African economies, Chinoda and Mashamba (2021) explored the relationship between fintech, financial inclusion, and income inequality, concluding that fintech plays a crucial role in reducing income disparities by improving financial accessibility. Similarly, the success of mobile money platforms such as M-Pesa in Kenya, as highlighted by Suri and Jack (2016), demonstrates fintech's potential to advance financial inclusion, even in areas with limited traditional banking infrastructure. Research by Mothobi and Kebotsamang (2024) has also underscored the transformative impact of mobile banking in enhancing financial inclusion across Sub-Saharan Africa. Meanwhile, Jagtiani and Lemieux (2019) further emphasized how fintech enables the creation of tailored financial products, such as microfinance, peer-to-peer lending, and customized insurance solutions, specifically designed for marginalized groups. Additionally, Frost et al. (2019) highlighted how advancements in big data and AI improve credit accessibility through enhanced accuracy of risk assessments, thereby broadening the reach of credit services. Given the above discussion in the literature, fintech has emerged as a powerful catalyst for financial inclusion. This demonstrates how technology, when integrated with existing financial systems, can push the boundaries of what can be achieved in terms of financial inclusion. Referring to the above hypothesis development arguments, the second research hypothesis was formulated as follows.

H2: *Financial technology development is positively associated with financial inclusion.*

RESEARCH METHOD

To explore the dynamic relationship between financial development, financial technology, and financial inclusion, the research design employed quantitative methods. This study utilized quantitative methods to collect and analyze numerical data with the aim of measuring the strength and direction of the relationships between the investigated variables. The study initially begins with descriptive statistics, subsequently followed by correlational analyses, panel regression analysis, and additional analysis, as a complementary robustness test.

Population and Sampling Methods

This study sought to identify relationships between financial development, financial inclusion, and financial technology, in G20 member countries. The G20 countries were chosen as the research setting due to several intrinsic factors related to the characteristics and global influence of this group. According to IMF (2020), the G20 countries comprise both advanced and emerging economies, collectively representing more than 80% of global gross domestic product (GDP). This indicates that the policies and economic developments in these countries will have significant and widespread impacts on the global economy. In this regard, the G20 also offers a unique laboratory to explore the interactions between financial development, financial inclusion, and financial technology innovation (Basnayake et al., 2024). With their diversity in financial system maturity and financial market development, the G20 countries provide unique opportunities for researchers to observe how various innovations and regulations influence access to financial services. For instance, studies by the World Bank (2019) have shown that countries with more developed financial systems tend to have higher levels of financial inclusion, and the role of financial technology in this process cannot be overlooked. Demirgüç-Kunt et al. (2018) emphasized the importance of fintech in driving financial inclusion, especially in G20 countries where technology adoption is relatively high. Additionally, G20 countries tend to have more complete and organized financial data, which strongly supports quantitative research (OECD, 2021). This enables researchers to collect and

analyze data with high precision, ensuring reliable and statistically valid results (Basnayake et al., 2024). Furthermore, since the policies adopted by the G20 countries often serve as benchmarks for other nations, research findings focusing on this group can provide relevant and practical insights for global policymaking.

Data collection

Data were extracted wfrom the Global Financial Development Database (GFDD), the World Bank database, the Bankscope commercial banking database, and the Thomson Reuters EIKON database. Data collection targeted the G20 countries with an observation period from 2012 to 2023. This timeframe was selected for several reasons: (i) The past decade has witnessed substantial advancements in financial technology (fintech). Since 2012, the fintech industry has rapidly evolved with the introduction of new technologies such as blockchain, mobile payments, and banking technologies. Studying the period from 2012 to 2023 allows researchers to capture data on how these innovations have been adopted and their impact on financial inclusion. (ii) The year 2012 also marked several years after the global financial crisis, during which many G20 countries implemented significant financial reforms. Observing this period provides insights into how changes in financial regulations and economic policies have influenced financial development and inclusion. (iii) During this period, many G20 countries experienced significant shifts in their economic structures, including changes in economic growth rates, investments in digital infrastructure, and technology adoption. Observing this timeframe enables an analysis of how these economic dynamics interact with financial inclusion. (iv) A longer and more recent period allows researchers to utilize more complete and relevant datasets, encompassing the latest technological developments and responses to the COVID-19 pandemic, which significantly impacted the digitization of financial services. (v) The end of the observation period includes the years of the COVID-19 pandemic, which accelerated digital transformation in many sectors, including the financial sector. Analyzing the period from 2012 to 2023 offers both historical and contemporary perspectives, enabling a more in-depth and representative study of the long-term impacts of financial development, financial inclusion, and the role of financial technology among G20 countries. This approach also helps in making better-informed predictions about future directions for policies and innovation in the financial sector.

Operational Definitions and Variable Measurements

To better understand the operationalization of each variable, this study also presents the definitions of variables, and their data sources as depicted in the following Table 1.

Table 1. Operational Definitions of Research Variables

No	Variable	Measures
Variable Y (Financial inclusion)		
1	CASHLESS_TRAN	: Retail cashless transactions per 100,000 adults
Variable X (Financial development)		
2	DEB_CARD	: Debit card (% age 15+)
3	CRE_CARD	: Credit card (% age 15+)
4	ATM	: ATMs per 100,000 adults
5	E_PAY	: Electronic payments used to make payments (% age 15+)
Variable X (Financial technology)		
6	EMONEY_ACC	: E-money accounts per 100,000 adults
7	FINTECH_ACC	: Financial institution account (% age 15+)
Control variables		
8	INT	: Real interest rate (%)

9	INF	: Inflation, consumer prices (annual %)
10	MCAP	: Market capitalization of listed domestic companies (% of GDP)
11	PLC	: Listed domestic companies, total
12	BANK_BRANCH	: Commercial bank branches (per 100,000 adults)

Regression Model

A longitudinal panel data analysis was employed to empirically test the relationships among the variables of interest. As outlined in the research model, financial inclusion was conceptualized as the dependent variable, and financial development and financial technology as independent variables. Regarding technical procedures, financial inclusion was measured using several proxies, including *Emoney_acc* and *Mobmon_tran*. To measure financial development, six proxies were utilized, consisting of *Bank_acc*, *Deb_card*, *Cre_card*, *ATM*, *E_pay*, and *Mob_trf*. Meanwhile, to measure the financial technology variable, the number of accounts associated with fintech companies (*Fintech_acc*) and the credit disbursed by fintech companies (*Fintech_cre*) in each G20 member country was used.

Additionally, to address potential endogeneity issues (e.g., eliminating bias from correlated variables), a panel data regression analysis was conducted using a set of country-level control variables. In the panel data format, observations were grouped along the time dimension and/or individual dimension. This structure indicates that standard OLS is unsuitable for making proper inferences in longitudinal (panel) data and would yield misspecified statistical test outputs when any form of correlation occurs among the independent variables (Mertens et al., 2016). Therefore, the white test standard error correction was considered appropriate to address heteroskedasticity issues, where the size or value of the observed variables varies across units but not within the time dimension or cross-sectional dependency in the data. Consequently, the researcher employed a fixed-effects model at the country level. The regression model notation for each dependent variable was formulated as follows.

$$CASHLESS\_TRAN_{i,t} = \alpha + \beta_1 DEB\_CARD_{i,t} + \beta_2 CRE\_CARD_{i,t} + \beta_3 ATM_{i,t} + \beta_4 EPAY_{i,t} + \beta_5 EMONEY\_ACC_{i,t} + \beta_6 FINTECH\_ACC_{i,t} + \beta \sum Controls_{i,t} + \gamma \sum Year + \gamma \sum Country + \varepsilon \qquad (1)$$

Moreover, to examine whether the relationship between debit/credit card usage and financial inclusion is non-linear due to fluctuations in the popularity of debit and credit cards in some countries, we also estimated extended models that included the squared terms of DEB_CARD and CRE_CARD. This specification allowed us to capture possible curvature effects, such as diminishing returns or threshold effects, in the association between card usage and cashless transactions.

Variables

Dependent variables

The subscript i in the statistical notation represents information related to company i, while the subscript t indicates information about a variable in year t. As shown in the empirical notation above, the researcher proposed one statistical model. In this model, the dependent variable used was CASHLESS_TRAN. This variable was calculated by accumulating the number of retail cashless transactions per 1,000 adults.

Independent variables

This study utilized six independent variables as proxies for measuring the concept of financial development. The first independent variable was DEB_CARD, calculated as the percentage of individuals aged 15 and above who own and use one or more debit cards. This variable indicates the prevalence of debit card use in daily transactions, reflecting financial inclusion and reliance on non-cash payment systems. The second independent variable was CRE_CARD, representing the percentage of individuals aged 15 and above who own and use one of more credit cards. This variable explores the extent to which consumer credit is available to individuals, serving as an indicator of the depth and sophistication of financial markets. The third independent variable was ATM, which represents the number of ATMs available per 100,000 adults. This variable indicates the accessibility and ease of access to physical banking services, which are critical for reducing physical barriers to financial transactions and enhancing financial inclusion. The fourth independent variable was EPAY, calculated as the percentage of individuals aged 15 and above who use electronic payments. This variable reflects the level of adoption of electronic payment technologies and the ease of using digital financial services in daily life. The fifth independent variable was EMONEY_ACC, which measures the number of e-money users per 100,000 adults. The sixth and final independent variable was FINTECH_ACC, representing the percentage of individuals aged 15 and above who have accounts with financial institutions, which may include traditional banks or non-bank financial institutions operated by fintech companies. These accounts can take traditional forms or be accessed through innovative digital platforms.

Control variables

In addition to the main independent variables, the issue of omitted variable bias was also considered, which could lead to inefficiency in the study's parameters. To address this, it was crucial to control for unobserved time-based characteristics at the country level, which might correlate with the explanatory variables in the proposed model. Previous studies have also recommended that the relationship between financial development and financial inclusion should be examined while controlling for certain country-level variables. To mitigate this issue, control variables that represent country-specific characteristics were also included, as suggested by the study of Nurazi & Usman, (2019).

The first control variable was INT, the real interest rate, which measures the return on investments or loans after adjusting for inflation. It is an important indicator of the cost of borrowing money and the return on investments. In financial research, real interest rates can influence investment and savings decisions, as well as access to credit, all of which are crucial to the dynamics of financial development and inclusion.

The second control variable, INF, represents the annual inflation rate, measured by changes in the consumer price index (CPI), reflecting changes in the price of goods and services purchased by households. High inflation rates can reduce purchasing power and impact the financial stability of individuals and businesses, which also affects financial inclusion. The third control variable, MCAP, represents the market capitalization of domestically listed companies, measuring the total value of shares issued by companies listed on the stock exchange as a percentage of GDP. This variable indicates the depth and size of the capital market in an economy, which can influence access to capital and economic growth. The fourth control variable, PLC, measures the total number of domestic companies listed on the stock exchange. This reflects the size and activity level of the domestic capital market. Larger and more active capital markets often provide greater opportunities for individuals and businesses to access funds through the stock market, affecting financial inclusion. The final control variable is Bank_branch, representing the number of commercial bank branches per 100,000 adults. This indicates the accessibility of traditional banking services. The availability of bank

branches can affect how easily individuals and businesses can access financial services, which is essential for improving financial inclusion.

Additional analysis

Recognizing that endogeneity could potentially hinder the estimation of research outcomes, additional analyses were conducted to ensure the robustness of the main results. Two supplementary analyses, incorporating a lagged model ($X_{i,t\text{ -1}}$) of the independent variables were consequently designed. Specifically, a lagged model was applied using data from the preceding year. Imbens and Wooldridge (2009) have emphasized that independent variables from a prior time period (t-1) cannot be correlated with the error term in the current period (t0). Lagged independent variables are therefore considered exogenous and deemed relevant factors in explaining variations in the contemporary dependent variable (t0). The statistical notation of the lagged model as an alternative dependent variable is presented in regression models 3 and 4, as shown below.

$$CASHLESS\_TRAN_{i,t} = \alpha + \beta_1 DEB\_CARD_{i,t-1} + \beta_2 CRE\_CARD_{i,t-1} + \beta_3 ATM_{i,t-1} +$$
$$\beta_4 E\_PAY_{i,t-1} + \beta_5 EMONEY\_ACC_{i,t-1} + \beta_6 FINTECH\_ACC_{i,t-1} + \beta \sum Controls_{i,t-1} + \gamma \sum Year +$$
$$\gamma \sum Country + \varepsilon \tag{2}$$

$$CASHLESS\_TRAN_{i,t} = \alpha + \beta_1 DEB\_CARD\_\Delta_{i,t} + \beta_2 CRE\_CARD\_\Delta_{i,t} + \beta_3 ATM\_\Delta_{i,t} +$$
$$\beta_4 EPAY\_\Delta_{i,t} + \beta_5 EMONEY\_ACC\_\Delta_{i,t} + \beta_6 FINTECH\_ACC\_\Delta_{i,t} + \beta \sum Controls_{i,t} + \gamma \sum Year +$$
$$\gamma \sum Country + \varepsilon \tag{3}$$

RESULT

Descriptive statistics

Table 2. The outcome of descriptive statistics analysis

VARIABLE	count	mean	sd	p25	p50	p75	min	max
CASHLESS_TRAN	227	66.225	130.329	14.607	14.607	14.607	7.271	730.256
DEB_CARD	227	88.549	16.610	95.564	95.564	95.564	25.945	96.170
CRE_CARD	227	49.073	12.993	52.580	52.580	52.580	2.439	77.074
ATM	227	720.681	2,920.228	26.241	82.629	131.286	17.726	15,403.830
EPAY	227	54.404	15.481	49.899	49.899	49.899	19.972	98.376
EMONEY_ACC	227	7.672	2.250	8.370	8.370	8.370	0.069	8.370
FINTECH_ACC	227	56.543	16.910	48.504	48.504	48.504	38.700	99.730
INTEREST	227	4.060	5.901	1.848	1.848	3.937	0.126	33.832
INF	227	3.173	3.196	0.706	2.069	4.517	(0.233)	16.332
MCAP	227	74.779	67.856	23.661	51.853	105.077	8.389	310.835
PLC	227	1,443.454	2,071.439	140.000	379.000	2,114.000	83.642	11,629.000
BANK_BRANCH	227	17.881	11.286	8.340	14.730	25.420	5.976	50.810

The descriptive analysis results indicate that the average number of retail cashless transactions is 66.23 per 100,000 adults, with substantial variation (standard deviation of 130.33). Most regions exhibit low retail cashless transactions, with a median value around 14.61, while the highest value reaches 730.26. The average debit card usage is 88.55%, indicating high penetration, with a median of approximately 95.56%. Credit card usage is lower, averaging 49.07%, with a standard deviation of 12.99 and a median of 52.58%. Some regions show very low credit card penetration, with a minimum value of only 2.44% and a maximum of 77.07%.

For the number of ATMs per 100,000 adults, the average is recorded at 720.68, but there is substantial variation with a standard deviation of 2,920.23. Most regions have between

26 and 131 ATMs per 100,000 adults, with an exceptionally high maximum value of 15,403 ATMs. The average electronic payment usage is 54.40%, with a median of approximately 49.90%, while the number of e-money accounts per 100,000 adults is relatively low, averaging 7.67 with minimal variation (standard deviation of 2.25). Most regions have e-money accounts close to 8.37.

The average financial institution account ownership was found to be 56.54%, with a standard deviation of 16.91 and a median of around 48.50%. The real interest rate averaged 4.06% but showed significant variation, with a maximum value reaching 33.83%. The average inflation rate was found to be 3.17%, with most regions having lower inflation, while the maximum reaches 16.33%. The average market capitalization was 74.78% of GDP, with wide dispersion, as some regions reach up to 310.84% of GDP. The number of domestic companies listed averaged 1,443.45, with a considerable standard deviation of 2,071.44. The median value suggests that most regions have between 140 and 2,114 domestic companies listed. The number of bank branches per 100,000 adults averaged 17.88, with a median of 14.73, while the maximum reaches 50.81 branches. These data illustrate significant disparities in banking infrastructure and access to financial services across the regions studied.

Correlation analysis

Table 3. Pearson correlation matrix outcomes

No	VARIABLE	1	2	3	4	5	6	7	8	9	10	11	12	VIF
1	CASHLESS_TRAN	1												
2	DEB_CARD	0.044	1											2.45
3	CRE_CARD	0.089	0.867***	1										3.82
4	ATM	-0.054	-0.016	-0.112	1									1.76
5	EPAY	0.064	0.180**	0.417***	-0.028	1								4.91
6	EMONEY_ACC	-0.017	0.140*	0.134*	0.069	0.125	1							1.55
7	FINTECH_ACC	0.039	-0.282***	-0.009	-0.013	0.861***	0.045	1						5.12
8	INTEREST	-0.01	-0.062	-0.091	-0.08	-0.131*	-0.182**	-0.086	1					1.34
9	INF	-0.157*	-0.146*	-0.136*	-0.082	-0.126	-0.150*	-0.072	0.214**	1				1.41
10	MCAP	0.018	-0.025	0.001	0.194**	0.148*	0.093	0.158*	-0.123	0.006	1			1.88
11	PLC	0.027	0.023	0.096	-0.131*	0.103	-0.042	0.124	-0.131*	-0.084	0.271***	1		1.67
12	BANK_BRANCH	0.146*	0.017	0.099	-0.179**	0.157*	-0.041	0.152*	0.002	-0.153*	-0.006	0.069	1	2.12

*Note: * denotes p<0.1, ** p<0.05, and *** p<0.01.*

Results of the correlation analyses conducted among the variables revealed several important findings. CASHLESS_TRAN (retail cashless transactions) exhibited a positive but insignificant correlation with most variables. However, there was a significant positive correlation shown between CASHLESS_TRAN and BANK_BRANCH (number of bank branches per 100,000 adults) with a coefficient of 0.146 *(p<0.1)*, indicating that the existance of more bank branches is associated with higher rates of cashless transactions. Debit card usage (DEB_CARD) was also shown to have a positive and significant correlation with credit card usage (CRE_CARD) with a coefficient of 0.867 *(p<0.01)*, suggesting that individuals who use debit cards are also more likely to use credit cards. However, there was a significant negative correlation between DEB_CARD and FINTECH_ACC (financial institution accounts) with a value of -0.282 *(p<0.01)*, indicating an inverse relationship between debit card usage and financial institution accounts.

Furthermore, CRE_CARD showed a significant positive correlation of 0.417 *(p<0.01)* with EPAY (electronic payments), indicating that credit card usage is associated with higher electronic payment usage. On the other hand, ATM had a significant negative correlation with BANK_BRANCH (-0.179 *(p<0.05)*), suggesting that higher availability of ATMs is associated with fewer bank branches. Meanwhile, EPAY had a highly significant positive correlation with FINTECH_ACC at 0.861 *(p<0.01)*, indicating that higher electronic payment usage is associated with greater incidence of financial institution accounts. Additionally, results

revealed a significant negative correlation between EPAY and INTEREST (-0.131 *(p<0.1)*), indicating that higher interest rates are associated with lower usage of electronic payments.

Real interest rates (INTEREST) were positively correlated with inflation (INF) with a value of 0.214 *(p<0.05)*, but negatively correlated with several other variables including EMONEY_ACC and EPAY. Furthermore, inflation (INF) demonstrated a significant negative correlation with DEB_CARD, CRE_CARD, and BANK_BRANCH, indicating that higher inflation is associated with lower usage of debit cards, credit cards, and bank branches. Market capitalization (MCAP) was significantly and positively correlated with ATM (0.194 *(p<0.05)*) and BANK_BRANCH (0.157 *(p<0.1)*), suggesting that larger capital markets are associated with greater banking infrastructure. The number of domestic companies listed (PLC) was found to be positively correlated with MCAP at 0.271 *(p<0.01)*, indicating a strong relationship between market capitalization and the number of listed companies.

A Variance Inflation Factor (VIF) analysis was also conducted to evaluate the potential presence of multicollinearity among the independent variables in the regression model. As shown in Table 3, all VIF values fell well below the commonly accepted threshold of 10, indicating that multicollinearity is not a serious concern in this study. The highest VIF values observed were for FINTECH_ACC (5.12) and EPAY (4.91), consistent with the positive and relatively high correlation reported between these variables in the correlation matrix. While these values are the largest in the set, they remain comfortably within acceptable limits, suggesting that their inclusion does not distort the stability or interpretability of the regression coefficients. Other variables, including CRE_CARD (3.82) and DEB_CARD (2.45), displayed moderate VIF values, reflecting some correlation with other predictors, but far from problematic levels. The remaining predictors, including ATM (1.76), EMONEY_ACC (1.55), INT (1.34), and INF (1.41) exhibited low VIFs, further confirming that the explanatory variables were sufficiently independent of one another.

Table 4. Panel regression outcome

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
DEB_CARD	0.844								-2.554
	(1.641)								(-0.934)
CRE_CARD		1.150*							0.667
		(1.740)							(0.532)
ATM			-0.00524***						-0.00503**
			(-2.932)						(-2.394)
EPAY				1.108*					2.508
				(1.950)					(1.370)
EMONEY_ACC					12.58***				12.72***
					(2.884)				(2.926)
FINTECH_ACC						1.362*			-0.115
						(1.682)			(-0.0850)
DEB_CARD^2							-0.021		
							(-1.03)		
CRE_CARD^2								-0.015	
								(-1.36)	
INTEREST	0.0499	0.0990	-0.265	0.133	0.646	0.0340	0.601	0.609	0.637
	(0.0672)	(0.134)	(-0.348)	(0.177)	(0.731)	(0.0457)	(0.64)	(0.65)	(0.680)
INF	-7.219***	-7.319***	-8.393***	-7.024***	-6.683***	-7.087***	-7.064***	-7.059***	-7.078***
	(-3.182)	(-3.318)	(-3.496)	(-3.185)	(-3.243)	(-3.226)	(-3.19)	(-3.18)	(-3.249)
MCAP	0.0407	0.0418	0.0918	0.0277	0.0118	0.0260	0.026	0.026	0.0288
	(0.571)	(0.588)	(1.155)	(0.388)	(0.164)	(0.361)	(0.32)	(0.32)	(0.333)
PLC	-0.000710	-0.00120	-0.00218	-0.000804	0.000788	-0.00120	-0.00115	-0.00114	-0.00117
	(-0.302)	(-0.516)	(-0.903)	(-0.342)	(0.341)	(-0.507)	(-0.49)	(-0.49)	(-0.489)
BANK_BRANCH	-0.283	-0.393	-0.584	-0.400	-0.349	-0.386	-1.002	-1.005	-1.047
	(-0.361)	(-0.492)	(-0.704)	(-0.504)	(-0.439)	(-0.477)	(-1.18)	(-1.18)	(-1.211)
Constant	-0.0812	23.42	95.54***	28.06	-10.83	18.25	88.521	87.412	100.7
	(-0.00138)	(0.540)	(2.818)	(0.701)	(-0.249)	(0.396)	(0.70)	(0.69)	(0.761)

Observations	227	227	227	227	227	227	227	227	227
R-squared	0.312	0.316	0.318	0.318	0.341	0.316	0.369	0.368	0.368
Adj R-squared	0.279	0.283	0.285	0.284	0.309	0.283	0.336	0.335	0.334
Year FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
Country FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
SE Clustered	YES	YES	YES	YES	YES	YES	YES	YES	YES

Note: * denotes p<0.1, ** p<0.05, and *** p<0.01.

Results of the regression analysis also show several key findings regarding the factors influencing CASHLESS_TRAN (retail cashless transactions). Debit card usage (DEB_CARD) did not consistently show a significant association with cashless transactions across all models. Although the coefficient was negative for Model (9) (-2.554), this relationship was not significant, preventing the conclusion that increased debit card usage leads to a decline in cashless transactions. Similarly, credit card usage (CRE_CARD) only showed a positive and significant association for Model (2) with a coefficient of 1.150 *(p<0.1)*, but this effect became insignificant for Model (9). This indicates that while credit card usage might be associated with an increase in cashless transactions, the results are not consistent across models.

A notable finding concerns the ATM variable, which showed a significant negative relationship with cashless transactions under Model (3) and Model (9), with coefficients of 0.00524 *(p<0.01)* and -0.00503 *(p<0.05)* respectively, suggesting that increased availability of ATMs is associated with lower levels of cashless transaction. This implies that the convenience of accessing cash through ATMs might discourage people from switching to cashless transactions. For EPAY (electronic payments), a significant positive impact was observed under Model (4) with a coefficient of 1.108 *(p<0.1)*, indicating that electronic payment usage contributes to higher levels of cashless transactions. However, for Model (9), this relationship became insignificant (coefficient 2.508), possibly indicating that other factors influence the strength of this relationship when additional variables are considered.

One of the strongest and most consistent predictors was EMONEY_ACC (e-money accounts). Under both Model (5) and Model (9), this variable exhibited a highly significant impact on cashless transactions, with coefficients of 12.58 *(p<0.01)* and 12.72 *(p<0.01)*. This underscores the importance of e-money accounts in driving cashless transactions in society. Conversely, inflation (INF) consistently showed a significant negative relationship across all models, with coefficients ranging from -7.219 *(p<0.01)* to -8.393 *(p<0.01)*. This suggests that as inflation rises, cashless transactions tend to decline. The negative impact of inflation may indicate that economic instability or rising prices lead people to control their spending by relying on cash.

Other variables, such as MCAP (market capitalization), PLC (number of listed companies), and BANK_BRANCH (number of bank branches), do not exhibit significant association with cashless transactions in any of the models. While some have negative coefficients, their effects are not statistically significant. Overall, these findings highlight that factors such as ATM availability, e-money accounts, and inflation are significantly associated with cashless transactions. Easy access to cash via ATMs tends to reduce cashless transactions, whereas an increase in e-money accounts strongly contributes to the growth of cashless transactions. Meanwhile, higher inflation suppresses the use of cashless transactions. Moreover, the results of the extended specification with quadratic terms in Table 4 show that the coefficients for both DEB_CARD² and CRE_CARD² -0.021 *(p>0.05)* from Model (7) and -0.015 *(p>0.05)* in Model (8) are statistically insignificant, indicating that the relationship between card usage and financial inclusion is adequately captured by a linear form.

Additional Analysis with Independent Lag Variables

Table 5. Results of additional analysis with lagged independent variables

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)
DEB_CAR-1	1.108**						-2.305
	(1.980)						(-0.863)
CRE_CARD-1		1.342*					0.572
		(1.947)					(0.437)
ATM-1			-0.00469**				-0.00459**
			(-2.584)				(-2.153)
EPAY-1				1.319**			2.479
				(2.230)			(1.352)
EMONEY_ACC-1					14.25***		14.24***
					(3.082)		(3.103)
FINTECH_ACC-1						1.648**	0.0356
						(1.975)	(0.0252)
INTEREST-1	0.0590	0.102	-0.263	0.146	0.717	0.0300	0.739
	(0.0920)	(0.159)	(-0.401)	(0.222)	(1.233)	(0.0463)	(1.180)
INF-1	-6.403***	-6.592***	-7.663***	-6.231***	-5.885***	-6.295***	-6.069***
	(-2.765)	(-2.915)	(-3.093)	(-2.756)	(-2.967)	(-2.796)	(-2.936)
MCAP-1	0.0710	0.0730	0.119	0.0561	0.0392	0.0537	0.0497
	(1.054)	(1.096)	(1.564)	(0.837)	(0.561)	(0.795)	(0.589)
PLC-1	-0.000233	-0.000790	-0.00149	-0.000328	0.00149	-0.000809	-0.000396
	(-0.103)	(-0.352)	(-0.633)	(-0.144)	(0.679)	(-0.356)	(-0.179)
BANK_BRANCH-1	-0.221	-0.332	-0.440	-0.346	-0.275	-0.334	-0.969
	(-0.291)	(-0.428)	(-0.539)	(-0.451)	(-0.344)	(-0.425)	(-1.129)
Constant	85.48	124.5**	204.2***	128.6**	87.51*	115.8*	174.5
	(1.161)	(2.110)	(4.000)	(2.274)	(1.791)	(1.876)	(1.319)
Observations	208	208	208	208	208	208	208
R-squared	0.330	0.335	0.331	0.338	0.368	0.335	0.396
Adj R-squared	0.296	0.301	0.297	0.304	0.334	0.300	0.353
Year FE	YES	YES	YES	YES	YES	YES	YES
Country FE	YES	YES	YES	YES	YES	YES	YES
SE Clustered	YES	YES	YES	YES	YES	YES	YES

*Note: * denotes p<0.1, ** p<0.05, and *** p<0.01.*

Regression analysis using lagged data from one year prior provided several important insights into the factors influencing retail cashless transactions (CASHLESS_TRAN). Debit card usage from the previous year (DEB_CARD-1) demonstrated a significant positive association through one model, indicating that it can contribute to higher cashless transactions. However, this relationship was not consistent across all models and became negative or insignificant in others. Similarly, credit card usage from the previous year (CRE_CARD-1) showed a significant positive association through one model but lost significance when additional variables were included, suggesting that its relationship with cashless transactions is contingent upon other factors. Interestingly, the availability of ATMs in the previous year (ATM-1) consistently exhibited a significant negative relationship with cashless transactions. This finding underscores the idea that easy access to cash through ATMs discourages individuals from adopting cashless payment methods. In contrast, electronic payment usage in the previous year (EPAY-1) initially showed a positive and significant effect on cashless transactions, suggesting that greater use of digital payment systems can drive cashless activity. However, this relationship weakens and becomes insignificant in more comprehensive models.

One of the most robust findings concerns e-money accounts from the previous year (EMONEY_ACC-1), which consistently exhibited a strong positive relationship with cashless transactions across all models. This result highlights the pivotal role of e-money in facilitating the transition to cashless economies. Similarly, financial institution accounts from the previous

year (FINTECH_ACC-1) showed a significant positive impact under some models, reinforcing the importance of fintech in expanding access to digital financial services. However, this effect was not universally observed across all models, indicating variability in its influence.

Macroeconomic variables also play a critical role. Inflation in the previous year (INF-1) emerged as a significant negative factor across all models, revealing that higher inflation correlates with a decline in cashless transactions. This suggests that economic instability and rising prices may lead individuals to favor cash transactions, possibly as a way to better control their spending. On the other hand, real interest rates from the previous year (INTEREST-1) did not exhibit any significant effects on cashless transactions, indicating a limited role for borrowing costs in influencing payment behaviors. Other variables, such as market capitalization (MCAP-1), the number of listed companies (PLC-1), and the number of bank branches (BANK_BRANCH-1), showed no significant effects on cashless transactions across the models, suggesting that these factors may have a more indirect or limited role in influencing payment preferences. In summary, the findings revealed that certain factor levels from the previous-year, such as the availability of e-money accounts and inflation, significantly shape cashless transactions. E-money accounts consistently drive the adoption of cashless payments, while higher inflation acts as a barrier. Meanwhile, the role of debit/credit cards, ATMs, and fintech varies depending on the context, highlighting the complex interplay of financial and macroeconomic factors in driving cashless behavior.

Additional Analysis with Change Variables (Delta)

Table 6. Results of additional analysis using change variables (delta)

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)
DEB_CARD_Δ	0.842						-2.551
	(1.626)						(-0.932)
CRE_CARD_Δ		1.153*					0.661
		(1.726)					(0.518)
ATM_Δ			-0.0056***				-0.00528**
			(-2.860)				(-2.262)
EPAY_Δ				1.110*			2.389
				(1.938)			(1.321)
EMONEY_ACC_Δ					14.77***		14.73***
					(2.942)		(2.939)
FINTECH_ACC_Δ						1.374*	-0.0371
						(1.683)	(-0.0278)
INTEREST_Δ	-0.504	-0.447	-0.825	-0.412	0.0655	-0.518	0.0560
	(-0.686)	(-0.610)	(-1.082)	(-0.549)	(0.0801)	(-0.700)	(0.0630)
INF_Δ	-7.076***	-7.184***	-8.307***	-6.870***	-6.666***	-6.934***	-7.132***
	(-3.008)	(-3.145)	(-3.328)	(-3.008)	(-3.130)	(-3.049)	(-3.152)
MCAP_Δ	0.0321	0.0331	0.0893	0.0185	0.00758	0.0165	0.0297
	(0.440)	(0.455)	(1.074)	(0.253)	(0.101)	(0.223)	(0.322)
PLC_Δ	-0.000541	-0.00106	-0.00209	-0.000638	0.000668	-0.00106	-0.00137
	(-0.218)	(-0.431)	(-0.821)	(-0.256)	(0.287)	(-0.424)	(-0.569)
BANK_BRANCH_Δ	-0.445	-0.571	-0.761	-0.581	-0.362	-0.565	-1.110
	(-0.516)	(-0.648)	(-0.837)	(-0.663)	(-0.409)	(-0.632)	(-1.156)
Constant	116.4	140.2**	209.7***	145.2**	109.0**	135.1**	225.0*
	(1.643)	(2.403)	(4.065)	(2.587)	(2.247)	(2.229)	(1.664)
Observations	208	208	208	208	208	208	208
R-squared	0.329	0.334	0.336	0.335	0.364	0.333	0.391
Adj R-squared	0.296	0.300	0.303	0.302	0.333	0.299	0.352
Year FE	YES	YES	YES	YES	YES	YES	YES
Country FE	YES	YES	YES	YES	YES	YES	YES
SE Clustered	YES	YES	YES	YES	YES	YES	YES

*Note: * denotes p<0.1, ** p<0.05, and *** p<0.01.*

Changes in debit card usage (DEB_CARD_Δ) showed a positive but insignificant coefficient for most models, including Model (1) with a coefficient of 0.842 and Model (7) with a negative coefficient of -2.551, which was also insignificant. This indicates that year-to-year changes in debit card usage do not significantly impact changes in cashless transactions. Change in credit card usage (CRE_CARD_Δ) demonstrated a significant positive relationship for Model (2) with a coefficient of 1.153 *(p<0.1)*, suggesting that increased credit card usage is associated with higher rates of cashless transactions. However, this relationship became insignificant for Model (7) (coefficient 0.661), indicating variability in its influence depending on the model used.

Change in the number of ATMs (ATM_Δ) showed a significant negative relationship with changes in cashless transactions. Model (3) yielded a coefficient of -0.0056 *(p<0.01)*, while Model (7), yielded a value of -0.00528 *(p<0.05)*, suggesting that an increase in the number of ATMs is associated with a decrease in cashless transactions. This finding reinforces earlier conclusions that greater access to ATMs reduces the adoption of cashless transactions, as people may prefer cash when ATMs are more accessible. Changes in electronic payment usage (EPAY_Δ) exhibited a significant positive effect for Model (4) with a coefficient of 1.110 *(p<0.1)*, but this became insignificant for Model (7) (coefficient 2.389). This suggests that increases in electronic payment usage have the potential to enhance cashless transactions, although this relationship may vary depending on other factors.

Changes in e-money accounts (EMONEY_ACC_Δ) consistently showed a highly significant positive effect across all models, with coefficients of 14.77 *(p<0.01)* for Model (5) and 14.73 *(p<0.01)* for Model (7). This underscores the strong relationship between increasing e-money accounts and the growth of cashless transactions, highlighting the critical role of e-money in promoting cashless adoption. Change in financial institution accounts (FINTECH_ACC_Δ) displayed a significant positive effect through Model (6) with a coefficient of 1.374 *(p<0.1)*, but this relationship became insignificant for Model (7) (-0.0371). This indicates that an increase in financial institution accounts can correlate with higher cashless transactions, though the relationship is not consistently significant.

Change in real interest rates (INTEREST_Δ) did not exhibit any significant association with change in cashless transactions across all models. In contrast, change in inflation (INF_Δ) consistently showed a highly significant negative relationship, with coefficients ranging from -6.666 *(p<0.01)* to -8.307 *(p<0.01)*. This indicates that rising inflation is associated with a decline in cashless transactions, reflecting the adverse impact of macroeconomic conditions on the adoption of cashless payments. Other variables, such as change in market capitalization (MCAP_Δ), change in the number of listed companies (PLC_Δ), and change in the number of bank branches (BANK_BRANCH_Δ), did not demonstrate significant relationships with change in cashless transactions across any models. Overall, the findings emphasize the importance of e-money accounts and electronic payments in driving cashless adoption, while increased ATM availability and inflation tend to hinder the growth of cashless transactions.

DISCUSSION

The findings of this study reveal several intriguing insights regarding the influence of financial development and the presence of financial technology on financial inclusion in G20 member countries. These findings are highly relevant in the context of global financial technology advancements and efforts to expand public access to formal financial services. Based on the results of the regression analyses, several variables related to financial development, such as credit card usage, electronic payments, and e-money accounts, demonstrate a significant positive association with financial inclusion. Conversely, the number of ATMs and inflation demonstrate a significant negative relationship with the adoption of

cashless transactions. This discussion aims to place these findings within the context of relevant literature and explore their implications for financial policy in G20 member countries.

First, regarding the relationship between financial development and financial inclusion, financial development through the use of digital payment instruments, such as credit cards and electronic payments, has been shown to promote financial inclusion. The findings of this study reinforce the conclusions of Demirgüç-Kunt et al. (2018), which highlighted that access to cashless and digital payment tools can expand public participation in formal financial systems. In the context of the G20 countries, the use of credit cards as a payment tool has increased alongside the adoption of digital payment technologies. This study demonstrates that credit card usage positively impacts financial inclusion, with increased credit card usage associated with higher rates of cashless transactions.

Conversely, the finding that the number of ATMs negatively impacts financial inclusion underscores the importance of balancing physical and digital infrastructure to enhance financial inclusion. This finding aligns with literature suggesting that greater ATM availability encourages more frequent use of cash, thereby hindering the adoption of cashless transactions and digital financial services (Gomber et al., 2017). According to Allen et al. (2016), traditional banking services that rely heavily on physical infrastructure, such as ATMs and bank branches, tend to slow the transition to digital financial services. This is particularly relevant in countries with widespread ATM access, where people may still prefer to use cash rather than digital financial services. Additionally, electronic payments have showed significant results in improving financial inclusion. Electronic payments are considered one of the most effective tools for providing broader and more inclusive access to formal financial services, especially for the unbanked population (Elgharib, 2024). In developing countries, including some G20 nations, electronic payments offer greater opportunities for previously unbanked populations to participate in the formal financial ecosystem.

Second, regarding the the role of financial technology in enhancing financial inclusion, financial technology (fintech) has emerged as a critical catalyst for enhancing financial inclusion globally, including in G20 countries. In this study, the variables of e-money accounts and fintech demonstrated a significant positive influence on financial inclusion. This finding aligns with the growing body of literature on the role of fintech in expanding access to financial services for underserved populations. Haddad and Hornuf (2019) emphasized that fintech creates new opportunities to provide more affordable, faster, and easily accessible financial services to the broader public. E-money accounts, as one of fintech's innovations, have been shown to significantly improve financial inclusion. This finding is supported by literature indicating that e-money services enable individuals, especially those without bank accounts, to participate in digital financial transactions without relying on traditional banking infrastructure (Beck et al., 2015). Fintech also addresses geographical and economic barriers that have historically limited access to formal financial services. According to Sahay et al. (2020), fintech can play a pivotal role in tackling economic inequities and accelerating financial inclusion, particularly in developing countries where traditional banking infrastructure is often inadequate.

Beyond e-money accounts, other fintech innovations such as peer-to-peer lending, mobile banking, and blockchain have created new avenues for accessing financial services. These innovations help reduce transaction costs, enhance transparency, and accelerate access to financial services (Arner et al., 2016). In G20 countries, fintech plays a vital role in advancing financial inclusion agendas by providing more inclusive and responsive digital financial solutions tailored to the needs of a broader population.

Apart from that, high inflation as one of the macroeconomics factors, has a significantly negative impact on financial inclusion, as evidenced by the findings of this study. The detrimental effects of inflation on financial inclusion have also been highlighted in previous

literature. According to Beck et al. (2011), high inflation tends to erode the purchasing power of individuals, which in turn affects their ability to participate in the formal financial system. High inflation is often accompanied by economic instability, which undermines public trust in the banking system and encourages reliance on cash rather than digital financial services. This study points the importance of stable macroeconomic policies in supporting the growth of financial inclusion. Stable fiscal and monetary policies can help control inflation and foster public confidence in formal financial services, including cashless transactions. In the context of the G20 countries, maintaining economic stability and low inflation should be a priority for governments and financial institutions to ensure the success of initiatives aimed at enhancing financial inclusion.

Theoretical Implications

The findings of this study also contribute to theoretical debates on financial development and financial inclusion. First, the negative association between ATM availability and financial inclusion reinforces theories that emphasize the substitutive relationship between traditional banking infrastructure and digital financial services. This suggests that financial development cannot be understood solely through physical access to banks, but must also account for the transition toward digital platforms. Second, the strong positive role of e-money accounts and electronic payments provides empirical support for innovation-driven financial development theories, particularly those rooted in Schumpeterian perspectives on the role of technology in driving economic and social transformation. These results extend financial development theory by underscoring the importance of nontraditional digital channels in facilitating inclusive financial systems.

Moreover, the consistent negative effect of inflation on financial inclusion highlights the interaction between macroeconomic stability and financial development theories, suggesting that institutional and policy contexts remain critical for understanding financial inclusion outcomes. Finally, by demonstrating the complementary but sometimes conflicting roles of traditional financial instruments (e.g., debit/credit cards, ATMs) and fintech solutions (e.g., e-money), the study advances the theoretical understanding of how financial development operates in hybrid systems where old and new infrastructures coexist.

Policy Implications

The findings of this study hold several key implications for financial policy in G20 member countries. First, governments and financial regulators should continue to support the development of fintech and digital financial services ecosystem to enhance financial inclusion. With an increasing number of people transitioning to digital financial services, regulators must ensure that the infrastructure supporting electronic payments and e-money is accessible to everyone, including those in remote areas. Second, policies promoting cashless transactions and reducing dependency on cash should be prioritized. While ATMs remain vital for cash access, this study highlights that excessive reliance on ATMs may hinder the adoption of cashless transactions. Therefore, balanced policies are necessary to ensure that digital and physical financial infrastructures complement each other in advancing financial inclusion. Third, policies aimed at maintaining economic stability and controlling inflation are crucial to fostering the growth of financial inclusion. High inflation can reduce the public's incentive to use formal financial services. Hence, governments must maintain macroeconomic stability through appropriate monetary policies to encourage greater trust and participation in formal financial systems.

Limitation and Future Research

While this study provides important insights into the relationship between financial

development, financial technology, and financial inclusion in the G20 countries, several limitations should be acknowledged. First, the analysis is based on secondary macroeconomic data, which may not fully capture household-level or firm-level variations in financial behavior. Future studies could complement this approach with micro-level survey data to provide a more granular understanding of financial inclusion dynamics. Second, the focus on G20 economies, while valuable due to their global influence, limits the generalizability of the findings to lower-income countries with different institutional and technological contexts. Future research could extend the analysis to a broader set of developing economies to assess whether similar patterns hold. Third, the study relies on proxies such as debit/credit card usage, ATM density, and e-money accounts, which, although widely used, may not fully reflect the multidimensional nature of financial inclusion. Future research could explore alternative or composite indices that account for the accessibility, affordability, and quality of financial services. Finally, the study employed a panel regression framework, which, despite controlling for fixed effects, cannot fully eliminate potential endogeneity or unobserved heterogeneity. Future research might apply advanced econometric methods, such as dynamic panel models or instrumental variable approaches, to further strengthen causal inferences.

CONCLUSION

The findings of this study offer key insights into the dynamics of financial development and financial inclusion, particularly within the context of the G20 member countries. The first research question explored the relationship between financial development and financial inclusion. The analysis revealed that financial development, measured through variables such as credit card usage, debit card usage, ATMs, and electronic payments, has a mixed impact on financial inclusion, as represented by cashless transactions (CASHLESS_TRAN). Credit card usage demonstrated a positive and significant relationship in certain models, suggesting that as people increasingly use credit cards, financial inclusion improves. Conversely, the availability of ATMs was found to have a negative impact, indicating that greater access to cash through ATMs may discourage the shift toward cashless transactions, thereby limiting financial inclusion. On the other hand, electronic payments and e-money accounts consistently exhibited a significant positive effect, highlighting that digital payment services contribute significantly to enhancing financial inclusion in the countries studied.

The second research question focused on the relationship between financial technology (fintech) and financial inclusion. The study found that fintech, represented by variables such as financial institution accounts (FINTECH_ACC) and e-money accounts (EMONEY_ACC), plays a critical role in expanding financial inclusion. E-money accounts, in particular, had a highly significant impact on increasing cashless transactions, underlining the transformative role of fintech in enabling broader participation in formal financial systems. These results strongly support the hypothesis that innovations in financial technology encourage more people to engage with the formal financial sector.

Given the aforementioned conclusion, this study underscores that financial development through digital services, such as electronic payments and fintech innovations, has a profound and positive relationship with financial inclusion. However, reliance on traditional banking infrastructure, such as ATMs, may hinder the transition to a more inclusive financial system. These findings highlight the need for balanced development of financial services, combining the strengths of digital innovations with strategic management of traditional infrastructure, to foster greater financial inclusion across the G20 nations.

This study acknowledges that G20 countries vary substantially in their level of technological advancement, which could influence the relationship between financial development, financial technology, and financial inclusion. A formal classification of countries

using measures such as the OECD Digital Readiness Scores or the ITU ICT Development Index could enable a more nuanced sub-group comparative analysis. However, given the relatively small sample size of the G20 panel (n = 20 countries), further splitting the sample would substantially reduce statistical power and potentially compromise the robustness of the panel estimations. Future research could address this limitation by incorporating larger cross-country datasets or multi-year pooled panels, allowing for the grouping of countries by technological readiness while retaining sufficient statistical power.

ACKNOWLEDGEMENT

REFERENCES

Ahamed, M.M., & Mallick, S.K. (2019). Is financial inclusion good for bank stability? International evidence. *Journal of Economic Behavior and Organization*, Vol. 157, pp. 403-427. https://doi.org/10.1016/j.jebo.2017.07.027

Allen, F., Demirgüç-Kunt, A., Klapper, L., & Martinez Peria, M. S. (2016). The foundations of financial inclusion: Understanding ownership and use of formal accounts. *Journal of Financial Intermediation,* Vol. 27, pp. 1-30. https://doi.org/10.1016/j.jfi.2015.12.003

Arner, D. W., Barberis, J., & Buckley, R. P. (2015). The evolution of fintech: A new post-crisis paradigm? *Georgetown Journal of International Law*, Vol. 47, pp. 1271-1319.

http://dx.doi.org/10.2139/ssrn.2676553

Ashoer, M., Jebarajakirthy, C., Lim, X., Mas'ud, M., & Sahabuddin, Z. A. (2024). Mobile fintech, digital financial inclusion, and gender gap at the bottom of the pyramid: An extension of mobile technology acceptance model. *Procedia Computer Science*, *234*, 1253-1260. https://doi.org/10.1016/j.procs.2024.03.122

Bank for International Settlements. (2018). *Annual report 2017/18*. Bank for International Settlements. https://www.bis.org/publ/arpdf/ar2018e.pdf

Basnayake, D., Naranpanawa, A., Selvanathan, S., & Bandara, J. S. (2024). Financial inclusion through digitalization and economic growth in Asia-Pacific countries. *International Review of Financial Analysis*, *96*, 103596. https://doi.org/10.1016/j.irfa.2024.103596

Bazhal, I. (2016). The Theory of Economic Development of J.A. Schumpeter: Key Features. *MPRA Paper 69883*, University Library of Munich, Germany, revised 25 Feb 2016.

Beck, T., Demirgüç-Kunt, A., & Levine, R. (2007). Finance, inequality and the poor. *Journal of Economic Growth*, 12(1), 27-49. https://www.jstor.org/stable/40216113

Beck, T., Demirgüç-Kunt, A., & Levine, R. (2011). Financial inclusion: Measuring progress and progress in measuring. *Journal of Economic Literature*, 53(3), 710-719.

Beck, T., Senbet, L. W., & Simbanegavi, W. (2015). Financial inclusion and innovation in Africa: An overview. *Journal of African Economies*, 24(1), i3-i11. https://doi.org/10.1093/jae/eju031

Benchimol, J., & Bozou, C. (2024). Desirable banking competition and stability. *Journal of Financial Stability*, 73, 101266. https://doi.org/10.1016/j.jfs.2024.101266

Bist, J. P. (2018). Financial development and economic growth: Evidence from a panel of 16 African and non-African low-income countries. *Cogent Economics & Finance*, *6*(1).

https://doi.org/10.1080/23322039.2018.1449780

Bourkhis, K. and Nabi, M.S. (2013), "Islamic and conventional banks' soundness during the 2007–2008 financial crisis", Review of Financial Economics, Vol. 22 No. 2, pp. 68-77, doi: 10.1016/j. rfe.2013.01.001.2.

Chinoda, T., & Mashamba, T. (2021). Fintech, financial inclusion and income inequality nexus in Africa. *Cogent Economics & Finance*, *9*(1), 1986926. https://doi.org/ 10.1080/23322039.2021.1986926.

Danisman, G.O. and Tarazi, A. (2020). Financial inclusion and bank stability: Evidence from Europe. *The European Journal of Finance*, Vol. 26 No. 18, pp. 1842-1855. https://doi.org/10.1080/1351847X.2020.1782958

Demirgüç-Kunt, A., & Levine, R. (2009). Finance and Inequality: Theory and Evidence. *Annual Review of Financial Economics*. 1 (287-318). https://doi.org/10.1146/annurev.financial.050808.114334

Demirgüç-Kunt, A., Klapper, L., Singer, D., Ansar, S., & Hess, J. (2018). The Global Findex Database 2017: *Measuring financial inclusion and the fintech revolution*. World Bank.

Elgharib, W, A. (2024). Financial inclusion, financial development and financial stability in MENA. *Review of Accounting and Finance*. 23 (4), 489-5050. https://doi.org/10.1108/RAF-05-2023-0146

Frost, J., Gambacorta, L., Huang, Y., Shin, H. S., & Zbinden, P. (2019). BigTech and the changing structure of financial intermediation. *Economic policy*, *34*(100), 761-799. https://doi.org/10.1093/epolic/eiaa003

Girma, A. G., & Huseynov, F. (2023). The Causal Relationship between FinTech, Financial Inclusion, and Income Inequality in African Economies. *Journal of Risk and Financial Management*, *17*(1), 2. https://doi.org/10.3390/jrfm17010002

Gizaw, T., Getachew, Z., & Mancha, M. (2024). Financial development and economic growth: evidence from emerging African and Asian countries. *Cogent Economics & Finance*, *12*(1). https://doi.org/10.1080/23322039.2024.2398213

Gomber, P., Koch, J. A., & Siering, M. (2017). Digital finance and fintech: Current research and future research directions. *Journal of Business Economics*, 87(5), 537-580. https://doi.org/10.1007/s11573-017-0852-x

Guru, B. K., & Yadav, I. S. (2019). Financial development and economic growth: panel evidence from BRICS. *Journal of Economics, Finance and Administrative Science*, *24*(47), 113-126. https://doi.org/10.1108/JEFAS-12-2017-0125

Haddad, C., & Hornuf, L. (2019). The emergence of the global fintech market: Economic and technological determinants. *Small Business Economics*, 53(1), 81-105. https://doi.org/10.1007/s11187-018-9991-x

International Monetary Fund. (2020). *World economic outlook: A long and difficult ascent*. International Monetary Fund. https://www.imf.org/en/Publications/WEO/Issues/2020/09/30/world-economic-outlook-october-2020

Jagtiani, J., & Lemieux, C. (2019). The roles of alternative data and machine learning in fintech lending: Evidence from the LendingClub consumer platform. *Financial Management*, *48*(4), 1009-1029. https://doi.org/10.1111/fima.12295

Lal, T. (2018). Impact of financial inclusion on poverty alleviation through cooperative banks. *International Journal of Social Economics*, 45 (5), pp. 808-828. https://doi.org/10.1108/IJSE-05-2017-0194

Levine, R. (1997). Financial Development and Economic Growth: Views and Agenda. *Journal of Economic Literature*, 35(22), 688-726. https://www.jstor.org/stable/2729790

Levine, R. (2005). *Finance and growth: theory and evidence*. Princeton University Press.

Mothobi, O., & Kebotsamang, K. (2024). The impact of network coverage on adoption of Fintech and financial inclusion in sub-Saharan Africa. *Journal of Economic Structures*, *13*(1), 5. https://doi.org/10.1186/s40008-023-00326-7

Nurazi, R., Usman, B. (2019). Impact of Financial Development on Income Inequality and Poverty in ASEAN. *Institutions and Economies*, 11 (3), pp 1-38.

OECD. (2021). *G20/OECD Report on Lessons Learnt and Effective Approaches to Protect Consumers and Support Financial Inclusion in the Context of COVID-19,* www.oecd.org/finance/lessons-learntand-effective-approaches-to-protect-consumers-and-support-financial-inclusion-in-the-context-ofCOVID-19.pdf.

Ozili, P. K. (2018). Impact of digital finance on financial inclusion and stability. *Borsa Istanbul Revie*w, 18 (4), 329-340. https://doi.org/10.1016/j.bir.2017.12.003

Rehman, S.U., Hussain, S., & Rasheed, A. (2024). Unleashing financial inclusion: the mediating role of digital marketing in the impact of fintech and behavioral intention. *Journal of Modelling in Management*. Vol. 19 No. 5, pp. 1670-1685. https://doi.org/10.1108/JM2-12-2023-0304

Rouse, M., Batiz-Lazo, B., & Carbo-Valverde, S. (2023). M-Pesa and the role of the entrepreneurial state in a cashless technology to deliver an inclusive financial sector. *Essays in Economic & Business History*, *41*(1), 109-133.

Sahay, R., von Allmen, U., Lahreche, A., Khera, P., Ogawa, S., Bazarbash, M., & Beaton, K. (2020). The promise of fintech: Financial inclusion in the post-COVID-19 era. *International Monetary Fund*. https://doi.org/10.5089/9781513512242.087

Sarma, M., & Pais, J. (2011). Financial inclusion and development. *Journal of International Development*, 23(5), 613-628. https://doi.org/10.1002/jid.1698

Schumpeter, J. A. (1911). *The Theory of Economic Development: An Inquiry into Profits, Capital, Credit, Interest, and the Business Cycle*. Transaction Publishers.

Suri, T., Jack, W., 2016. The long-run poverty and gender impacts of mobile money. *Science* 354 (6317), 1288–1292. DOI: 10.1126/science.aah5309

Sussman, O., Begg, D., & Repullo, R. (1993). A theory of financial development. In A. Giovannini (Ed.), *Finance and Development: Issues and Experience* (pp. 29–64). chapter, Cambridge: Cambridge University Press.

Tirole, J. (1994). On banking and intermediation. *European Economic Review*, *38*(3-4), 469-487. https://doi.org/10.1016/0014-2921(94)90085-X

Ülgen, F. (2015). Schumpeterian innovations, financial innovations and instability: An institutional perspective. *Cuadernos de Economía*, *38*(106), 46-53. https://doi.org/10.1016/j.cesjef.2014.09.003

Vo, D.H., Nguyen, N.T. and Van, L.T.H. (2021). Financial inclusion and stability in the Asian region using bank-level data. *Borsa Istanbul Review*. 21 (1), pp. 36-43. https://doi.org/10.1016/j.bir.2020.06.003

Vuković, D. B., Hassan, M. K., Kwakye, B., Febtinugraini, A., & Shakib, M. (2024). Does fintech matter for financial inclusion and financial stability in BRICS markets? *Emerging Markets Review*, *61*, 101164. https://doi.org/10.1016/j.ememar.2024.101164

World Bank. (2019). *World development report 2019: The changing nature of work*. World Bank. https://www.worldbank.org/en/publication/wdr2019