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The relationship between digital financial inclusion, gender inequality, and economic growth: dynamics from financial development

Dinh Le Quoc
University of Finance and Marketing, Ho Chi Minh City, Vietnam

Abstract

Purpose – This article employs a panel vector autoregression (PVAR) model to examine the relationship between digital financial inclusion (DFI), economic growth (EG), and gender equality (GE) across different levels of financial development.

Design/methodology/approach – Based on the current financial development dynamics, this study applies the PVAR method to two groups of countries: the first group represents the high financial development group, and the second group represents the low financial development group, during the period from 2015 to 2021.

Findings – The findings from impulse response functions reveal that digital financial inclusion fosters economic growth in nations with advanced financial systems, while simultaneously mitigating gender inequality. Conversely, in countries with less developed financial infrastructures, digital financial inclusion stimulates economic growth but exacerbates gender disparities. Moreover, the variance decomposition analysis indicates that the linkage between economic growth, digital financial inclusion, and gender inequality is more intertwined in countries with limited financial development than in those with well-established financial systems.

Originality/value – Effective deployment of new technologies relies heavily on technological infrastructure. This policy focuses on constructing and developing information technology infrastructure to create favorable conditions for the implementation of new DFI technologies. This study also emphasizes promoting equitable education and training by ensuring that both women and men have equal opportunities to access quality education and training. This may involve investing in early childhood education, providing access to primary education, and offering scholarships to women in technology, science, and engineering fields.

Keywords Digital financial inclusion, Economic growth, Gender inequality

Paper type Research paper

1. Introduction

Gender inequality (GI) exerts a profoundly detrimental influence on economic growth (EG). As highlighted by Ahang (2014), achieving parity in female labor force participation rates with males could potentially inject an additional 28 trillion USD into the global GDP, translating to a substantial 26% surge. Consequently, since 2015, numerous nations have embarked on initiatives to fortify the legal framework concerning GI, thereby catalyzing economic growth (EG). Rwanda stands out as a stellar exemplar in this regard, lauded for its pioneering efforts to

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bolster women's representation in both political and economic spheres. As per UN Women's data (2021), Rwanda reached a milestone in 2016 by attaining 50% female representation in its lower house. Similarly, Iceland enacted legislation in 2018 mandating that companies maintain a minimum of 40% female presence on their boards of directors. Norway, too, has been at the forefront of implementing policies to augment women's involvement in politics and the economy, with a longstanding requirement dating back to 2006 mandating a minimum of 40% female members on their boards of directors. These proactive measures aim to amplify women's presence in decision-making arenas, fostering a more egalitarian environment and thereby propelling EG (UN Women, 2021). Nonetheless, achieving gender parity within society remains an arduous endeavor, with projections suggesting it could span an extensive timeframe of approximately 130 years (UN Women, 2021).

In recent years, there has been a burgeoning emphasis on financial inclusion (FI) by governments and central banks worldwide, driven by its perceived capacity to bolster economic growth (EG) and alleviate gender inequality (GI). It is regarded as a pivotal factor capable of accelerating countries' progress towards achieving gender parity (World Bank, 2014). Presently, technological advancements have catalyzed a shift in FI, ushering in not only qualitative but also quantitative transformations and heralding the era of digital financial inclusion (DFI) (Khera *et al.*, 2021; Oanh and Dinh, 2024; Dinh *et al.*, 2024). At its essence, DFI harnesses digital technology, leveraging the internet and mobile devices to deliver financial services, diverging from conventional infrastructure such as bank branches or Automated Teller Machines (ATMs). This quantitative paradigm shift facilitates individuals and small to medium-sized enterprises to broaden their access to financial services in a more convenient manner (Khera *et al.*, 2021). This perspective underscores that DFI directly influences the economy and empowers economic actors—particularly women who may encounter barriers to formal financial services—by furnishing avenues for capital provision and utilization, thus optimizing economic resources (Ozili, 2018).

Currently, inquiries into the interplay among DFI, GI, and EG are predominantly characterized by their specific areas of focus. For instance, Ahmad *et al.* (2021) and Khera *et al.* (2022) delved into the correlation between DFI and EG, while Gammage *et al.* (2017) and Kofman and Payne (2021) scrutinized the relationship between DFI and GI. Conversely, Klasen and Minasyan (2017) and Altuzarra *et al.* (2021) investigated GI and EG. With the escalating prevalence of DFI and the increasing gravity of GI, simultaneous exploration of all three relationships could offer a comprehensive insight into the role of DFI in both EG and GI. Furthermore, a recent study by Oanh *et al.* (2023) highlighted variations in the level of financial inclusion (FI) based on the financial development (FD) levels of countries. Rafindadi and Ozturk (2017) employed the Autoregressive Distributed Lag (ARDL) method to examine the impact of FD, economic development (ED), and trade on energy consumption in South Africa from 1970 to 2011, revealing that FD stimulates energy demand in the region. Conversely, Rafindadi and Ozturk (2016) scrutinized the influence of FD, EG, and trade on electricity consumption in Japan from 1970 to 2012, disclosing that FD exacerbates electricity-related challenges in Japan, illustrating the multifaceted role of FD. Expanding on the groundwork laid by Oanh *et al.* (2023), our study probes into the relationship between GI and DFI across two categories: high-FD countries (HFDCs) and low-FD countries (LFDCs). This approach facilitates a comparative analysis of DFI's contributions to both GI and EG between these distinct groups of nations.

Given the multifaceted nature of DFI, it cannot be adequately captured by a single variable. Consequently, researchers employ a diverse array of metrics and methodologies to assess its various dimensions. For example, Thaddeus *et al.* (2020) utilized five indicators—ATM count, bank branch density, outstanding loans, mobile money transactions, and mobile agent shops—analyzing each indicator's impact on growth. In contrast, Khera *et al.* (2021) employed Principal Component Analysis (PCA), incorporating metrics such as mobile subscriptions, internet penetration, mobile money account penetration, online bill payment

prevalence, and mobile payment usage. Building on these approaches, Oanh *et al.* (2023) proposed a comprehensive method that considers both supply and demand aspects of DFI, offering a globally applicable framework for research in this field.

A lack of methodological consistency becomes apparent when examining previous research on the correlation between DFI, EG, and GI. For instance, Klasen and Lamanna (2009) utilized the Ordinary Least Squares (OLS) method, Inoue and Hamori (2016) employed the Generalized Method of Moments (GMM) regression, and Huang *et al.* (2021) used the Fully Modified Ordinary Least Squares (FMOLS) and ARDL methods. In the current study, we address this inconsistency by adopting the Panel Vector Autoregression (PVAR) method. This approach enables us to examine the concurrent interactions among these three relationships, guided by the hypothesis that DFI fosters improvements in gender inequality while also stimulating economic growth. Analyzing the research findings, we aim to propose policy implications tailored to high- and low-financial development countries, fostering inclusive and sustainable economic development pathways.

The content of this study proceeds as follows. Section 2 presents the theoretical foundations and previous studies; Section 3 describes the data and introduces the PVAR method; Section 4 presents the experimental results of PVAR analysis; and Section 5 provides conclusions and policy implications.

2. Review of existing literature

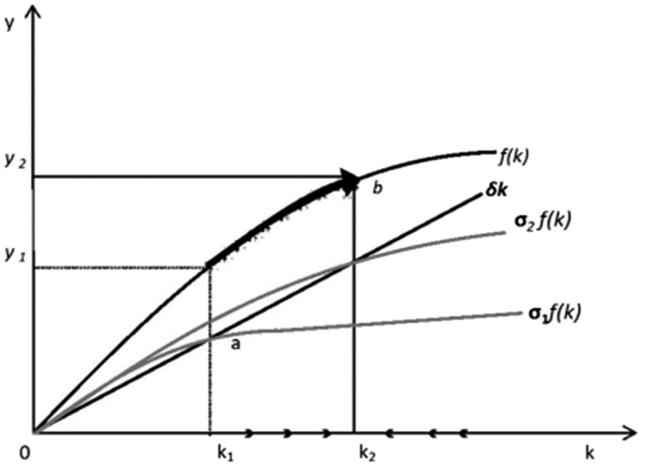
2.1 Theoretical frameworks related to DFI, EG, and GI

Research on FD highlights four main drivers of EG. Firstly, there is an emphasis on establishing accessible payment mechanisms for all, especially those with limited incomes. Secondly, financial intermediaries boost transaction volume and reallocate resources, improving resource allocation (Odeniran and Udeaja, 2010). Thirdly, risk management in the financial system mitigates liquidity risks, enabling smoother financing for investments and promoting innovative risk-taking (Greenwood and Jovanovic, 1990; Bencivenga and Smith, 1991). Lastly, the financial sector provides information on investment opportunities and available capital, enhancing the impact of asymmetric information (Ross, 2004).

From a production function perspective, Hicks (1969) argued that the transformation of investment and savings into economic output necessitates the role of financial development and technological advancement (Schumpeter, 1912). Figure 1 illustrates the Solow growth model, where the shift in savings from $\delta 1$ to $\delta 2$ leads to an enhanced steady-state capital stock from k1 to k2, consequently increasing output as well. This implies that through financial development, the quality of investment can be enhanced. Figure 2 illustrates the upward shift of the production function. Economic growth also stimulates savings. Figure 2 illustrates the new steady state, where the corresponding output per labor not only surpasses the initial levels k1 and y1 but also exceeds higher levels resulting from increased savings and investment.

The financial sector plays a crucial role in enhancing the production function by overseeing investment projects effectively. Unlike the Solow model, which focuses on short to medium-term effects of financial development, the Schumpeterian model acknowledges the long-term impact on economic growth and technological advancements. Schumpeter (1912) highlighted the necessity of a robust financial sector for entrepreneurial innovation. Without access to financing, innovation would be hindered, impeding sustained economic growth. DFI assumes a vital role in this context by introducing innovative financial products aimed at promoting savings among low-income individuals (Odeniran and Udeaja, 2010).

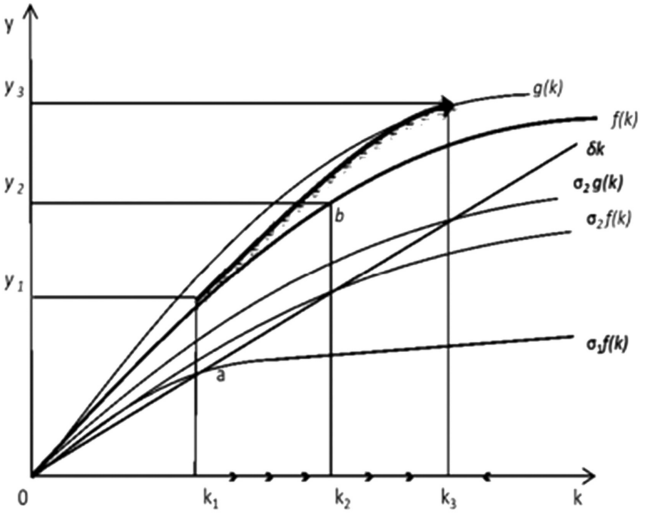
According to the productivity theory (Sen, 1995), uneven distribution of power (in education, politics, and labor) and gender equality will influence EG. Altuzarra *et al.* (2021) further asserted that when men and women lack equal opportunities to access economic



Source(s): Odeniran and Udeaja (2010)

Figure 1.
Illustrates how savings affect the accumulation of capital

resources, employment, education, and authority, it results in a waste of human resources. Specifically, women will be restricted from participating in the workforce and accessing high-value jobs, leading to an economy being unable to fully harness its potential. The full and equitable participation of women in the economy contributes to creating an environment conducive to innovation, diversification, and sustainable growth. GI in financial access has been extensively documented in previous research, including studies by Demirgüç-Kunt *et al.* (2013), Ghosh and Vinod (2017), and Kaur and Kapuria (2020). Despite notable advancements, women continue to face disparities in accessing financial services compared to men in many regions worldwide (Kazemikhasragh *et al.*, 2022). A significant barrier to obtaining bank



Source(s): Odeniran and Udeaja (2010)

Figure 2.
Illustrates the impact of savings on output

accounts for women is often their lower income levels, which may not meet the requirements for opening an account (Aterido *et al.*, 2013). Moreover, women encounter greater challenges in securing employment opportunities in developing countries, leading to a global gender gap in labor force participation rates, which are 26.5% lower for women than men (Kuhn *et al.*, 2018). Additionally, societal expectations often confine women to familial and caregiving roles rather than business or entrepreneurial endeavors (Eagly and Karau, 2002), resulting in their overrepresentation in low-skilled and undervalued occupations such as domestic work. Therefore, with the development of DFI and the expansion of financial services to previously excluded individuals, services like online account registration, debit cards, and accessible loans can bring opportunities to narrow GI (Yang *et al.*, 2022). This contribution aligns with the EG theory of productivity proposed by Sen (1995).

According to the human capital theory (Galor and Weil, 2000), human capital refers to the knowledge, skills, and abilities of individuals that contribute to productivity and economic output. GI can potentially limit the development of human resources by excluding women from empowered opportunities, such as education and politics, as well as labor market participation. When the market value of women's time in the labor market is relatively low, women tend to be responsible for childcare and household duties within the family. This leads to higher reproductive capacity and lower EG, as population increase has a direct negative impact on long-term economic activity, and human capital accumulation occurs at a slower rate (through a trade-off between quantity and quality). Furthermore, the perspective of Klasen and Wink (2003) highlighted the importance of women's employment in enhancing their bargaining power within the family. This not only benefits women but also promotes growth, including higher savings. Savings behavior differs between men and women (Seguino and Floro, 2003), leading to increased investments in health and education for their children. This, in turn, enhances human capital for future generations, driving EG.

Therefore, the participation rate of women in the labor force and their empowerment play a crucial role in EG (Altuzarra *et al.*, 2021). According to the perspective of financial inequality by Clark *et al.* (2017), women often lack the financial resources to invest in education, which may result in lower educational attainment. As a result, they primarily engage in low-skilled labor markets and often receive lower welfare benefits. The increasing income inequality contributes to an economic environment that struggles to achieve stable growth.

The theories discussed above offer various perspectives on the contribution of DFI to GI and EG, highlighting the nuanced factors influencing access to financial services across different countries. The level of FD plays a crucial role in determining the accessibility and effectiveness of DFI initiatives. As FD improves, so does DFI, leading to varying degrees of success in addressing GI and driving EG. This relationship is further explored in a study by Oanh *et al.* (2023), where the authors examined the interplay between DFI, GI and EG in relation to the level of FD.

2.2 The linkage between DFI, GI, and EG

Currently, there is no standardized method for comprehensively measuring DFI, largely due to data accessibility challenges, particularly in less financially developed countries (LFDCs) with limited internet access. Various approaches have been proposed in the literature. Thaddeus *et al.* (2020) utilized five indicators including ATM count, commercial bank branch count, outstanding credit from commercial banks, mobile money transaction rate, and mobile agent outlet count. Khera *et al.* (2021) employed PCA to formulate a DFI metric based on indicators such as mobile subscriptions per 100 people, internet usage rate, adult mobile phone account penetration, internet-based bill payment rate, and mobile payment usage rate. Ismael and Ali (2021) crafted a DFI variable using metrics like mobile phone online shopping, online bill payment engagement, and mobile money transaction frequency per 1,000 adults.

More recently, Shen *et al.* (2021) developed a DFI index based on metrics such as commercial bank branch count, ATM count, internet user count, financial account holder percentage, debit cardholder count, and phone/internet banking usage rate for account access and bill payment. Daud (2023) integrated traditional financial inclusion (FI) and digital variables to create a DFI measure. In our study, we utilize PCA to create a DFI variable with seven components as detailed in Table 1. This approach offers the advantage of global applicability and facilitates cross-regional comparisons.

Furthermore, research on the relationships between DFI, GI, and EG has typically explored individual connections. For instance, Ahmad *et al.* (2021), Khera *et al.* (2021), Shen *et al.* (2021), and Khera *et al.* (2022) examined the correlation between DFI and EG, whereas Gammage *et al.* (2017), Yang *et al.* (2022), and Kofman and Payne (2021) focused on DFI and GI. Similarly, GI and EG were explored by Klasen and Minasyan (2017), and Altuzarra *et al.* (2021). Notably, there is a gap in the literature as no studies have simultaneously examined the tripartite relationship among DFI, GI, and EG. Thus, this study aims to fill this gap by simultaneously investigating these three relationships.

In terms of the research scope and methods, previous studies have explored various scopes. For instance, Inoue and Hamori (2016) used GMM regression to examine 37 sub-Saharan African countries, while Kim *et al.* (2018) investigated the relationship between FI and EG across 55 countries. More recently, Dahiya and Kumar (2020) studied the relationship between EG and DFI in India, and Huang *et al.* (2021) examined the relationship between DFI and EG in the EU (27 countries) from 1995 to 2015 using FMOLS and ARDL models. Dollar and Gatti (1999) studied the impact of GI on EG in developing countries, finding that GI hurts EG. Seguino (2000) explored the impact of GI in education on production activities, revealing that GI in education contributes to national economic improvement. Klasen and Lamanna (2009) studied the impact of GI in education and employment on EG in the Middle East, North Africa, and South Asia from 1960 to 2000 using OLS. Their research demonstrated that as GI in education decreases, its detrimental effect on growth prospects in MENA and South Asia diminishes. However, there is a lack of research on DFI that considers the role of FD. Previous studies related to FD have consistently played a role as an EG factor, as seen in research by Rafindadi and Yusof (2013), Rafindadi and Yusof (2015), Rafindadi *et al.* (2023) and Rafindadi and Almustapha (2017). However, they have not examined FD in the context of its role in promoting DFI growth. Following the research approach of Oanh *et al.* (2023), we conducted research across countries with high and low levels of FD.

3. Data

3.1 Research variables

(1) Digital Financial Inclusion (DFI): As discussed in section two, measuring DFI is not straightforward due to its multifaceted nature. Relying on a single variable to capture its complexity is inadequate. Hence, researchers employed various indices to gauge FI. Drawing on insights from Purva Khera *et al.* (2021) and Oanh (2023), our study constructs DFI using seven components: IUI, NCC, NCB, NMM, FTS, LCB, and DCB.

	Break year	Prob. > χ^2
Dependent variable: EG		
GI	2018	0.2133
DFI	2018	0.1234

Source(s): Processed by the author using Eviews 12.0 software

Table 1. The outcomes of the Wald test to identify structural breaks

(2) Economic Growth Variable (EG): Based on Thaddeus *et al.* (2020), the EG variable is measured using the annual average per capita gross domestic product (GDP) growth rate.

(3) Gender Inequality Variable (GI): Based on the research of Seth (2009) and Ohiomu and Ogbeide-Osaretin (2019), the GI index is constructed based on three dimensions: reproductive health, empowerment (political and educational), and labor force. The GI indicates the loss in human development potential due to the inequality between males and females in these dimensions. The GI ranges from 0 (when women and men have equal values) to 1.

3.2 Methodology

3.2.1 PCA. The research model is represented as:

$$DFI_j = W_{j1}X_1 + W_{j2}X_2 + \ldots + W_{j7}X_7$$

Where weights (W1, W2, W3, W4, W5, W6 and W7) are assigned to each component, and X1, X2, X3, X4, X5, X6 and X7 represent the measured variables. Data normalization is crucial to mitigate biases due to measurement unit differences, typically scaling data between 0 and 1. Various normalization methods, like min-max normalization by Han *et al.* (2011) and Oanh (2024), have been suggested. In our study, we normalize DFI using a specific formula, ensuring the index falls within the range of 0–1.

$$DFI_i = \frac{DFI_i - DFI_{min}}{DFI_{max} - DFI_{min}} \ (*)$$

3.2.2 PVAR. To study the relationship among the three variables- DFI, EG, and GI- we propose using the PVAR model. This model has the advantage of treating all variables as endogenous, thereby reflecting equal relationships among them. The structure of the research model is presented as follows:

$$Y_{i,t} = W_1 Y_{i,t-1} + \ldots + W_k Y_{i,t-k} + \beta_x X_{i,t} + u_i + \varepsilon_{i,t}$$

$Y_{i,t} = (GDP_{i,t}, GI_{i,t}, DFI_{i,t})$ is a random vector of dimension (1×3) comprising the endogenous variables; $X_{i,t}$ denotes the vector containing exogenous variables. The measurement and data for the variables are presented in Table 2.

Additionally, we perform tests to identify structural breaks in time-series data. This approach aids in mitigating any imperfections related to the data and enhancing the fitting of the PVAR model. If the data shows abrupt changes or experiences specific events that may impact the relationships between variables (if structural changes can be identified), we can consider employing multiple PVAR models for specific periods instead of using a single PVAR model. The structural changes can be tested using a Wald test with the null hypothesis of no structural break. The results in Table 1 indicate no abrupt structural changes during the study period. Therefore, the period from 2015 to 2021 is considered an ideal timeframe to implement the PVAR model, as the interactions between variables are stable.

3.2.3 Dataset. The data for the study is collected from 2015 to 2021, covering 56 countries (Figure 3). Based on the research by Oanh *et al.* (2023), we calculate the average FD index for all countries during this period. Subsequently, the average FD indices for each country are compared with the global average FD. The results of this classification are visually described in Figure 3, consisting of 22 LFDCs and 34 HFDCs. Australia has the highest FD index, followed by Japan, while the Kyrgyz Republic and Algeria have the lowest FD indices. The Frequency Conversion method was employed to address limitations stemming from sample

Variable	Symbol	Measurement	Studies	Data source
Main variable				
Economic growth	EG/ GDP	Annual growth rate of GDP per capita (%)	Chinoda and Kapingura (2023)	WB
Gender Inequality	GI	Gender Inequality Index (GI)		Our world in data
Digital Financial Inclusion	DFI			
+Percentage of internet users	IUI	Individuals using the Internet as a percentage of the population	Oanh (2023, 2024), Oanh and Dinh (2024)	WB
+Mobile subscription	FTS	Mobile subscription per 100 people (%)		WB
				FAS
				FAS
+Number of credit cards	NCC	Number of credit cards per 1,000 adults		FAS
+Number of debit cards	NCB	Number of debit cards per 1,000 adults		
+Number of mobile money transactions	NMM	Number of mobile money transactions (during the reference year) per 1,000 adults		
+ Outstanding loans from commercial banks	LCB	Loans from commercial banks divided by GDP		WB, FAS
+ Outstanding balance of deposits of commercial banks	DCB	Deposits from commercial banks divided by GDP		WB, FAS
Control variables				
Population growth rate	POP	Annual population growth rate (%)	Khera *et al.* (2022)	WB
Trade openness	OPEN	Total import and export of goods and services divided by GDP (%)	Chinoda and Kapingura (2023)	WB
Unemployment rate	UNE	The number of unemployed people divided by a country's labor force (%)	Kim *et al.* (2018)	WB
Economic Integration	FDG	Net Foreign direct investment divided by GDP (%)	Chineye *et al.* (2020)	WB
Urban population	UR	Urban population as a percentage of total population	Nkalu *et al.* (2019)	WB
Inflation Rate	INF	Annual CPI growth rate (%)	Oanh *et al.* (2023)	WB
Interest rate	IR	Lending interest rate (%)	Oanh *et al.* (2023)	WB

Note(s): WB= World Bank, FAS= Financial Access Survey
Source(s): Compiled by the author

Table 2. Description of variables

size and timeframe. This method converts the annual data into quarterly observations, thereby enhancing the reliability of the PVAR model results.

4. Research results

4.1 PCA results

The PCA results in Table 3 highlight substantial contributions to DFI from IUI, LCB, and DCB. This suggests that countries should focus on expanding supply-side factors (LCB and DCB) and increasing IUI to enhance DFI.

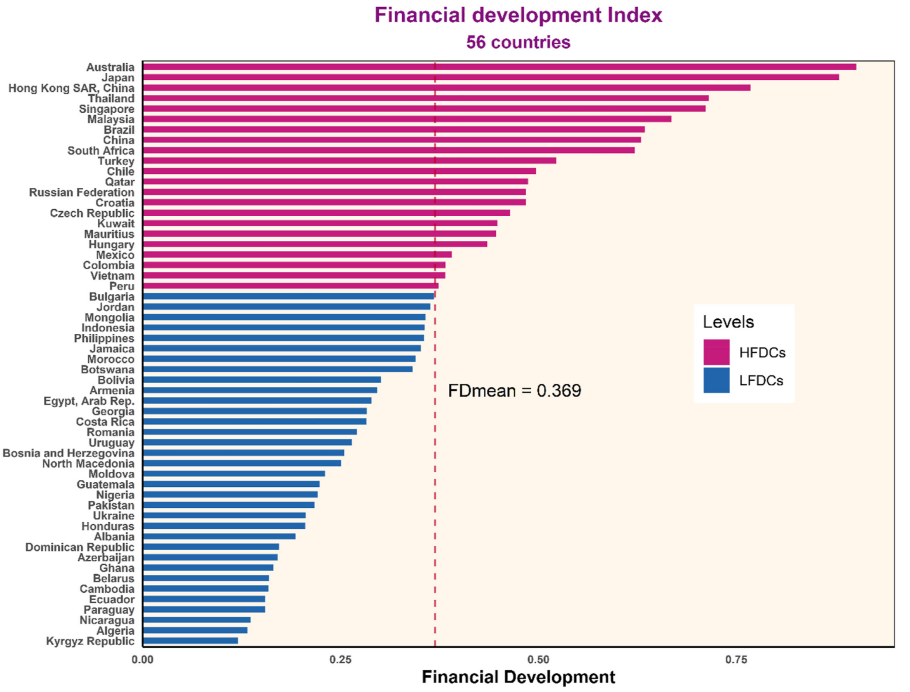


Figure 3.
LFDCs and HFDCs

Source(s): Figure by authors

4.2 PVAR results

4.2.1 Descriptive statistics. Table 4 shows that the EG and DFI indices in HFDCs are higher than in LFDCs. Additionally, the results also indicate that LFDCs exhibit higher levels of GI compared to HFDCs.

4.2.2 Unit root test results. The stationarity test results, as described in Table 5, provide insights into the characteristics of the variables. In LFDCs, variables such as IR, INF, FDG, UNE, and DFI are stationary at the I(0) level. Similarly, in HFDCs, variables like IR, INF, TFP, CO2, POP, FDG, DFI, and OPEN remain stable at the I(0) level. By employing differencing, the authors ensure that all variables become stationary at the I(1) level. This outcome suggests that variables exhibit varying degrees of stationarity, justifying the utilization of the PVAR method for analysis.

4.2.3 Optimal lag selection. The results of the optimal lag selection are presented in Tables 6 and 7. The optimal lag for the model in LFDCs is found to be 2, while for HFDCs, it is 1.

4.2.4 Examining for autocorrelation. Table 8 presents the autocorrelation test for the model in LFDCs, which shows that at lag 2, there is no autocorrelation in the model. Similarly, for HFDCs, the autocorrelation test at lag 1 indicates no autocorrelation in the model.

DFI	LCB	DCB	FTS	IUI	NCC	NCB	NMM
	0.384	0.396	0.287	0.387	0.214	0.121	0.165

Table 3.
PCA result

Source(s): Processed by the author using Eviews 12.0 software

	LFDCs				HFDCs			
	Mean	Std	Min	Max	Mean	Std	Min	Max
EG	3.5718	4.4105	−14.5974	26.1703	3.9330	4.5643	−15.1365	34.5000
GI	0.3773	0.1335	0.1340	0.6830	0.2847	0.1312	0.5630	0.040
DFI	0.2585	0.0931	0.0000	0.3981	0.4124	0.1715	0.0356	1.0000
POP	0.9746	1.0815	−1.8543	2.7641	1.2308	2.0775	−1.8328	19.3604
OPEN	79.7188	28.5770	16.3522	157.9743	102.7438	82.3379	22.1060	442.6200
UNE	7.9943	7.0950	0.1300	37.3200	7.3833	5.2531	0.1000	29.4500
FDG	4.3578	4.4128	−5.1603	54.3653	5.7751	10.1819	−40.0866	109.0253
UR	55.7656	13.7937	19.0550	82.5400	71.5265	18.9186	26.6830	100.0000
INF	6.2052	6.4667	−1.5841	59.2197	4.5981	4.0745	−4.8633	29.5066
IR	6.0832	3.9607	0.4093	22.3000	4.7570	4.2380	0.0100	25.4092

Source(s): Processed by the author using Eviews 12.0 software

Table 4. Descriptive statistical results for the period 2015–2021

Variables	LFDCs		HFDCs	
	Coef	Prob	Coef	Prob
EG	113.6374	0.0000***	68.0191	0.2230
DFI	65.3177	0.1011	139.470	0.0000***
GI	109.603	0.0000***	81.1357	0.0401**
POP	48.1055	0.6278	136.360	0.0000***
OPEN	64.3177	0.1174	77.6587	0.0623*
UNE	79.9999	0.0076***	68.4326	0.2128
FDG	82.2137	0.0048***	107.175	0.0002***
UR	122.214	0.0000***	60.1339	0.2634
INF	95.1962	0.0002***	93.2648	0.0038***
IR	87.2118	0.0016***	92.9477	0.0041***

Source(s): Processed by the author using Eviews 12.0 software

Table 5. The outcomes of the unit root test

Lags	LogL	LR	FPE	AIC	SC	HQ
0	−545.521	NA	0.022538	4.721009	5.025565	4.843722
1	971.9857	2908.555	7.82E−08	−7.84988	−7.414801*	−7.67458
2	1015.718	27.13663*	6.81e−08*	−7.989320*	−7.16267	−7.65624

Source(s): Processed by the author using Eviews 12.0 software

Table 6. Lag selection optimization for LFDCs

Lags	LogL	LR	FPE	AIC	SC	HQ
0	−3377.64	NA	22.64863	32.50605	31.66651	31.57094
1	−313.745	245.3646	1.11e−10*	5.468531*	10.13544	7.990784
2	−228.459	133.9296	2.31E−10	6.139031	12.71783	8.79916

Source(s): Processed by the author using Eviews 12.0 software

Table 7. Lag selection optimization for HFDCs

The stability test results of the PVAR model are depicted in Figure 4, where the eigenvalues of the characteristic polynomial all lie inside the unit circle. This suggests that the PVAR model demonstrates stability and resilience across various periods.

4.2.5 Impulse response function (IRF) results. Figure 5 indicates that a 1% increase in the DFI index leads to a 0.024% increase in EG in the second period, accompanied by a 0.0013% increase in GI in the first period. Conversely, a shock causing a 1% increase in EG results in a 0.0009% increase in the DFI index in the second period and a 0.0053% increase in GI in the first period. These findings reaffirm the positive two-way correlation between the DFI index and EG, consistent with Ahmad *et al.* (2021), suggesting that DFI stimulates economic activity and serves as a source and utilization of capital, thereby promoting EG. Similarly, there is a negative correlation between GI and DFI (Figure 5), indicating that as DFI increases, GI decreases. This can be attributed to the new heavy burden of family responsibilities falling on men in LFDCs, where women face challenges in labor force participation and employment opportunities compared to men (Kazemikhasragh *et al.*, 2022).

Women in these countries are often confined to familial and societal roles rather than business roles (Eagly and Karau, 2002). They tend to be overrepresented in low-skilled and low-value jobs, such as caregiving and domestic work while facing limited access to managerial and leadership positions, reducing opportunities for high-paying or entrepreneurial work. Furthermore, women in these countries often encounter difficulties in accessing essential personal documents required for labor contracts, opening bank accounts, or borrowing from financial institutions (Hanmer and Elefante, 2019). For instance, in Pakistan, a lower percentage of women (79%) possess national identification cards compared to men (90%), which significantly hampers their access to financial services. This gender disparity is influenced by legal, regulatory, and cultural norms, such as the requirement for spousal consent or restrictions on women's autonomy, including the need for their husband's permission to work or drive. These norms create significant barriers for women in accessing financial services or even opening a bank account. Until 2016, the Family

Table 8. Autocorrelation examination

LFDCs			HFDCs		
Lags	LM stat	Prob	Lags	LM stat	Prob
1	14.9748	0.1403	1	7.0135	0.6764
2	6.6667	0.6767			

Source(s): Processed by the author using Eviews 12.0 software

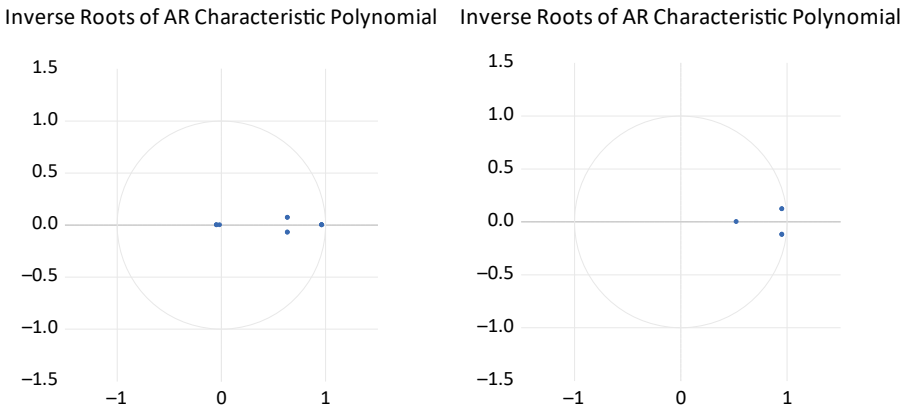
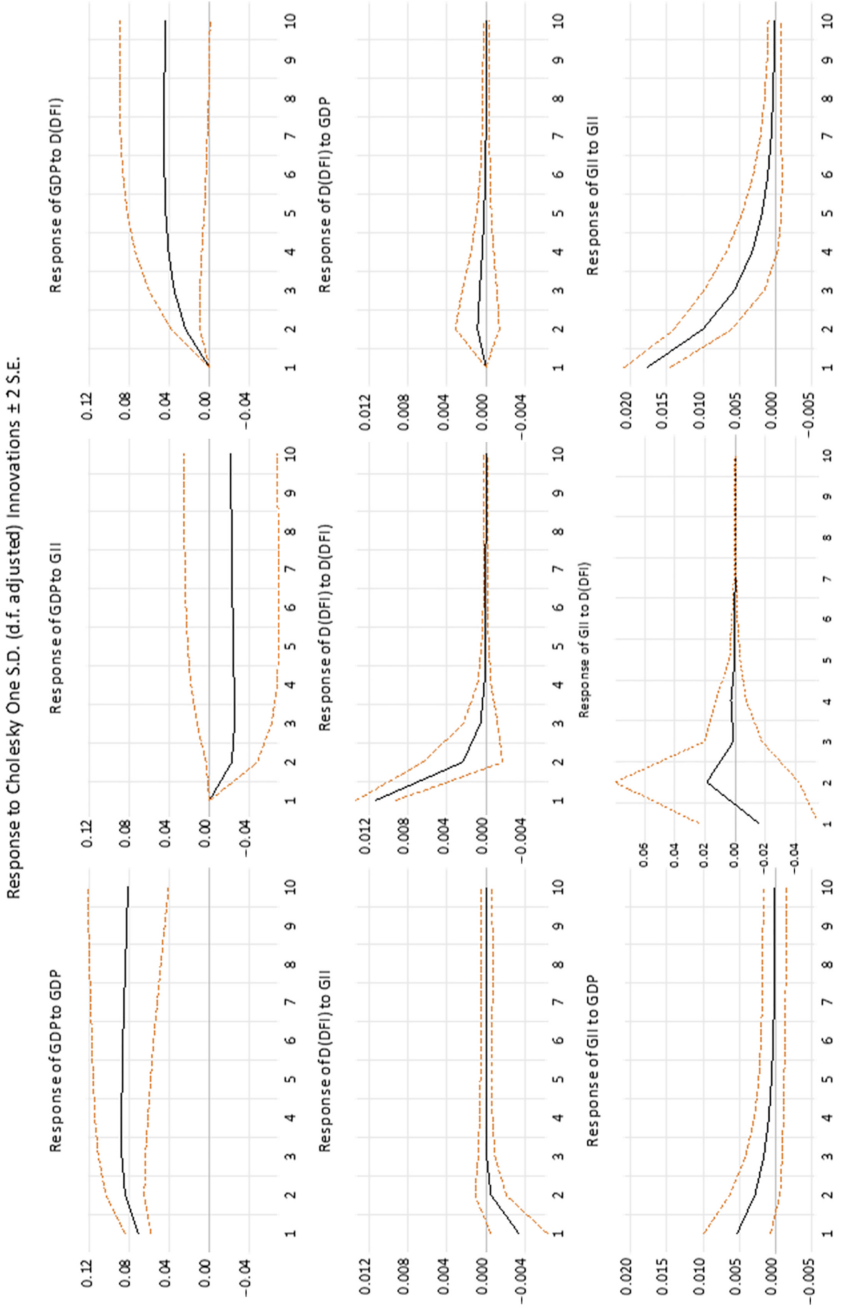


Figure 4. Testing the stability of the model

Source(s): Processed by the author using Eviews 12.0 software



Source(s): Processed by the author using Eviews 12.0 software

Figure 5.
IRF results for LFDCs

Law of the Democratic Republic of Congo prohibited married women from independently managing finances or registering businesses without spousal consent. These constraints greatly impede women's economic participation and their ability to access digital financial services (Kazemikhasragh *et al.*, 2022).

Furthermore, Figure 5 highlights the complex relationship between GI and GDP. While GI tends to hinder EG, an increase in EG often exacerbates GI in these countries. These results align with previous research by Seth (2009) and Ohiomu and Ogbeide-Osaretin (2019) regarding the reduction of GI through DFI, but add the dimension of considering EG. Moreover, this study integrates the DFI variable, which includes the internet usage rate – an important indicator of the comprehensiveness of technology in financial applications, which previous studies have overlooked. Additionally, unlike previous research focusing on specific regions or countries, such as sub-Saharan Africa, and ASEAN, this study considers financial development as a driver of EG, revealing contrasting results between HFDCs and LFDCs. Specifically, in HFDCs, DFI reduces GI, whereas in LFDCs, DFI exacerbates GI.

Figure 6 displays the impulse response function (IRF) results for HFDCs. It shows that a 1% increase in the DFI index leads to a 0.0020% increase in EG and a 0.0015% decrease in GI in the second period. Conversely, a shock causing a 1% increase in EG results in a 0.0015% increase in the DFI index in the second period and a 0.2% decrease in GI in the first period. Similar to LFDCs, the results indicate a positive relationship between GDP and DFI in HFDCs. However, in HFDCs, DFI not only promotes EG but also reduces GI, aligning with the perspective of Yang *et al.* (2022). The development of DFI in HFDCs contributes to reducing GI and bridging the gender gap in education and employment access. The variance decomposition results in Table 9 demonstrate that the relationship between EG, DFI, and GI is more intertwined in LFDCs compared to HFDCs.

5. Conclusion and policy implications

5.1 Conclusion

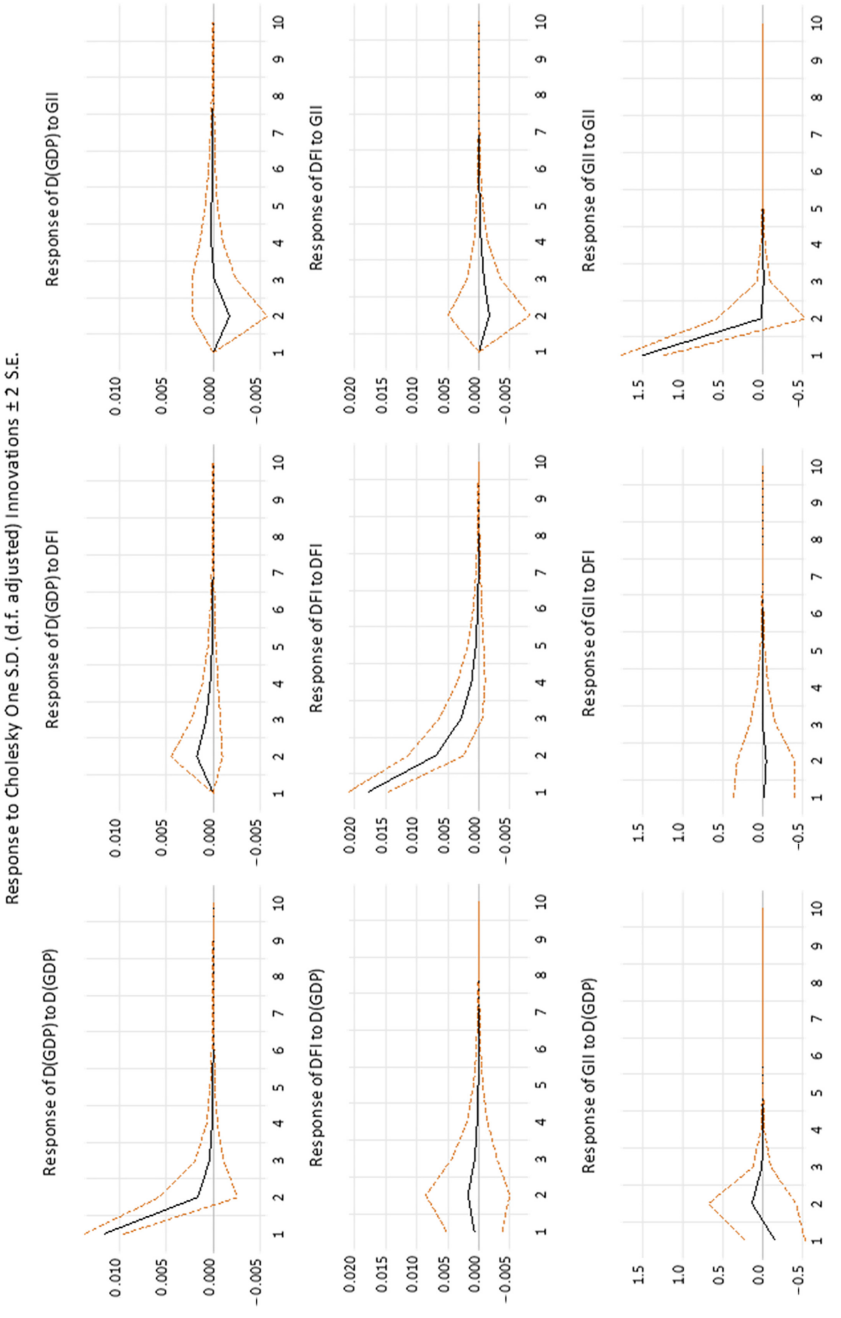
The relationship between GI and EG has become a crucial topic in both research and practice. GI poses economic challenges, such as limiting rights and economic opportunities for women, impacting investments in education and healthcare, and reducing the labor force. Currently, financial development has expanded globally, accompanied by the use of DFI as a tool to support the participation and FI of both small and medium enterprises and individuals, including both men and women. While previous studies have highlighted the role of DFI in narrowing GI, they have not thoroughly explored its impact on EG, which is an essential factor for any nation's development. Therefore, our study aims to examine the relationship between DFI, GI, and EG, to investigate whether DFI can simultaneously promote EG and narrow GI. Moreover, DFIs heavily rely on FDs, and countries with higher FDs will experience a more significant impact from comprehensive finance. Thus, our research scope is divided into two groups: LFDCs and HFDCs during the period from 2015 to 2021.

The results of impulse response functions indicate that in HFDCs, DFI stimulates EG while reducing GI. Similarly, in LFDCs, DFI promotes EG but increases GI. Additionally, the VD results demonstrate that the relationship between EG, DFI, and GI in LFDCs is more interconnected compared to HFDCs. Based on these findings, the study suggests some appropriate policy implications.

5.2 Policy implications

For LFDCs:

(1) Promoting Internet: Creating favorable conditions for individuals and businesses to engage in online business activities, access information, and build DFI, thereby promoting EG.



Source(s): Processed by the author using Eviews 12.0 software

Figure 6.
IRF results for HFDCs

LFDCs Timeframe	EG	DFI	GI	Period	HFDCs EG	DFI	GI
GDP/EG							
1	100	0	0	1	100	0	0
2	96.18	2.7	1.12	2	97.13	2.52	0.35
3	94.5	3.9	1.6	3	90.8	8.4	0.8
4	91.64	5.56	2.8	4	89.13	9.91	0.96
DFI							
1	0.69	99.13	0.18	1	1.72	98.15	0.13
2	3.86	95.16	0.98	2	2.89	96.31	0.8
3	6.26	92.13	1.61	3	5.78	93.12	1.1
4	8.07	90.13	1.8	4	6.94	91.46	1.6
GI							
1	1.51	0.36	98.13	1	0.98	0.89	98.13
2	3.07	0.8	96.13	2	2.8	1.1	96.1
3	5.86	1.01	93.13	3	5.4	1.3	93.3
4	8.59	1.31	90.1	4	6.04	1.96	92

Source(s): Processed by the author using Eviews 12.0 software

Table 9. Results of variance decomposition (VD)

(2) Ensuring equitable access to digital finance: Developing financial education programs and enhancing the financial literacy and digital skills of individuals, particularly those who have not previously used financial technologies.

(3) Redesigning gender equality policies: Providing financial education as a prerequisite for women to access formal financial services. Building financial infrastructure and providing financial services to rural and underserved areas to enhance financial access for both men and women.

For HFDCs:

(1) Developing technological infrastructure: Constructing and developing information technology infrastructure to create favorable conditions for the implementation of new DFI technologies.

(2) Promoting equitable education and training: Ensuring equal opportunities for both women and men to access quality education and training, including investing in early childhood education, providing access to primary education, and offering scholarships to women in technology, science, and engineering fields.

(3) Enhancing financial access in rural areas: Deploying mobile registration points to provide financial services to those living far from city centers and developing digital financial solutions such as mobile payments and online banking to enhance convenience for everyone, everywhere. This will reduce geographical distances and enhance financial access for both men and women in rural areas.

To reduce GI:

(1) Promoting financial literacy programs tailored to women and fostering a supportive environment for women entrepreneurs.

(2) Designing digital financial tools to address gender-specific needs.

(3) Advocating for policies that narrow the digital gender gap, providing equal opportunities for women to access and benefit from digital financial services.

5.3 Further research suggestions

Although Industry 4.0 originated from network infrastructure and intelligent industrial concepts in the 1970s and gained significant momentum in the early 21st century, this study focuses on the years 2015–2021 due to data constraints. Future research endeavors should aim to collect additional data to improve the overall quality of the study. Furthermore, variables related to DFI, such as digital payment usage, school fee transfers, and frequency of online purchases, can be collected from the World Bank. However, the available period is limited to only three non-consecutive years. Therefore, future studies should further enhance and complete the data collection process to further investigate these variables.

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About the author

Dinh Le Quoc is affiliated with the Faculty of Finance and Banking at the University of Finance, Marketing, Ho Chi Minh City, Vietnam. His research focuses on sustainable development in finance and banking, with interests in green finance, green growth and digital financial inclusion. Dinh Le Quoc can be contacted at: dinhle2807@gmail.com