INTERNATIONAL JOURNAL OF SCIENTIFIC RESEARCH AND INNOVATIVE STUDIES
IJSRIS journal
ISSN: 2820-7157
Advancing Knowledge, Inspiring Innovation
www.ijsrisjournal.com
INDEXED JOURNAL
PEER REVIEWED Rigorous & Transparent
DOI: CROSSREF Member
OPEN ACCESS For Global Visibility
BI-MONTHLY Timely Publication
WIDE READERSHIP High Impact & Visibility
AUTHOR FRIENDLY Fast | Supportive | Reliable

RECEIVED 19 June 2026
ACCEPTED 10 July 2026
PUBLISHED 1 August 2026
Pages from: 227 to 234
August 2026 | Volume 5 | Number 4

Digital finance and economic growth in CEPGL countries: a dynamic analysis using Panel data (2000–2024)

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ABSTRACT

The digital transformation of financial systems is one of the major shifts in contemporary economies and is attracting growing interest in developing countries, where shortcomings in traditional banking coexist with the rapid spread of digital technologies. Digital finance is thus likely to improve access to financial services, reduce transaction costs, facilitate payments and enhance the efficiency of financial intermediation. However, its effects on economic growth remain contingent on the quality of digital infrastructure, the level of human capital, the institutional and regulatory environment, and its integration with the financing of productive activity. This article analyses the effect of the development of digital finance on economic growth in the countries of the Economic Community of the Great Lakes Countries (CEPGL) – namely the Democratic Republic of the Congo, Rwanda and Burundi – over the period 2000–2024. The study utilises panel data and a composite index of digital

finance development (ISFD), supplemented by variables relating to information and communication technologies (ICT), digital financial education (FinEduDig), public-private partnerships in ICT (PPP_ICT) and the money supply. The econometric strategy is based successively on stationarity tests, Kao's cointegration test, the estimation of an ARDL panel model, and robustness and causality tests. The results highlight the existence of a long-run relationship between the variables studied, but do not confirm the hypothesis of a positive and statistically significant effect of the development of digital finance on economic growth. The research hypothesis is therefore rejected. This seemingly paradoxical result is, however, qualified by the Dumitrescu-Hurlin causality test, which reveals a unidirectional causality from the development of digital finance towards economic growth, with a probability associated with the Z-bar statistic of 0.0319. The null hypothesis of non-causality is thus rejected at the 5 per cent significance level. These results suggest that digital finance has real potential for economic transformation, but that this potential remains insufficiently translated into aggregate growth in CEPGL countries. The article therefore advocates an integrated policy combining the development of digital and energy infrastructure, financial inclusion, financial and digital literacy, improved regulation, and the channelling of financial innovation towards productive investment.

Keywords: Digital finance; economic growth; ARDL model using panel data; cointegration; causality; CEPGL; financial inclusion.

1. Introduction

Digital transformation is now one of the main forces reshaping contemporary economies. The spread of information and communication technologies, smartphones, digital platforms, mobile money, electronic payment systems and the services offered by fintech companies has profoundly altered the ways in which people access financial services. In developing economies, this transformation is of particular significance, as it offers the possibility of circumventing certain constraints associated with the low density of traditional banking networks and of extending access to financial services to populations that have historically been excluded from formal financial institutions. The progress made in digital payments and financial inclusion in recent years illustrates this capacity to transform financial systems (Demirgüç-Kunt et al., 2022) .

From a theoretical perspective, financial development is traditionally regarded as a factor capable of supporting economic growth through several complementary mechanisms: mobilisation of savings, improved capital allocation, selection of investment projects, risk diversification and reduction of transaction costs. From this perspective, the efficiency of the financial system influences an economy's ability to transform available savings into productive investment and, consequently, to improve its overall productivity **(Levine, Ross, 2005) .** Digital finance has the potential to extend these mechanisms by introducing digital technologies into financial intermediation processes, which can reduce access costs, speed up transactions and improve the flow of information.

This development is in line with the foundations of endogenous growth theory, according to which technological progress and innovation are key determinants of long-term dynamics. Romer **(Romer, 1990)** shows, in particular, that the accumulation of knowledge and technological innovation can be integrated into the growth process and generate lasting effects on productivity. Applied to digital finance, this perspective leads us to view financial and technological innovations as potential instruments for improving economic efficiency, provided that they are effectively integrated into the processes of production, investment and human capital accumulation.

However, the assumption that digital finance automatically has a positive effect on growth needs to be qualified. The mere existence of access to digital financial services does not guarantee either their productive use or their ability to bring about lasting change to economic structures. Weak digital infrastructure, the high cost of connectivity, energy shortages, a lack of digital skills, inadequate consumer protection and the limitations of the regulatory environment can significantly reduce the expected benefits of financial digitalisation. Recent literature thus highlights that fintech companies and digital finance can promote financial inclusion, but that their economic effects depend largely on the institutional context and the conditions under which they are deployed (Salay, R., et al., 2020) .

This issue is of particular importance in the countries of the Economic Community of the Great Lakes Countries (CEPGL), comprising the Democratic Republic of the Congo, Rwanda and Burundi. These economies share common characteristics, notably uneven access to banking services, infrastructure deficits, significant territorial heterogeneity and varying levels of digital development. In such an environment, digital finance can serve as a tool for modernising the financial system and broadening access to financial services, but its potential to contribute to growth depends on its ability to go beyond merely facilitating transactions and become part of a broader dynamic of investment financing, business development and productivity improvement.

The central question of this article is therefore as follows: **What is the effect of the development of digital finance on economic growth in CEPGL countries?** The aim is to analyse this relationship over the period 2000–2024, distinguishing between short- and long-term dynamics and taking into account several factors likely to influence the effect of digital finance on growth.

The research hypothesis formulated is as follows: **the development of digital finance has a positive and significant effect on economic growth in CEPGL countries**.

The scientific value of this research lies in the analysis of a relationship that remains insufficiently documented in the specific context of CEPGL countries. Whilst the literature generally tends to associate financial development and technological innovation with improved economic performance(**Levine, R & Romer, P., 2005, 1990**) , this study seeks to determine whether this theoretical relationship is indeed borne out in a regional context characterised by significant structural and institutional constraints.

2. Literature review and theoretical framework

2.1. Finance, financial intermediation and economic growth

The relationship between financial development and economic growth is a major focus of the economic literature. The financial system performs several fundamental functions in an economy: it mobilises savings, facilitates the allocation of resources, improves investment selection, contributes to risk management and reduces transaction costs. These functions help to increase the efficiency of capital allocation and can thus support investment and productivity (Levine, Op.Cit, 2005) .

From this perspective, financial development should not be viewed solely in terms of the size of the banking system or the volume of credit, but also in terms of its capacity to make financial services more accessible, more efficient and better suited to the needs of economic agents. Digital finance appears precisely as an extension of this logic, by introducing digital technologies into the mechanisms of financial intermediation and service delivery.

In light of this literature, the relationship between finance and growth therefore appears to be firmly established in theoretical terms, but it cannot be regarded as uniform or automatic. The traditional mechanisms of financial intermediation identified by Levine (2005), notably the mobilisation of savings, the allocation of capital, risk management and the reduction of transaction costs, presuppose the existence of a financial system that is sufficiently deep and efficient to transmit these functions to the real economy. However, in the CEPGL countries, persistent limitations in banking penetration and disparities in access to financial infrastructure suggest that the intensification of financial development may follow different paths from those observed in economies with more mature banking systems. This observation leads us to shift the focus of the analysis from traditional finance alone to digital finance, whose instruments can broaden access to financial services whilst altering the costs, timeframes and terms of financial intermediation. This research is situated precisely within this analytical framework, seeking to determine whether this digital transformation of financial mechanisms has indeed led to improved economic growth in the three CEPGL countries over the period 2000–2024. It thus differs from approaches that analyse financial development primarily through traditional banking indicators, by considering digital finance as a multidimensional factor capable of influencing growth dynamics.

2.2. Digital finance and financial inclusion

Digital finance represents a significant evolution in contemporary financial systems. It encompasses, in particular, electronic payments, mobile money, digital banking services, payment platforms and solutions offered by fintech companies. By reducing geographical constraints and certain costs associated with traditional finance, these innovations can help to broaden access to financial services.

Sahay et al. (Salay, R., et al., 2020) show that innovations in the field of financial technology can promote financial inclusion by facilitating access to financial services and reducing certain traditional barriers. This dynamic is particularly important in countries where banking infrastructure is underdeveloped. Similarly, international data on financial inclusion show the rapid growth of digital payments and the use of digital financial services, whilst highlighting the persistence of significant disparities between countries and population groups (Demirgüç-Kunt et al., 2022) .

However, financial inclusion cannot automatically be equated with increased economic growth. Access to a digital account or payment service only produces substantial macroeconomic effects if the financial resources thus mobilised are effectively channelled towards investment, entrepreneurship, the accumulation of human capital and the expansion of productive activities.

The literature shows that digital finance helps to reduce the geographical, informational and transactional barriers that traditionally limit access to financial services, but this improvement in inclusion does not automatically guarantee macroeconomic effects on growth. The analytical challenge therefore lies in the ability of digital financial services to go beyond simply facilitating payments and to channel the resources mobilised towards investment, entrepreneurship and productive activities. It is from this perspective that the present research is framed, assessing—beyond financial inclusion—the overall effect of the development of digital finance, as measured by a composite index (ISFD), on economic growth in CEPGL countries.

2.3. Technological innovation and endogenous growth

The theory of endogenous growth provides a relevant framework for understanding the mechanisms likely to link digital finance and economic growth. In **Romer's (1990)** model, technological progress and the accumulation of knowledge constitute internal drivers of growth. Innovations can generate productivity gains and produce spillover effects across the entire economy.

Applied to the financial sector, this approach suggests that the digitalisation of financial services can improve transaction efficiency, reduce information costs and facilitate access to finance. Nevertheless, the impact of technology on growth remains contingent on the environment in which it is introduced. A financial innovation may exist without immediately bringing about a significant transformation of the productive structure if the complementary infrastructure, skills, institutions and investment mechanisms are insufficient.

Thus, the relationship between digital finance and growth appears to be more of a conditional relationship than a mechanical one. The development of digital finance may act as a facilitating condition for growth without necessarily, on its own, being a sufficient cause of it.

The endogenous theory developed by Paul Romer in 1990 suggests that technological innovation and the accumulation of knowledge can sustainably improve productivity and support growth, which provides a theoretical foundation for analysing digital finance as a financial innovation. However, this effect remains contingent upon the availability of digital infrastructure, human capital, institutional quality and the ability of economies to integrate innovations into production processes. This research therefore sets out to empirically verify whether the development of digital finance does indeed constitute a factor of growth in CEPGL countries over the period 2000–2024, distinguishing in particular between its short- and long-term dynamics.

3. Data and methodology

3.1. Scope of the study and data

The study covers the three CEPGL member countries, namely the Democratic Republic of the Congo, Rwanda and Burundi, over the period from 2000 to 2024. The choice of this period allows us to examine a phase characterised by the gradual acceleration of the spread of digital technologies and the transformation of payment and financial intermediation systems.

The dependent variable is economic growth, measured by the logarithm of real gross domestic product (Log_GDP). The key explanatory variable is the synthetic digital finance development index (ISFD), constructed to capture the multidimensional nature of digital finance development.

The model also incorporates several control variables that may influence economic growth: information and communication technologies (ICT), digital financial education (FinEduDig), public-private partnerships in the ICT sector (PPP_ICT) and the money supply. The inclusion of these variables aims to avoid attributing effects exclusively to digital finance that might in fact result from complementary factors linked to the economic and institutional environment.

3.2. Econometric strategy

The empirical strategy follows a step-by-step econometric sequence. It begins with an analysis of the stationarity properties of the variables, continues with Kao's cointegration test to identify the possible existence of a long-run equilibrium relationship, and then employs the ARDL approach using panel data to distinguish between short-run and long-run effects.

The value of the ARDL approach using panel data lies precisely in its ability to model both short-term adjustments and long-term equilibrium relationships simultaneously. The error correction mechanism thus enables us to understand how short-term imbalances are gradually resolved in order to bring the system back towards its equilibrium path.

Kao's cointegration test is used to verify the existence of a long-run relationship between economic growth, the development of digital finance and the control variables. The presence of such a relationship implies that the variables can move in tandem in the long run despite the existence of transitory short-run fluctuations.

Finally, the analysis is supplemented by robustness tests and the Dumitrescu–Hurlin causality test. The latter makes it possible to examine the direction of causality in a heterogeneous panel and to determine whether changes in one variable help to explain future changes in another variable (Dumitrescu, E.-I. & Hurlin, C., 2012) .

4. Empirical results

4.1. Results of preliminary analyses and cointegration

The preliminary analyses presented in the appendices indicate that the selected variables exhibit properties compatible with the application of an ARDL approach to panel data. This stage is an essential prerequisite for dynamic estimation, insofar as it enables the temporal properties of the time series to be determined and prevents an erroneous econometric interpretation of the observed relationships.

Kao's cointegration test highlights the existence of a long-run relationship between economic growth, the development of digital finance and the control variables. This result suggests that, despite short-term fluctuations, the variables under study follow a common long-run equilibrium path.

The existence of a cointegration relationship is particularly important for interpreting the relationship between digital finance and growth. It implies that changes in the digital financial system form part of a long-term structural dynamic with economic performance. However, this long-term relationship does not necessarily mean that the coefficient associated with digital finance is positive and statistically significant. Co-integration indicates the existence of a common equilibrium, whilst the sign and significance of the coefficients determine the nature of the economic effect.

4.2. Results of the dynamic estimation

The dynamic ARDL model estimates using panel data in the appendices do not confirm the hypothesis that the development of digital finance has a positive and statistically significant effect on economic growth in CEPGL countries.

More specifically, the composite index of digital finance development does not exhibit the expected positive effect in the baseline estimates. Several components of the digital ecosystem also produce negative or ambiguous effects. The result thus leads to the rejection of the first research hypothesis.

This result must, however, be interpreted with caution. The rejection of the hypothesis does not mean that digital finance is devoid of any economic utility. Rather, it means that, under the structural and institutional conditions observed in CEPGL countries during the period studied, its development has not yet translated into a sufficiently robust positive and significant effect on aggregate economic growth.

This conclusion is consistent with the view that financial innovations do not automatically generate macroeconomic gains when the complementary conditions necessary for their productive diffusion are not in place. In particular, the development of financial access must be accompanied by improvements in the quality of institutions, infrastructure and productive capacities in order to generate sustainable effects on the economy (P. Romer, 1990 & R. Levine, 2005) .

4.3. Results of the causality test

The Dumitrescu-Hurlin causality test provides a particularly important additional finding. It reveals a unidirectional causality running from the development of digital finance towards economic growth, with a probability associated with the Z-bar statistic of 0.0319.

As the probability is below the conventional 5 per cent threshold, the null hypothesis of non-causality is rejected. There is therefore a statistically significant causal relationship running from digital finance to economic growth, although the study does not identify any significant reverse causality in the results presented.

This result is particularly interesting in light of the rejection of the main hypothesis. It reveals a key distinction between causality and a statistically significant average effect. Digital finance may help to explain future variations in growth without, however, producing—in the estimated model—a positive and statistically significant effect of sufficient magnitude to validate the initial hypothesis. The causality detected by the Dumitrescu-Hurlin test must therefore be interpreted as the existence of a capacity for time-series transmission, whilst the ARDL estimates using panel data suggest that this capacity does not yet translate into a sufficiently robust positive effect on aggregate growth (Dumitrescu & Hurlin, 2012) .

5. Discussion of the results

The central finding of this research is, at first glance, counter-intuitive. Whilst the economic literature generally associates financial development with improved capital allocation and accelerated growth (Levine, Op. Cit., 2005) , the estimates obtained for the CEPGL countries do not confirm a positive and significant effect of digital finance on economic growth. **The research hypothesis is therefore rejected**. However, this conclusion does not necessarily call into question the

potential of digital finance; rather, it suggests that this potential remains contingent on the structural characteristics of the economies studied.

One explanation lies in the persistent weakness of digital and energy infrastructure. Digital finance requires relatively reliable connectivity, affordable internet access, adequate energy supply and secure payment infrastructure. Where these conditions are not met, the expansion of digital financial services may remain fragmented and fail to reach a critical mass sufficient to produce significant macroeconomic effects. Financial digitalisation may therefore improve certain individual applications without simultaneously bringing about a transformation of the entire productive system.

A second explanation relates to the weak link between digital finance and the financing of the real economy. The rise in mobile payments and digital transactions does not necessarily translate into a corresponding increase in productive investment. For digital finance to have a significant impact on growth, it must enable resources to be channelled towards businesses, SMEs, agriculture, entrepreneurship and job-creating activities. In other words, the central issue is not merely that of access to financial services, but also that of their capacity to finance productive activities and improve the efficiency of capital allocation – a mechanism at the heart of the relationship between finance and growth (Levine, Op.Cit, 2005) .

A third explanation relates to human capital and the skills required for the productive use of digital tools. The digital divide is not limited to a lack of access to infrastructure; it also concerns the ability of households and businesses to use digital services effectively. Financial and digital literacy thus emerge as a key factor in converting technological access into economic gains. This perspective is consistent with research showing that expanding financial access must be accompanied by improvements in the ability to use and understand financial services in order to produce lasting effects on inclusion and development (Salay et al. & Demirgüç-Kunt et al., 2020, 2022) .

A fourth explanation relates to the quality of the institutional and regulatory environment. Trust is a fundamental prerequisite for the development of digital financial services. Consumer protection, transaction security, cybersecurity and regulatory stability determine the willingness of households and businesses to adopt digital solutions on a sustainable basis. In contexts where these conditions remain fragile, the spread of digital finance may be rapid in terms of service usage, whilst remaining limited in its capacity to transform economic structures.

A fifth interpretation of the findings involves distinguishing between the diffusion of digital finance and its economic deepening. Digital services may experience rapid growth without the financial system as a whole becoming sufficiently deep to support productive investment. The effect of digital finance on growth may therefore be delayed or depend on a prior maturation phase. This interpretation is consistent with the long-term relationship highlighted by the Kao test: digital finance and growth are linked in an equilibrium trajectory, but the transmission mechanisms capable of converting this relationship into actual growth may still be incomplete.

Finally, the result of the Dumitrescu-Hurlin causality test provides a crucial nuance. The unidirectional causality from digital finance to growth, which is significant at the 5 per cent threshold with a probability of 0.0319, shows that the development of digital finance has explanatory power with regard to the dynamic growth . The apparent paradox between causality and the absence of a significant positive effect must therefore be understood as a sign of economic potential that has not yet been fully realised. Digital finance appears to influence the growth trajectory, but its aggregate effect remains limited by constraints that prevent financial innovations from being fully transformed into investment, productivity and economic diversification. This result leads to a more nuanced conclusion than that of a simple lack of effectiveness: digital finance appears to be a potential lever for growth, the effects of which remain conditional.

6. Economic policy implications

The findings of this study call, *first and foremost*, for the strengthening of digital and energy infrastructure in CEPGL countries. The development of digital finance can only produce sustainable macroeconomic effects if people and businesses have reliable and affordable access to digital networks and electricity. Public and private investment should therefore prioritise improving connectivity, extending digital coverage and reducing disparities between urban and rural areas.

Secondly, public policies should promote a closer link between digital finance and productive investment. The objective should no longer be solely to increase the number of users of digital financial services, but to strengthen the capacity of these services to finance SMEs, micro-enterprises, agriculture and entrepreneurship. Digital finance must gradually evolve from an instrument primarily geared towards payments into a genuine channel for financing the real economy.

Thirdly, financial and digital literacy should be a strategic priority. The widespread adoption of digital tools is not enough if users lack the knowledge required to use them productively and securely. Financial literacy programmes should therefore incorporate a digital dimension in order to improve the ability of households, entrepreneurs and small businesses to use digital financial services.

Fourthly, CEPGL countries would benefit from enhancing the interoperability of their payment systems. Greater regional integration of digital financial infrastructure could facilitate cross-border transactions, reduce transfer costs and support regional economic integration. Such an approach would be particularly relevant in an economic area characterised by intensive cross-border trade and the need to streamline the movement of capital and goods.

Fifthly, improving the quality of regulation is an essential prerequisite for the sustainable development of digital finance. Public authorities should strengthen mechanisms for consumer protection, data security, cybersecurity and the supervision of digital operators. Clear and appropriate regulation can help to boost user confidence and create an environment conducive to innovation.

Finally, the establishment of a regional mechanism for financial and technological innovation could provide an appropriate institutional response to the challenges identified. Such a mechanism could foster cooperation between banks, fintech companies, telecommunications operators, universities, research centres and public authorities. The aim would be to create a regional ecosystem capable of transforming digital innovations into solutions tailored to the needs of the CEPGL economies and to gradually strengthen their contribution to growth.

7. Conclusion

The aim of this article was to analyse the effect of the development of digital finance on economic growth in the CEPGL countries – namely the Democratic Republic of the Congo, Rwanda and Burundi – over the period 2000–2024. The empirical analysis employed a panel data approach combining stationarity tests, Kao's cointegration test, ARDL estimation using panel data, and the Dumitrescu-Hurlin causality test.

The results highlight the existence of a long-term relationship between economic growth, the development of digital finance and the control variables. However, the dynamic estimates do not confirm the existence of a positive and statistically significant effect of digital finance on economic growth. **The research hypothesis, according to which the development of digital finance would have a positive and significant effect on economic growth in CEPGL countries, is therefore rejected.**

This result is an important finding, but it should not be interpreted as indicating a complete lack of economic potential in digital finance. The Dumitrescu-Hurlin causality test does indeed reveal a unidirectional causality running from the development of digital finance to economic growth, with a probability of 0.0319, which is significant at the 5 per cent threshold (Dumitrescu & Hurlin, 2012) . There is therefore a transmission mechanism from digital finance to growth dynamics, even if this transmission has not yet resulted in a positive and significant effect in the estimates considered.

The overall conclusion is thus qualified. In CEPGL countries, digital finance does not yet constitute an autonomous and sufficiently powerful driver of economic growth. Its effectiveness depends on complementary conditions relating to the quality of digital and energy infrastructure, the development of human capital, financial and digital literacy, financial inclusion, the quality of regulation, and the integration of financial innovations into the financing of the productive economy. This conclusion is consistent with the idea that technological and financial innovation only produces its full effects when supported by a favourable institutional and productive environment (P. Romer, 1990 & R. Levine, 2005) .

Ultimately, the challenge for CEPGL countries is therefore no longer merely to promote the uptake of digital finance, but to create the conditions that will enable this uptake to be converted into productivity gains, productive investment and economic diversification. The identified causal link between digital finance and growth suggests that the potential exists; however, the rejection of the hypothesis of a positive and significant effect indicates that this potential remains only partially realised. Public policy should therefore aim not only to expand the digital ecosystem, but also to integrate it with infrastructure, human capital, productive finance and regional economic integration.

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APPENDICES

1. Test for stationarity of variables (Levin–Lin–Chu unit-root test)

Variable	Stationarity at level	First difference	Order of Integration
Log GDP	0.0000	-	I(0)
Log_ISFD	0.0012	-	I(0)
ICT	0.0325	-	I(0)
Log_FinEduDig	0.0000	-	I(0)
Log_PPP_ICT	0.0000	-	I(0)
Currency	0.9120	0.0000	I(1)

Source: Results obtained using STATA 17.0 software

2. KAO Cointegration Test

```
. xtcointtest kao log_PIB log_ISFD NTIC log_FinEduDig log_PPP_ICT_USD Monnaie

Kao test for cointegration
--------------------------

H0: No cointegration                        Number of panels       =      3
Ha: All panels are cointegrated             Number of periods      =     23

Cointegrating vector: Same
Panel means:          Included              Kernel:           Bartlett
Time trend:           Not included          Lags:             1.33 (Newey-West)
AR parameter:         Same                  Augmented lags:   1
------------------------------------------------------------------------------
                                            Statistic         p-value
------------------------------------------------------------------------------
 Modified Dickey-Fuller t                   -10.1389          0.0000
 Dickey-Fuller t                             -2.3839          0.0086
 Augmented Dickey-Fuller t                   -3.5495          0.0002
 Unadjusted modified Dickey-Fuller t         -9.8547          0.0000
 Unadjusted Dickey-Fuller t                  -2.3555          0.0092
------------------------------------------------------------------------------
```

Source: Results obtained using STATA 17.0 software

3. ARDL dynamic models

	(1)	(2)	(3)	(4)
	PMG Model		MG model	
VARIABLES	ecm1	SR	ecm4	SR
ecm1		-0.000634***		
		(2.77e-05)		
D.log_ISFD		-0.000226		-0.00143*
		(0.00114)		(0.000769)
D.ICT		1.033		1.034
		(1.033)		(1.034)
D.log_FinEduDig		-0.0348***		-0.0601**
		(0.00167)		(0.0288)
D.log_PPP_ICT		7.71e-05*		-0.0168
		(3.96e-05)		(0.0168)
D.Currency		6.22e-06**		-5.22e-06**
		(2.45e-06)		(2.39e-06)
L. ICT	0.00543		-0.247	
	(0.0114)		(0.278)	
L.log_FinEduDig	-28.77***		-81.75	
	(6.265)		(76.34)	
L.log_PPP_ICT	0.0142		152.7	
	(0.0359)		(152.7)	

L.Currency	0.0310***		0.00201	
	(0.00643)		(0.00605)	
ecm4				-0.00215*
				(0.00114)
Constant		-1.964		-1.936
		(2.066)		(2.079)
Observations	72	72	72	72

Standard errors in brackets

**** p<0.01, ** p<0.05, * p<0.1*

Source: Results obtained using STATA 17.0 software

6. Hausman test for dynamic models

```
                 ---- Coefficients ----
                |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
                |       MG          PMG         Difference       Std. err.
----------------+----------------------------------------------------------------
        NTIC    |
         L1.    |   -.2469782    -.2469782               0               0
log_FinEdu~g    |
         L1.    |   -81.75194    -81.75194               0               0
log_PPP_IC~D    |
         L1.    |    152.7113     152.7113               0               0
     Monnaie    |
         L1.    |    .0020146     .0020146               0               0
----------------------------------------------------------------------------

                          b = Consistent under H0 and Ha; obtained from xtpmg.
           B = Inconsistent under Ha, efficient under H0; obtained from xtpmg.

Test of H0: Difference in coefficients not systematic

    chi2(0) = (b-B)'[(V_b-V_B)^(-1)](b-B)
            = 0.00
Prob > chi2 =    .
(V_b-V_B is not positive definite)
```

Source: Results obtained using STATA 17.0

7. Dumitrescu–Hurlin causality test

```
. xtgcause log_PIB log_ISFD


Dumitrescu & Hurlin (2012) Granger non-causality test results:
------------------------------------------------------------
Lag order: 1
W-bar =          2.7516
Z-bar =          2.1453   (p-value = 0.0319)
Z-bar tilde =    1.6820   (p-value = 0.0926)
------------------------------------------------------------
H0: log_ISFD does not Granger-cause log_PIB.
H1: log_ISFD does Granger-cause log_PIB for at least one panel (Pays).
```

Source: Results obtained using STATA 17.0

APPENDIX 8 (Summary): Database used

Country	Year	FinTech	Internet	TelepMobile	Mobile Money	Digital Payments	ICT	FinEduDig	PPP_ICT	DigitalTransCost	Real GDP	ATM	Currency	ISFD	ZiATM	ZiFinTech
1	2000	0	1	1.3	0	0	2	2	0	15	300	80	3.42308139669861	2.4800857142857144	0.0606	0
1	2001	0	3.5	2.08	0	0	4.5	4.5	0	14.8	320	90	2.85740812895541	2.924414285714286	0.0909	0
1	2002	0	6	2.86	0	0	7	7	0	14.6	325	100	2.91725803901463	3.3687428571428577	0.1212	0
1	2003	1	8.5	3.64	0	0	9.5	9.5	0	14.4	368	110	3.16074494763066	3.8148571428571425	0.1515	0.0125
1	2004	1	11	4.42	0	0	12	12	10	14.2	382	122	5.06281053286604	4.259185714285714	0.1818	0.0125
1	2005	1	13.5	5.2	0	0	14.5	14.5	20	14	400	130	4.2985310260745	4.703514285714286	0.2121	0.0125
1	2006	2	16	7.76	0.4	0.2	17	17	30	13.8	420	142	5.54535538315526	5.489628571428571	0.2424	0.025
1	2007	3	18.5	10.32	0.8	0.4	19.5	19.5	40	13.6	430	150	6.3767881694153	6.275742857142857	0.2727	0.0375
1	2008	3	21	12.88	1.2	0.6	22	22	50	13.4	460	160	7.38692429885378	7.060071428571429	0.303	0.0375
1	2009	4	23.5	15.44	1.6	0.8	24.5	24.5	60	13.2	470	175	9.73296477064675	7.8461857142857125	0.3333	0.05
1	2010	5	26	18	2	1	27	27	70	13	500	188	9.02941039225904	8.632299999999999	0.3636	0.0625
1	2011	7	28.5	21.4	5.2	2.8	29.5	29.5	80	12.8	520	191	9.8949001756785	10.16877142857143	0.3939	0.0875
1	2012	9	31	24.8	8.4	4.6	32	32	90	12.6	530	200	10.4910922620386	11.705242857142855	0.4242	0.1125
1	2013	11	33.5	28.2	11.6	6.4	34.5	34.5	100	12.4	545	210	10.7235574589915	13.241714285714286	0.4545	0.1375
1	2014	13	36	31.6	14.8	8.2	37	37	110	12.2	550	230	11.1174080264245	14.778185714285714	0.4848	0.1625
1	2015	15	38.5	35	18	10	39.5	39.5	120	12	600	230	11.5984767365492	16.314671428571426	0.5152	0.1875
1	2016	18	41	37	21.4	12.4	42	42	130	11.8	620	240	13.4749337236825	17.767214285714285	0.5455	0.225
1	2017	21	43.5	39	24.8	14.8	44.5	44.5	140	11.6	630	240	12.8354393279869	19.219757142857137	0.5758	0.2625
1	2018	24	46	41	28.2	17.2	47	47	150	11.4	660	260	12.6564111724281	20.672300000000003	0.6061	0.3
1	2019	27	48.5	43	31.6	19.6	49.5	49.5	160	11.2	685	260	16.7186874641726	22.124842857142855	0.6364	0.3375
1	2020	30	51	45	35	22	52	52	170	11	700	270	21.7477739808735	23.577385714285715	0.6667	0.375
1	2021	34	53.5	47	38.75	25.25	54.5	54.5	180	10.8	720	290	21.5564385603114	25.20314285714286	0.697	0.425
1	2022	38	56	49	42.5	28.5	57	57	190	10.6	730	300	21.986457	26.8289	0.7273	0.475
1	2023	41	58.5	51	46.25	31.75	59.5	59.5	200	10.4	760	310	22.12578946	28.452871428571427	0.7576	0.5125

1	2024	45	61	53	50	35	62	62	210	10.2	780	320	22.3056427	30.07862857142857	0.7879	0.5625
2	2000	0	6	0.5	0	0	5	5	0	15	350	150	14.1564719784408	3.1103857142857145	0.2727	0
2	2001	0	8.5	1.2	0	0	8	8	10	14.8	370	160	13.6638227776705	3.5432857142857146	0.303	0
2	2002	1	11	1.9	0	0	11	11	20	14.6	395	170	14.6344590405009	3.9779714285714287	0.3333	0.0125
2	2003	1	13.5	2.6	0	0	14	14	30	14.4	410	180	13.983088097597	4.410871428571428	0.3636	0.0125
2	2004	2	16	3.3	0	0	17	17	40	14.2	435	190	13.7813518200786	4.845557142857143	0.3939	0.025
2	2005	2	18.5	4	0	0	20	20	50	14	455	200	13.7624375262056	5.2784571428571425	0.4242	0.025
2	2006	4	21	10.2	2	1.6	23	23	60	13.8	470	210	15.5353523799413	7.014928571428572	0.4545	0.05
2	2007	5	23.5	16.4	4	3.2	26	26	70	13.6	490	220	17.0505411887058	8.749614285714285	0.4848	0.0625
2	2008	7	26	22.6	6	4.8	29	29	80	13.4	510	230	15.6995263439751	10.486099999999999	0.5152	0.0875
2	2009	8	28.5	28.8	8	6.4	32	32	90	13.2	520	240	14.3347317746841	12.220785714285714	0.5455	0.1
2	2010	10	31	35	10	8	35	35	100	13	550	250	15.5542868759791	13.957257142857143	0.5758	0.125
2	2011	12	33.5	42	15	12.4	38	38	110	12.8	570	260	17.3342732712618	16.636585714285715	0.6061	0.15
2	2012	14	36	49	20	16.8	41	41	120	12.6	595	270	17.2458905705942	19.31591428571429	0.6364	0.175
2	2013	15	38.5	56	25	21.2	44	44	130	12.4	615	280	17.9823176390729	21.993457142857142	0.6667	0.1875
2	2014	17	41	63	30	25.6	47	47	140	12.2	635	290	18.9488961574076	24.672785714285713	0.697	0.2125
2	2015	22	43.5	70	35	30	50	50	150	12	650	300	20.8162554781801	27.357471428571433	0.7273	0.275
2	2016	28	46	72	39	33	53	53	160	11.8	670	310	20.288049168884	28.9868	0.7576	0.35
2	2017	33	48.5	74	43	36	56	56	170	11.6	695	320	19.7081417149906	30.614342857142855	0.7879	0.4125
2	2018	39	51	76	47	39	59	59	180	11.4	710	330	21.7307882385639	32.24367142857143	0.8182	0.4875
2	2019	44	53.5	78	51	42	62	62	190	11.2	735	340	21.3544486905459	33.87121428571429	0.8485	0.55
2	2020	51	56	80	55	45	65	65	200	11	750	350	25.1477472790838	35.50232857142857	0.8788	0.6375
2	2021	58	58.5	81.5	58.75	48.75	68	68	210	10.8	775	360	26.0617481878019	37.13344285714287	0.9091	0.725
2	2022	66	61	83	62.5	52.5	71	71	220	10.6	792	370	25.5730826285685	38.76634285714285	0.9394	0.825
2	2023	73	63.5	84.5	66.25	56.25	74	74	230	10.4	816	380	26.3281033455288	40.39745714285714	0.9697	0.9125
2	2024	80	66	86	70	60	77	77	240	10.2	830	390	27.6741530972272	42.028571428571425	1	1

3	2000	0	1	0.2	0	0	3	3	0	15	300	60	17.1728550609034	2.314285714285714	0	0
3	2001	0	3.5	0.56	0	0	5	5	0	14.8	320	70	17.2257816352167	2.6986142857142856	0.0303	0
3	2002	0	6	0.92	0	0	7	7	0	14.6	345	80	21.2523406830438	3.082942857142857	0.0606	0
3	2003	0	8.5	1.28	0	0	9	9	0	14.4	360	90	24.0243463141909	3.467271428571429	0.0909	0
3	2004	0	11	1.64	0	0	11	11	0	14.2	385	100	22.3254125001561	3.8516000000000004	0.1212	0
3	2005	0	13.5	2	0	0	13	13	10	14	422	110	23.2228639248364	4.2359285714285715	0.1515	0
3	2006	0	16	3.6	0.6	0.4	15	15	20	13.8	425	120	26.2748698373922	4.940257142857144	0.1818	0
3	2007	0	18.5	5.2	1.2	0.8	17	17	30	13.6	440	130	24.619613407841	5.644585714285713	0.2121	0
3	2008	1	21	6.8	1.8	1.2	19	19	40	13.4	465	140	25.2588848848776	6.350700000000002	0.2424	0.0125
3	2009	1	23.5	8.4	2.4	1.6	21	21	50	13.2	480	150	25.8770374379	7.055028571428571	0.2727	0.0125
3	2010	1	26	10	3	2	23	23	60	13	505	160	28.2427285653968	7.759357142857143	0.303	0.0125
3	2011	1	28.5	13	4.8	3.2	25	25	70	12.8	525	170	26.805998695761	8.9494	0.3333	0.0125
3	2012	1	31	16	6.6	4.4	27	27	80	12.6	540	180	26.1297784433938	10.139442857142857	0.3636	0.0125
3	2013	2	33.5	19	8.4	5.6	29	29	90	12.4	565	190	25.8819425264112	11.33127142857143	0.3939	0.025
3	2014	2	36	22	10.2	6.8	31	31	100	12.2	580	200	26.4533319187798	12.521314285714286	0.4242	0.025
3	2015	2	38.5	25	12	8	33	33	110	12	610	210	25.0432787550205	13.711357142857143	0.4545	0.025
3	2016	2	41	29	14.6	9.4	35	35	120	11.8	620	220	24.4852969840702	15.187114285714287	0.4848	0.025
3	2017	3	43.5	33	17.2	10.8	37	37	130	11.6	645	230	26.2974722725836	16.664671428571427	0.5152	0.0375
3	2018	3	46	37	19.8	12.2	39	39	140	11.4	665	240	30.3917072741844	18.140428571428572	0.5455	0.0375
3	2019	4	48.5	41	22.4	13.6	41	41	150	11.2	685	250	35.5510470669746	19.617971428571426	0.5758	0.05
3	2020	4	51	45	25	15	43	43	160	11	700	260	37.9686462481577	21.093728571428574	0.6061	0.05
3	2021	5	53.5	48.25	27.5	17.5	45	45	170	10.8	710	270	40.1966074541253	22.606985714285717	0.6364	0.0625
3	2022	6	56	51.5	30	20	47	47	180	10.6	740	280	46.8363774737702	24.120242857142852	0.6667	0.075
3	2023	7	58.5	54.75	32.5	22.5	49	49	190	10.4	765	290	44.7565558445588	25.6335	0.697	0.0875
3	2024	8	59.1	35	25	34	50	48	220	12.6	752	211	45.74	23.751085714285715	0.4576	0.1

Data sources: WDI/WB, IMF, GSMA, ITU	
Legends: CEPGL member countries	
	1: DRC
	2: RWANDA
	3: BURUNDI