Financial innovation and financial inclusion in European countries: How do they interact?

Alina Cristina Nuta[1], Ibrahim Cutcu[2], Felix Puime-Guillen[3]

[1] *Danubius International University, Faculty of Economics and Business Administration, Romania; Azerbaijan State University of Economics (UNEC), Women Researchers Council, Azerbaijan, ORCID: 0000-0003-3248-644X, alinanuta@univ-danubius.ro (corresponding author);*
[2] *Hasan Kalyoncu University, Department of Economics, Turkey, ORCID: 0000-0002-8655-1553, icutcu@gmail.com;*
[3] *University of A Coruna, Faculty of Economics and Business, Spain, ORCID: 0000-0001-7341-9134, felix.puime@udc.es.*

Abstract: *The most challenging moments in economic history necessitated adaptability to new realities and foreshadowed innovative reactions from economic agents. The recent global health crisis compelled all the stakeholders to find viable solutions to prevent the economic recovery from stalling. As finance serves as the fuel that keeps the economic engine running, exploring the factors affecting financial innovation is pivotal. Europe's digital transition strategy provides a vibrant approach to bolstering the digital economy and financial landscape. This study evaluates the link between financial inclusion and financial innovation in selected European countries moderated by digital technology. Moreover, subsequent factors related to socio-economic development, like the standard of living, education, urbanization, and globalization, are studied to assess their impact on financial innovation. The study used new-generation panel data techniques to analyze the selected European countries from 2000 to 2020. Durbin Hausman's cointegration test shows a long-run relationship. Our findings from fully modified ordinary least square (FMOLS) and dynamic ordinary least squares (DOLS) tests highlighted an inverse relationship between financial inclusion and financial innovation. Thus, expanding the inclusion of people in the financial ecosystem will not increase the usage of innovative financial tools. However, it will only encourage access to essential financial services and products, considering the high levels of financial inclusion in Europe and the newcomers' financial and digital literacy levels. Additionally, the preference for using cash in European countries, which is still at high levels, also explains our results regarding the indirect connection between financial inclusion and financial innovation diffusion. Moreover, a strong direct correlation is observed between education, standard of living, and urbanization. Konya causality analysis results displayed a causal relationship between independent variables and financial innovation in different countries.*

Keywords: *Digital technology, innovative finance, inclusion, education, Europe.*

JEL Classification: *Q55, D1, F65, I25.*

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Introduction

The long history of economic thought examined innovation and financial innovation from different perspectives. Investment in human capital is strongly connected with innovation. Innovation is the key to performance and

development, driven by the "new" element in activity. At the same time, innovation in finance has generally been associated with positive outcomes for a large part of the literature (Bernier & Plouffe, 2019), but it has also been related to negative events, such as crises (Beck et al., 2016).

On the other hand, financial inclusion can augment the innovation of the financial sector by expanding the demand for money and new, personalized, and innovative financial products. Education is the key element, as well as rapid economic development. Additionally, literature has not reached a consensus regarding the impact of financial development on innovation; beyond a positive (Levine, 2005) or negative relationship, some works found a non-linear relationship (Trinugroho et al., 2021), suggesting a positive impact until a certain threshold has been reached, after which the innovation is disheartened.

The definition of financial innovation constantly evolves, making it challenging to standardize measures in the literature. Many studies have analyzed financial innovation's influence on financial inclusion because expanding the range of financial services as much as possible through innovative tools and philosophy will enhance inclusivity. Additionally, few studies analyzing India's context raise doubts about the inclusivity capacity of innovation in finance, specifically concerning women, unbanked, and vulnerable communities (Kanungo & Gupta, 2021; Venkatraman & Reddy, 2021). However, no study has analyzed the impact of financial inclusion on financial innovation broadly. To fill the literature gap, our study aims to empirically evaluate the existence of causality between financial inclusion and innovative financial products and its interpretation in the pursuit of sustainable development goals in the rapid expansion of digital technology. A marginal aim is to investigate the role of globalization, education, and living standards on financial innovation. Additionally, the study will assess the role of urbanization as a driver for social modernization on financial innovation. Thus, this approach argues that extending inclusion in the financial ecosystem will not result in more innovative financial product usage, but contrary, especially when there is a high level of inclusion, as is the case with selected developed countries from Europe, beyond which additional players in the system will not demand more innovation, but only basic financial services. A relevant reason to sustain this finding is related to the fact that additional consumers are usually vulnerable people or belong to vulnerable communities, especially in developing countries. However, this is not the only reason, considering the specific consumer preference for financial tools in European countries, which is closely related to cash usage. This study aims to ascertain the main factors that affect financial innovation in European countries, analyzing the role of the standard of living, urbanization, internet usage, financial inclusion, and globalization.

The research contribution to the literature can be highlighted in the following ways. The study addresses an unexplored connection between financial inclusion and financial innovation, giving rationales behind the negative impact of inclusion on financial innovation at a certain level of inclusion and considering the specific profile of financial instrument users from Europe. This is an important finding for institutional stakeholders, which should address the financial skills gap of financially excluded people and create relevant programs for them. Moreover, the diversity of cash users' profiles within European countries and their high preference for not owning or using digital payment tools requires the continued adaptation of the cash strategy of European authorities, according to their diminished propensity to be active actors in the financial digital landscape. Additionally, this paper used data considering the use of electronic payment instruments from the European Central Bank as a proxy for the financial innovation variable and the access and depth components of the financial development index to construct a proxy for the financial inclusion variable, which has not been used in previous studies. Moreover, new generation panel data analysis techniques were used in the methodology. The study's methodology, which aims to determine the link between financial innovation and financial inclusion in EU states, includes descriptive statistics analyzed via graphical presentations of the variables. Subsequently, cross-section dependence test, panel unit root test, homogeneity test, panel cointegration test, coefficient estimator analysis (fully modified ordinary least square – FMOLS and dynamic ordinary least squares – DOLS), and panel causality tests are performed. As can be seen,

current and new-generation analyses were used in all analyzers.

Thus, the primary focus of this research is to investigate the relationship and impact of financial innovation on financial inclusion in selected EU countries. In this context, the main hypothesis of the study is that there is a long-term relationship between financial innovation and financial inclusion. The structure of the paper continues with the literature review. In the following section, the econometric approach is presented. Next section points out the results and discussion, followed by the conclusions and policy implications presented in the last section.

1 Theoretical background

The theory of the national innovation system explains the advancement of innovation (Watkins et al., 2015). Education (human capital) has greater importance for innovation, as models of endogenous growth suggested (Romer, 1994) by generating technological change, in contrast with learning-by-doing models (Arrow, 1962) in which technologies have a secondary role.

Previous studies approached innovation in finance as a response to regulation (Silber, 1983), explained by the fact that new practices or new financial tools appear when different constraints affect the financial decisions of firms and households. Financial inclusion is strongly correlated with financial stability, both positively and negatively (Nuta et al., 2024). The widely allocated financial resources feature of financial inclusion positively affects financial stability by contributing to more equitable and less risky interactions, an increase in formal institutions' involvement, and reduced costs (Hua et al., 2023; Oanh et al., 2023; Saha & Qin, 2023; Yin et al., 2020; Yu et al., 2023). Conversely, when financial inclusion is based on improperly regulated fintech innovation, adverse effects, such as volatility, risk spillover, as well as excessive credit, and inflation, will negatively impact financial stability (Boot et al., 2021). Moreover, a good-bad financial inclusion distinction is established in the literature (Hua et al., 2023; Oanh et al., 2023). They argue that after a certain threshold, the expansion of financial inclusion became "bad finance," accompanied by over-indebtedness and systemic risk. In addition, Hua et al. (2023) discovered an inverted U-shaped link between these two variables.

Financial inclusion plays a crucial role in the real economy by providing access to resources for those in need. However, it has limitations when it comes to fostering innovation. Moreover, there can be a crowding-out effect, where the demand for money for general spending by individuals without an investment mindset may limit the potential for borrowing for productive purposes. In this context, financial literacy becomes essential.

Financial innovation and financial inclusion are not always compatible. As Anderloni and Carluccio (2007) highlighted, inclusion in the financial market and access to financial services become difficult for specific categories of people in an innovative-intensive landscape. Moreover, a very complex financial network will supply more personalized services for households and firms but is also subject to induced contagion processes and financial shocks. As well, the intricacy of certain "opaque" financial products will lead to increasing risks, not only to exclusive access and inequality (Botta et al., 2022). Conversely, research of Niankara (2023) on the Arab regional payment system that used Global Findex surveys pointed out the importance of financial inclusion in enhancing digital payment solutions, considering the Helical theory framework of Carayannis and Campbell (2012). The debate on financial innovation, inclusion, and globalization still lacks consensus in the literature. Moreover, globalization (especially financial globalization), besides the diversification of financial resources and extension of the range of instruments available for business financing and investments, can diminish the costs of transactions, improve risk sharing and the information transfer and transparency between counterparties, and can facilitate the uniformization of standards disclosure and a stronger discipline. Contrariwise, financial globalization may not have similar effects on financial development or innovation because of the relevance of the internal domestic markets (e.g., financial, capital, and labor), which are more powerful and can catalyze in different ways the financial environment, as highlighted in Wei (2018) research. As the literature suggested, globalization tends not to be such a pivotal factor for developed nations.

In a study of Tesega (2022) on 33 African countries evaluating the association between financial globalization and financial development, the author found mixed effects:

a reduced level of financial globalization had a negative impact on financial development, while higher levels of globalization positively affected financial development. A more recent study (Zheng et al., 2023) found a significant boost of globalization to technological innovation, enhanced by the robustness of the institutional quality of a specific country. The main channel by which the positive effect becomes evident is financial development. Nevertheless, a study by Ghosh (2017) suggested that globalization can diminish the resources dedicated to innovative firms. Additionally, a greater concentration of the financial ecosystem may generate an expansion of the financing cost, including for innovative activities. The innovative impetus of a country is not only a matter of human capital deployment but also dependent on the country's development level and also, on internal and external financial resources. Considering the social advancement of a country (standard of living), which reflects the domestic potential of that country to become more innovative and use technology-based tools, this study also identifies the external financial capabilities to evaluate their potential in shaping financial innovation by including globalization in the model. The rationale behind including the standard of living in the model is that innovation is a resource-consuming process (O'Sullivan, 2006) and may occur in the presence of certain disposable income at the individual or societal level. Innovation enhances development. The feedback effect is also noticeable. Thus, a higher standard of living and economic empowerment will support and boost innovation by enhancing the quality of education and upskilling people, attracting more innovation (Madgavkar, 2023).

2 Research methodology

2.1 Data

Some of the variables selected for this study were previously used to explain the effects of various features on financial development in different groups. However, the literature used them separately without covering the complex relationships that are discussed and explained in this research. Moreover, by adding urbanization and gross national income, the results will shed light upon the influence social development has on financial innovation, which is paramount for the characteristics of modern society. The primary constraint of the data range of the research is the standard data problem. The analyses are based on annual data for the period 2000–2020 due to the standard data constraint of the variables of selected

Tab. 1: Dataset and sources

Variables	Definition	Source
Financial innovation (*FIN*)	The use of electronic payment instruments in a specific country	European Central Bank
Financial inclusion (*FINC*)	The average of financial institution access and depth and financial markets access and depth indices	IMF
Individuals using internet (*IU*)	The number of internet users in a country	World Bank
Mean years of schooling (*MYS*)	The educational attainment levels of people aged 25 and more	UNDP (United Nations Development Programme)
Globalization (*GLB*)	Measures three aspects of globalization (social, economic, and political)	KOF Swiss Economic Institute
Urban population (% total population; *URB*)	People living in urban areas	World Bank
Gross nation income per capita (constant 2017 international USD; *GNI*)	Standard of living in selected countries	UNDP

Source: own

European countries. In this regard, financial innovation (*FIN*) is used as the dependent variable, and financial inclusion (*FINC*), individuals using the internet (*IU*), mean years of schooling (*MYS*), and globalisation (*GLB*) variables are used as independent variables. For the globalization measurement, we used the KOF globalization index (Gygli et al., 2019). Additionally, urbanization (*URB*) and gross national income (*GNI*) variables, known to affect the dependent variable of financial innovation, are incorporated in the model as control variables. The explanatory notes of all variables included in the model are displayed in Tab. 1.

In the research, the model created within the hypothesis framework is constructed as follows.

$$LNFIN_{it} = \beta_0 + \beta_1 FINC_{it} + \beta_2 LNIU_{it} + \\ + \beta_3 MYS_{it} + \beta_4 LNGLB_{it} + \beta_5 LNURB_{it} + \\ + \beta_6 LNGNI_{it} + \varepsilon_{it} \quad (1)$$

where: i = 1, 2, 3, ..., N denotes cross-sectional data; t = 1, 2, 3, ..., T indicates time dimension; and ε – error term. In the analyses, financial innovation (*FIN*), gross national income (*GNI*), urban population (*URB*), globalization (*GLB*), and individuals using the internet (*IU*) variables are logarithmized and transformed into the model.

For the other variables, we did not use logarithms since they are ratios or indices. The study's methodology, which aims to determine the relationship between financial innovation and financial inclusion in EU countries, is as follows: descriptive statistics are analyzed via graphical presentations of the variables. Subsequently, cross-section dependence test (CD_{lm1} and LM_{adj}), panel unit root test, homogeneity test, panel cointegration test, coefficient estimator analysis (FMOLS and DOLS) and panel causality (Konya) tests are performed.

2.2 Descriptive statistics and graphical analysis

In econometric applications, changes and fluctuations of variables over the years are observed through graphical analyses. The graphical view and interpretations of the variables of the research are shown in Fig. 1.

When Fig. 1 is analyzed, it is observed that the highest level of *LNFIN* variable is observed in France and Germany, while it reaches its lowest point in Malta. Furthermore, Luxembourg differs from other countries in *LNGNI* variable. While *LNURB* variable fluctuates at the same level in almost all countries, Romania and Portugal are at the minimum level. Regarding the *LNGLB* variable, it is understood that

Tab. 2: Basic statistical tests for variables

Variables	Observations	Mean	Median	Maximum	Minimum	Std. dev.	Skewness	Kurtosis	Jarque-Bera
LNFIN	420	7.0316	7.4164	10.1621	2.5960	1.7772	−0.4473	2.4336	19.6201 (0.0000)
LNGNI	420	10.5101	7.4164	11.4422	9.4034	0.3988	−0.4441	2.9533	13.8430 (0.0009)
LNURB	420	4.3021	7.4164	4.5858	3.9661	0.1661	−0.1205	2.0552	16.6372 (0.0002)
LNGLB	420	4.4030	7.4164	4.5124	4.0867	0.0832	−1.3259	4.6672	171.6984 (0.0000)
LNIU	420	3.8402	1.2384	4.5896	−0.5057	1.1032	−2.8005	10.5196	1,546.4240 (0.0000)
FINC	420	0.5215	7.4164	0.8454	0.0356	0.2011	−0.5817	2.1922	35.1087 (0.0000)
MYS	420	11.5274	7.4164	14.1322	6.7827	1.4855	−0.8202	3.4058	49.9667 (0.0000)

Note: *LNFIN* – financial innovation; *LNGNI* – gross national income; *LNURB* – urban population; *LNGLB* – globalization; *LNIU* – individuals using the internet; *FINC* – financial inclusion; *MYS* – mean years of schooling.

Source: own

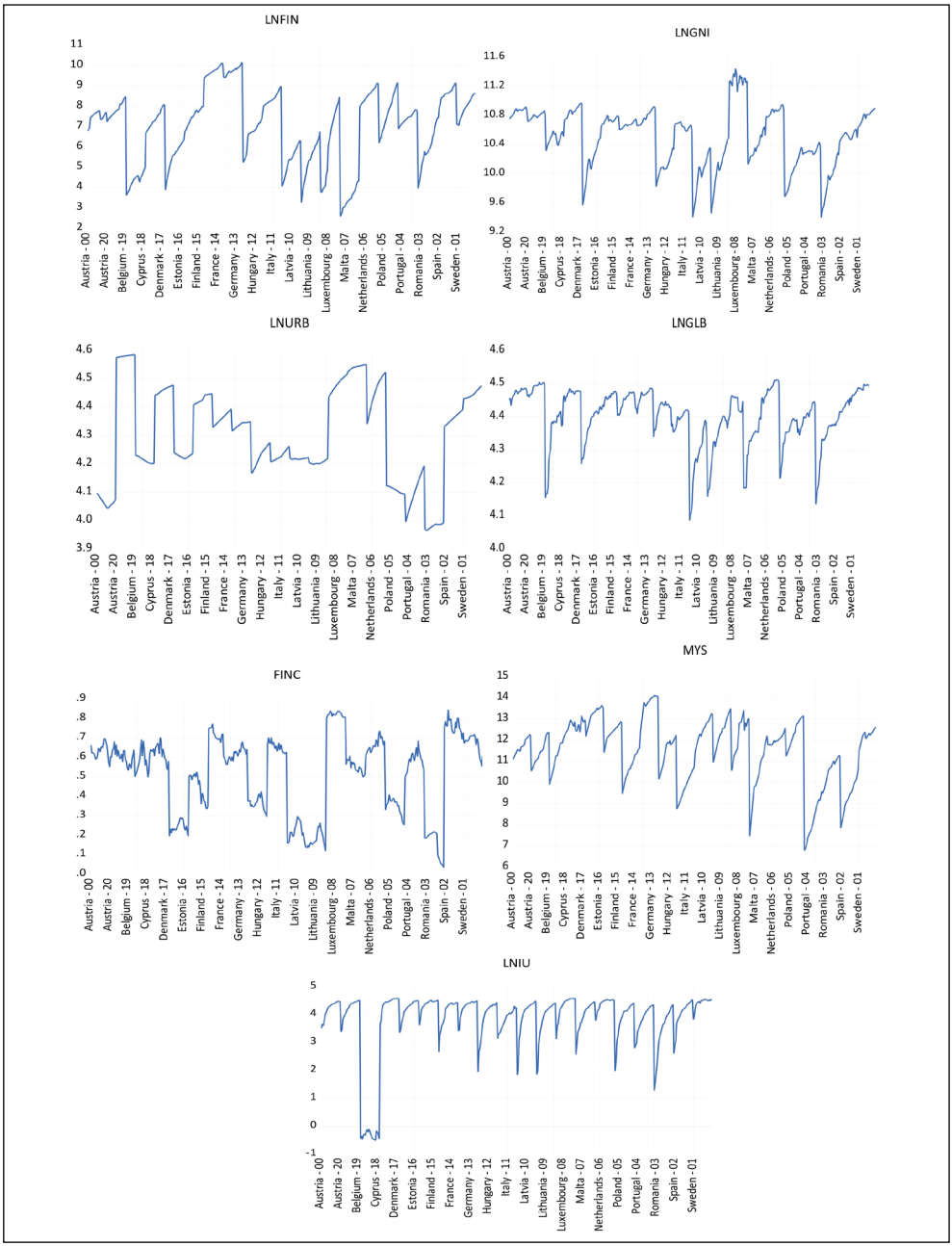

Fig. 1: Graphical representation of variables

Note: *LNFIN* – financial innovation; *LNGNI* – gross national income; *LNURB* – urban population; *LNGLB* – globalization; *LNIU* – individuals using the Internet; *FINC* – financial inclusion; *MYS* – mean years of schooling.

Source: own

countries such as Romania and Lithuania, which joined the EU afterward, are at low levels. While *FINC* variable generally fluctuates in all countries, it peaks in Luxembourg and at the bottom in Romania and Spain. In *MYS* variable, all countries except Portugal fluctuate around the same band. In *LNIU* variable, similar fluctuations are observed in all countries except Cyprus. In Cyprus, *LNIU* variable has negative values.

The basic descriptive statistics are displayed in Tab. 2. When the data are evaluated, according to the kurtosis value, it is seen that *LNGLB* and *LNIU* variables are pointed (with values greater than 3), while the other variables are flattened (with values less than 3). According to the skewness value, all variables are negatively (right) skewed since they are less than zero. The results of the Jarque-Bera test indicate that all the variables are significant and do not conform to a normal distribution.

2.3 Empirical approach

In this part of the research, where the link between *FIN* and *FINC* is examined, annual data for selected EU countries for the period 2000–2020 are used. The main reasons for preferring European Union countries in the selection of the country sample are as follows: i) the high share of EU countries in the world economy; ii) being made up of countries that continuously increase their *FIN* investments in the world; iii) high level of *FINC* with the adoption of a common currency.

Within the scope of the research hypothesis that there is a long-run relationship between *FINC* and *FIN*, the model built in the study is first presented, and the methodology to be used is explained.

3 Results and discussion

3.1 Cross-section dependence test

The existence of a cross-sectional relationship between variables was further analyzed. With globalization, the interdependence of countries is increasing, increasing the interdependence between variables. In other words, the effect of positive or negative shocks experienced in one country is expected to affect other countries due to the interdependence process. In the research, the independence relationship between the European Union countries should also be analyzed, and some evaluations should be made based on the findings. The country group involved in the study's analysis is 20 countries. For this reason, the cross-sectional dimension is $N = 20$. The time dimension is 21 ($T = 21$) since the periods of 2000–2021 are analyzed. Since $T > N$ (Pesaran, 2004) CD_{lm} and LM_{adj} tests of Pesaran et al. (2008) are employed in the study.

Pesaran (2004) was used and formulated as the Equations (2–3):

$$\mathrm{LM} = T \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} P_{ij}^2 \tag{2}$$

Tab. 3: Results of cross-section dependence test – Part 1

Variables	CD tests	CD_{lm1} (BP, 1980)	CD_{lm2} (Pesaran, 2004)	CD (Pesaran, 2004)	LM_{adj} (Pesaran et al., 2008)
LNFIN	*T*-statistics	3,451.304*	167.301*	58.367*	166.801*
	Probability	0.000	0.000	0.000	0.000
LNGNI	*T*-statistics	2,419.465*	114.369*	41.535*	113.869*
	Probability	0.000	0.000	0.000	0.000
LNURB	*T*-statistics	2,870.727*	137.518*	22.492*	137.018*
	Probability	0.000	0.000	0.000	0.000
LNGLB	*T*-statistics	3,212.898*	155.071*	56.270*	154.571*
	Probability	0.000	0.000	0.000	0.000

Tab. 3: Results of cross-section dependence test – Part 2

Variables	CD tests	CD_{lm1} (BP, 1980)	CD_{lm2} (Pesaran, 2004)	CD (Pesaran, 2004)	LM_{adj} (Pesaran et al., 2008)
LNIU	*T*-statistics	3,317.846*	160.455*	55.545*	159.955*
	Probability	0.000	0.000	0.000	0.000
FINC	*T*-statistics	1,099.278*	16.644*	23.381*	46.144*
	Probability	0.000	0.000	0.000	0.000
MYS	*T*-statistics	3,163.137*	152.518*	54.561*	152.018*
	Probability	0.000	0.000	0.000	0.000

Note: *, **, and *** indicate that the series are stationary at 1, 5, and 10% significance levels; *LNFIN* – financial innovation; *LNGNI* – gross national income; *LNURB* – urban population; *LNGLB* – globalization; *LNIU* – individuals using the internet; *FINC* – financial inclusion; *MYS* – mean years of schooling.

Source: own

$$\mathrm{CD} = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\rho_{ij}\right) \qquad (3)$$

where: *T* and *N* represent the time and the number of cross-section units (*N*).

Looking at Tab. 3, which tests the cross-sectional dependence relationship in selected EU countries, it is seen that the probability values of the variables are statistically significant at the 1% level, which admits cross-sectional dependence. This is also consistent with the theory and with the current world environment. That is to say, it can be derived that a shock to one EU country will influence other countries.

3.2 Panel unit root analysis

In panel data analyses, unit root tests are performed to eliminate the spurious regression problem. In this research, the CIPS unit root test is used because of the previously determined cross-sectional dependence. The CIPS unit root test is used because it provides consistent analysis results for cases with $T > N$.

As the unit root test results are shown in Tab. 4, according to the CIPS statistic results

Tab. 4: Unit root test results

Variables	Level	1st differential
LNFIN	−2.469	−4.809**
LNGNI	−2.553	−5.158*
LNURB	−2.553	−3.846***
LNGLB	−1.865	−4.430**
FINC	−3.504	−6.473*
MYS	−2.679	−5.373*
LNIU	−2.400	−3.680***

Note: *, **, and *** indicate that the series are stationary at 1, 5, and 10% significance levels; 1, 5, and 10% critical values are −4.96, −4.00 and −3.55, respectively; *LNFIN* – financial innovation; *LNGNI* – gross national income; *LNURB* – urban population; *LNGLB* – globalization; *LNIU* – individuals using the internet; *FINC* – financial inclusion; *MYS* – mean years of schooling.

Source: own

calculated for the whole panel, all variables are unit-rooted at their level values. When the variables are differenced at first order, *LNGNI*, *FINC*, and *MYS* variables become stationary at 1% significance level, *LNFIN* and *LNGLB* variables become stationary at 5% significance level, and finally, *LNURB* and *LNIU* variables become stationary at 10% significance level. The condition is met since variables become stationary at the same level I(I).

3.3 Homogeneity test

The homogeneity test aims to identify whether a modification in one country has a comparable impact on other countries. In this scenario, it is anticipated that coefficients will exhibit heterogeneity in models designed for countries with distinct economic structures. Conversely, coefficients are expected to display homogeneity in models created for groups of countries sharing similar economic structures. This study employs the slope homogeneity test (Delta test) introduced by Hashem Pesaran and Yamagata (2008) to assess homogeneity. The Equations (4–5), for these tests, are given below.

$$\hat{\Delta} = \sqrt{N}\left(\frac{N^{-1}\tilde{S} - k}{\sqrt{2k}}\right) \tag{4}$$

$$\hat{\Delta}_{adj} = \sqrt{N}\left(\frac{N^{-1}\tilde{S} - E(Z_{iT})}{\sqrt{Var(\tilde{Z}_{iT})}}\right) \tag{5}$$

Tab. 5 presents the homogeneity test results. The coefficients are heterogeneous. This indicates that the effect of a change in the variables included in the model on *FIN* differs in each country.

3.4 Durbin-Hausman cointegration test and coefficient estimator analysis results

In this analysis, the Durbin-Hausman cointegration test developed by Westerlund (2008) is used to analyze the long-run relationship between the variables. Many reasons distinguish the Durbin-Hausman test from others and make it more robust. The most important is that the test considers the cross-sectional dependence between variables and is a second-generation panel cointegration test (Westerlund, 2008). Since heterogeneity is captured according to the Delta test results in the research, the DH group test statistical results will generate more reliable results in the cointegration test.

Recognizing that employing group statistics is more suitable for analysis due to the observed changes in slope coefficients and the heterogeneity of variables in Tab. 6, the study considers

Tab. 5: Results of the homogeneity test

	Test statistics	Probability value
Delta	10.697*	0.000
Delta$_{adj}$	13.410*	0.000

Note: *, **, and *** indicate that the panel coefficients are heterogeneous at 1, 5, and 10% significance levels, respectively.

Source: own

Tab. 6: Durbin-Hausman cointegration test results

Test statistics	Statistics value	Probability value
Durbin-Hausman group	980.919*	0.000
Durbin-Hausman panel	17.172*	0.000

Note: *, **, and *** indicate a long-run relationship between the variables at 1, 5, and 10% significance level, respectively.

Source: own

the results of the Durbin-Hausman group statistic, upon scrutinizing the probability values of the Durbin-Hausman panel statistic. It is deduced that a long-term relationship exists between the variables as the value is below 0.05. Consequently, it is inferred that a lasting association exists between *FIN* and *FINC*. Identifying long-term relationships between variables suggests that the essential condition for coefficient estimation has been met. The FMOLS method, introduced to the literature by Phillips and Hansen (1990), generates consistent and reliable results in coefficient estimation of small samples, estimating the long-run impact of the independent variables (Yurdakul, 2018). DOLS estimates the coefficient by considering the leads and lags of the first differences of the variables, being more effective small observations models (Pata & Tütüncü, 2017).

When Tab. 7 is analyzed, according to the FMOLS coefficient estimator, the following variables have a relationship with the dependent variable financial innovation (*LNFIN*) in the specified direction and significance level:
i) *LNGNI*, *LNURB*, and *MYS* at 1% significance level;
ii) the positive direction between *LNIU* at a 10% significance level;
iii) there is a negative correlation between *FINC* at a 1% significance level.

According to the DOLS coefficient estimator, the following variables are related to the dependent variable financial innovation (*LNFIN*) in the specified direction and significance level:
i) *LNGLB* is negatively correlated at 5% significance level;
ii) a positive relationship between *LNGNI*, *MYS*, and *LNIU* at 1% significance level;
iii) a positive relationship between *LNURB* at 5% significance level;
iv) *FINC* is negatively correlated at the 10% significance level.

The results highlighted in Tab. 7 show how socio-economic variables influence *FIN*. The most important result consists of an indirect relationship between financial inclusion and innovation. In this sense, in European countries included in the panel, it was observed that an increase in *FINC* (considering that European countries included in the model dispose of a certain level of inclusiveness) would not increase *FIN*. This upshot is possible because newcomers in the financial ecosystem are vulnerable people or socio-enterprises searching for financial resources for their basic needs and usually have low financial literacy profiles. In fact, according to the latest European Commission survey on financial literacy (the Eurobarometer from 2023), only 18% of EU citizens have a high level of financial literacy. Among the countries surveyed (the Netherlands, Sweden, Slovenia, and Denmark) only three achieved the highest levels of financial literacy, with percentages of 28, 27, and 27%, respectively. In contrast, a significant portion of EU citizens exhibit low levels of financial literacy, with Finland at 27%, Latvia at 24%,

Tab. 7: FMOLS-DOLS estimation results

Variables	FMOLS estimator			DOLS estimator		
	Coefficient	Standard error	*p*-value	Coefficient	Standard error	*p*-value
LNGLB	−0.0632	0.3922	0.8720	−2.4663**	0.7624	0.0014
LNGNI	1.2020*	0.1068	0.0000	2.3088*	0.1828	0.0000
LNURB	10.2504*	2.4408	0.0000	15.0373**	5.3412	0.0043
MYS	0.4347*	0.0365	0.0000	0.2330*	0.0499	0.0000
LNIU	0.07471***	0.0438	0.0890	0.2371*	0.0659	0.0004
FINC	−1.4658*	0.2285	0.0000	−0.5808***	0.3094	0.0617

Note: *, **, and *** indicate a significance level of 1, 5, and 10% respectively; *LNFIN* – financial innovation; *LNGNI* – gross national income; *LNURB* – urban population; *LNGLB* – globalization; *LNIU* – individuals using the internet; *FINC* – financial inclusion; *MYS* – mean years of schooling.

Source: own

Belgium at 22%, Spain at 22%, and Poland at 20%, although the European countries are developed countries. Our outcomes are also confirmed by Kanungo and Gupta (2021) and Venkatraman and Reddy (2021) but are in contrast with Carayannis and Campbell (2012). According to these important results, intensive literacy programs, both for financial and digital skills, are needed. In this manner, many aspects will be solved: better spending decisions, proper investments, and increased demand for innovative and specialized financial products that can bring more social gains and may help target sustainable development goals (Hua et al., 2023; Luu et al., 2023). Additionally, other relevant results of this study point out the positive correlation between socio-economic variables and *FIN*. In this respect, education is a crucial factor that can enhance financial *FIN*, having the potential of multiplication and more personalization and secure financial products and services. The standard of living is influenced by technology and *FIN* and, at the same time, can encourage *FIN*, bearing in mind the fact that the "new" element, specific to innovation, can be cost-dependent. The study's results identify a positive relationship between the economic development level of the analyzed countries and the appetite for *FIN*, which also confirms Madgavkar's (2023) findings. Urbanization is found to be directly correlated with *FIN*. Cities' development increases the greed for sophisticated financial instruments and alternative financing especially in the context of the need for greener and more human-centered living places. Finance seems to evolve across the increasing trend of urbanization, as Grafe and Mieg (2019) have found. Societal and development changes potentiate the innovation of financing infrastructure and tools. Local stakeholders, as well as companies, investors, and civil society, are important in the decision-making process for further innovation in urban financing. According to the DOLS econometric approach, globalization was negatively correlated with *FIN*, which is in line with Wei (2018). The findings related to the negative connection between globalization and *FIN* are also consistent with the conclusion of Atsu and Adams (2023). They suggested a similar effect of foreign direct investments on innovation.

Further, the study shows a positive relationship between internet intensity/use and *FIN* in European countries. As can be observed, digital performance, internet usage, and the scope for which the internet is used in European countries present different characteristics, even if there is not a significant difference between the best-positioned country (Denmark, 96.44% of individuals are using the internet) and the worse positioned (Bulgaria, where 78.97% of individuals are using the internet), while the average at the European Union is 88.59%, according to DESI (2023). Individuals are using the internet for internet banking at various levels across Europe, with Norway being top-ranked at 95.84%, followed by Finland and Denmark at similar percentages. On the opposite side, Romania occupies the last spot with only 19.19% of individuals using the internet for banking purposes, close to Bulgaria (22.44%), while the average EU-27 is 59.66% in 2022. These figures offer a concrete perspective of the internet utility in Europe and must also be correlated with the level of basic digital skills evaluated by DESI (2023), which show high levels in Finland, the Netherlands, Ireland, and Denmark (from 79.18% to 68.65%), while Bulgaria and Romania are placed on the last positions (31.18% and 27.82%, respectively). The conclusion highlights the importance of digital skills in using the internet not only for socializing but also for taking care of day-to-day activities, such as paying bills, money transfers, e-commerce, investments, and being more efficient and productive. In this sense, national institutions should increase citizens' digital skills to properly implement the digital transformation strategy, which can positively affect society.

3.5 Kónya causality test

Kónya (2006) devised this test to explore causal relationships between variables, utilizing the seemingly unrelated regressions (SUR) estimator proposed by Zellner (1962). One notable advantage of this test is its applicability to heterogeneous panels, allowing for separate causality tests for individual countries within the panel.

Tab. 8 shows a unidirectional causality relationship from *LNFIN* to *FINC* in Italy at the 5% level and in Estonia, Lithuania, and Spain at the 10% level. These results align with Carayannis and Campbell (2012), presenting the advantages of a more innovative financial

Tab. 8: Kónya causality results

Country	Wald statistics	Critical values			Wald statistics	Critical values		
		1%	5%	10%		1%	5%	10%
	H0: Δ*LNFIN* does not Granger-cause Δ*FINC*				*H0:* Δ*FINC* does not Granger-cause Δ*LNFIN*			
Estonia	74.703***	136.764	104.091	74.710	1.102	628.498	358.315	271.266
Italy	130.466**	151.045	108.055	90.855	29.069	1556.290	850.882	635.556
Lithuania	93.797***	143.062	120.077	79.036	88.469	1603.970	761.667	371.579
Spain	88.973***	164.349	127.054	87.604	0.014	728.096	533.366	321.083
	H0: Δ*LNFIN* does not Granger-cause Δ*LNGNI*				*H0:* Δ*LNGNI* does not Granger-cause Δ*LNFIN*			
Austria	14.867	161.487	107.042	73.008	78.950***	177.272	118.152	77.476
Belgium	124.073***	226.889	169.307	119.274	7.445	130.217	77.333	51.671
Cyprus	110.416***	146.150	116.240	82.893	11.530	154.351	130.411	90.702
Denmark	79.677***	174.348	93.892	78.644	78.398***	217.710	96.768	76.057
Estonia	10.370	164.214	130.447	105.374	95.057**	121.310	91.503	72.537
Finland	54.720	139.293	89.622	79.074	89.247***	166.666	110.851	86.442
France	117.889**	289.224	101.977	85.352	5.298	185.771	113.231	94.089
Germany	105.725**	283.083	102.024	87.253	53.865	180.800	126.265	110.511
Hungary	69.835	141.606	87.854	77.016	142.029*	140.237	108.778	79.467
Italy	75.869	114.921	101.777	85.301	148.012*	131.203	112.237	75.954
Lithuania	94.516***	150.726	99.344	85.941	40.111	171.069	114.214	82.367
Luxembourg	47.592	111.676	80.694	68.276	144.700**	478.506	99.135	81.523
Portugal	85.816***	170.196	106.843	83.353	8.793	166.606	141.483	94.922
Romania	4.151	178.788	101.368	71.295	75.881***	203.785	114.716	74.871
	H0: Δ*LNFIN* does not Granger-cause Δ*LNGLB*				*H0:* Δ*LNGLN* does not Granger-cause Δ*LNFIN*			
Denmark	91.647***	197.632	104.472	79.750	29.894	575.619	296.358	225.049
Hungary	92.006***	165.62	100.929	91.661	4.682	1299.074	668.684	403.629
Lithuania	47.648	146.004	118.711	99.363	563.881**	677.086	390.770	307.448
Luxembourg	46.08	126.725	102.400	75.650	1024.512*	1012.928	484.753	304.680
Malta	135.912*	110.400	89.754	78.934	717.630**	1171.860	620.492	377.478
Netherlands	113.669**	141.320	87.930	66.284	341.468***	929.489	396.318	326.449
Poland	34.949	190.550	112.149	95.074	199.551***	408.959	332.183	198.352
Romania	202.194*	125.664	103.164	85.532	3.069	1678.927	1065.714	437.505
	H0: Δ*LNFIN* does not Granger-cause Δ*MYS*				H0: Δ*MYS* does not Granger-cause Δ*LNFIN*			
Lithuania	0.629	154.794	99.877	70.819	358.701*	184.874	115.400	84.029
Luxembourg	1.022	214.372	147.075	83.158	146.406*	124.290	100.352	64.601
Romania	90.553*	172.957	104.443	80.043	−11.051	134.460	121.672	73.129
Sweden	36.800	261.304	103.430	85.589	79.785*	273.890	101.558	75.132
	H0: Δ*LNFIN* does not Granger-cause Δ*LNIU*				*H0:* Δ*LNIU* does not Granger-cause ΔLNFIN			
Finland	14.983	216.490	119.143	90.425	92.956***	264.477	133.870	89.577
Luxembourg	92.038***	150.095	111.418	91.608	2.545	163.629	110.774	94.195
Netherlands	82.977***	154.273	120.231	75.652	1.963	197.656	105.310	59.345
Portugal	49.988	158.460	95.542	78.719	90.746**	122.590	87.482	72.495
Sweden	97.234***	161.016	108.281	90.181	121.305**	145.997	86.320	76.446

Note: *, **, and *** indicate that there is causality from the first variable to the second variable at 1, 5, and 10% significance levels, respectively; *LNFIN* – financial innovation; *LNGNI* – gross national income; *LNURB* – urban population; *LNGLB* – globalization; *LNIU* – individuals using the internet; *FINC* – financial inclusion; *MYS* – mean years of schooling.

Source: own

environment for the inclusivity issue. The emergence of new financial tools has increased access to financial funds for households and firms, favoring economic transactions and increasing people's standard of living. There is no causality relationship between *FINC* and *LNFIN* in any country.

Additionally, it shows a unidirectional causality relationship from *LNFIN* to *LNGNI* at a 5% level in France and Germany and at a 10% level in Belgium, Cyprus, Denmark, Lithuania, and Portugal. From *LNGNI* to *LNFIN*, a unidirectional causality relationship is found at the 1% level in Hungary and Italy, at the 5% level in Estonia and Luxembourg, and at the 10% level in Austria, Denmark, Finland, and Romania. The financial development of a country is critical for its development and especially for the just transition process, which is an essential goal for European Union member states. Moreover, the inverse relationship is also confirmed by our results and integrates the capacity of the level of economic development to attract and impel innovative finance features.

Moreover, Tab. 8 demonstrates a unidirectional causality relationship from *LNFIN* to *LNGLB* at 1% level in Malta and Romania, 5% level in the Netherlands, and 10% level in Denmark and Hungary. There is a unidirectional causality relationship from *LNGLB* to *LNFIN* at 1% level in Luxembourg, 5% level in Lithuania, 10% level in the Netherlands and Poland. While globalization enhances the openness of an economy, financial transactions must adjust and adapt to the new standards and conditions, alongside internalizing new techniques and frameworks from the external economic associate.

Besides, Tab. 8 shows a unidirectional causality relationship from *LNFIN* to *MYS* only in Romania at 1% level. There is a unidirectional causality relationship from *MYS* to *LNFIN* at 1% level in Lithuania, Luxembourg, and Sweden. Education is fundamental for innovation, and financial innovation depends on education from the perspective of creating new features, instruments, and organizational channels to facilitate resource utilization and financial stability. More highly skilled people will increase awareness of properly utilizing more specialized tools.

Finally, Tab. 8 displays a unidirectional causality relationship from *LNFIN* to *LNIU* at 10% level in Luxembourg, the Netherlands, and Sweden. There is a unidirectional causality relationship from *LNIU* to *LNFIN* at 5% level in Portugal and Sweden and at 10% level in Finland.

Our findings demonstrate the emergence of the interconnection between *FIN* and internet intensity. Most financial instruments require access to an internet connection, which is critical for process implementation. According to European Central Bank statistics, in the European area, the number of ATMs increased from 198,994 to 276,602 from 2000 to 2021; in the same period, the number of point-of-sale (POS) terminals increased from 3.3 million to more than 13 million. Card payments are most intensely used in Portugal (70%), while Slovakia and Finland (38%) have the highest share of credit transfers. In Germany, we can observe the most considerable level of direct debits, while the highest percentage of E-money transactions can be observed in Luxembourg (93%), followed by Italy, with 15%. According to a report on new digital payment methods at the European countries' level, the features desired by the general public from a new payment method are related to the potential to exist as a one-stop solution with reduced costs and that is not too complex. Meanwhile, traders are oriented towards minimized costs, instant payments, security, and easy integration into their operations.

Conclusions

This study used FMOLS and DMOLS techniques to evaluate the link between *FINC* and *FIN*. Other socio-economic variables were also assessed based on their correlation with *FIN* in selected European countries from 2000 to 2020. While the main part of the literature analyzed the role of *FIN* in pursuing *FINC*, only a few studies evaluated some factors influencing *FIN*. In contrast, the literature did not dig deep into considering the potential or limitation of *FINC* to boost innovation. Thus, this study examines the impact of digital technology, *FINC*, standard of living, and other economic and social variables on *FIN*. According to the main findings, the widespread use of financial services will not entail an increase in *FIN*, and the study identified several explanations. On the one hand, the newcomers in the financial ecosystem are usually people who lack tech skills or financial literacy (confirmed by the European Commission Eurobarometer

figures released in 2023) and are searching for traditional financial products; on the other hand, they do not consider innovative financial services due to their risk-adversity and security reasons or the fear of losing or not being able to control their data, also in line with Macchiavello and Siri (2022), Preziuso et al. (2023) and Tran and De Koker (2019). The right to choose how households can access financial services, guaranteed by European regulation, can be one factor of the propensity for consuming traditional financial products instead of innovative ones using digital tools, also in line with Zamora-Pérez et al. (2024) findings. In order to develop a positive connection between *FINC* and *FIN*, these factors (e.g., skills, literacy, security, personal data status/control, and privacy) must be addressed by the regulators at the national and European levels. Rigorous actions are needed to preserve individual integrity and enhance the personal capacity of equitably self-integrating in the financial ecosystem. Additionally, tighter regulations should address these technology-led financial stability concerns (Ahnert et al., 2022).

The results suggested a strong causal correlation between *FINC* and *FIN* in countries like Estonia, Italy, Lithuania, and Spain. Moreover, *FIN* is significantly correlated with the standard of living in Austria, Denmark, Estonia, Finland, Hungary, Italy, Luxembourg, and Romania. The main findings represent valuable support for policymakers, enhancing the practical value of this research. In this sense, several specific policy options are arising from the study results. Based on the demonstration that enhancing financial literacy at the national level is critical for attaining the social permeability for using innovative finance tools, the authorities should expand the target of formal and informal financial education programs to less addressed categories. In Europe, central banks and various financial authorities are involved in such programs to check the impact and adjust the key features for broader social significance. For example, the Bank of Italy conducts a triennial survey on financial literacy (IACOFI), observing the effects of informal programs for increasing digital financial skills. As a result, financial literacy improved during the last five years, creating the premises for further usage of innovative financial tools (Banca d'Italia, 2023). In Romania, the Institute for Financial Studies created a framework for offering various school programs as supplementary sources of financial education besides the formal curriculum. Other national authorities can replicate these good practices to enhance financial education and address the gaps among social groups, considering that younger people in European countries do not own a digital payment tool (Zamora-Pérez et al., 2024).

In addition, there is a need to correlate the digital skills of citizens and their demand for digital products and services to improve the benefits of using technology for various economic actions. The relevance of using the internet in a larger economic sphere is pivotal for economic development and *FIN* stir. In this sense, financial institutions must include incentives for digitalizing the transactions to ease access and encourage the electronic transfer of money. Besides national actions, European decision-makers must expand the funding coverage of the Digital Europe Programme and include various financing opportunities to support the financial digital instruments and ease digital innovation in payments. Our findings confirm Zamora-Pérez et al. (2024) results, showing that transactions in cash are widely used in the euro area despite the spread of digital payment tools. According to this study, the most relevant factors supporting these cash preferring patterns are financial literacy and digital skills, alongside with individual personal choices. As our findings highlighted, the financial inclusivity of individuals must be correlated with an increase in financial literacy and financial-specific digital skills in European countries, which have a different approach to cash usage than other developed economies. The demand-side limitations, like personal habits, for adopting innovative financial tools are significant for this phenomenon and must be considered. Additionally, access to cash must remain an ongoing pursuit for European financial authorities (see Eurosystem cash strategy) to keep the financial ecosystem balanced at the European level. As supported by the European Central Bank's latest survey (Zamora-Pérez et al., 2024), cash remains a key payment method for European citizens (52% at points of sale) and companies (88%), even if it has been on a slight downward trend in recent years. The most important reasons for this preference are related to security, reliability, and privacy. Digital payments are correlated to privacy concerns by the Europeans. The simple expansion of users in the financial

landscape will not increase the use of innovative financial products based on new technologies. What requires the involvement of the authorities in organizing financial and digital literacy programs and co-involvement of consumers in the ongoing changing process of their habits and preferences, becoming more and more familiar with the new digital products and their advantages, especially to be prepared for the issuing of central bank digital currencies.

Engaging additional individuals and firms in using financial services and products at this level of inclusivity in European countries is less important for developing innovative finance tools. However, it is relevant from the perspective of the "no one left behind" principle of sustainable development goals. The importance of payment preferences of European consumers represents one of the main supports of our study results. According to two recent studies published by European Central Bank (Zamora-Pérez et al., 2024) the individuals' preference for cash payments and the reticence in using digital technologies is widely known in the euro area, and this would be an expected behavior of newcomers in the European financial landscape also. This explains why more financially included people will not conduct automatically to an increase in the demand for innovative financial services and products. The inertia of payment habits is still present in the European financial ecosystem, which the financial authorities must further analyze, understand, and address. However, financial institutions should develop innovative and risk-sharing tools and methods to spur accountable usage and be better involved in users "financial education path, while governments and regulators should focus on new users" healthier and innovative financial behaviors. Furthermore, digital financial literacy should be integrated into both formal and informal education programs in partnership with various stakeholders to facilitate the acceptance and use of technology-driven financial services.

The study limitations refer to the sample of countries included in the analysis. In this sense, an approach of emerging countries, where *FINC* is at reduced levels, should be carried out. Moreover, using different indicators for the *FIN* variable could bring more light to the research literature. Another important objective for future research could be evaluating a feedback effect between *FIN* and *FINC*.

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