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FinTechs and Financial Literacy:

Assessing their Joint Impact on Financial Inclusion in the MENA Region

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FinTechs and financial literacy: Assessing their joint impact on financial inclusion in the MENA region

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Abstract

This study investigates how the interaction between FinTech adoption and financial literacy affects financial inclusion in MENA countries. While existing literature examines these factors separately, no empirical evidence explores their joint impact on financial inclusion, particularly in developing and emerging economies. Also addressing a major gap in the literature where both dimensions are rarely examined together using robust multidimensional measures, it is the first study to employ a financial inclusion index (FII by Sarma, 2008) as the dependent variable and to measure financial literacy using the innovative Financial Knowledge Index (FKI), which provides a composite and multidimensional assessment of financial literacy at the country level. The study employs robust econometric methods using annual data from 2004 to 2022 for 13 MENA countries, allowing for the estimation of both individual and interactive effects of FinTech adoption and financial literacy on financial inclusion. The results reveal that the separate impact of FinTech adoption and financial literacy on financial inclusion is negative; also, the interaction between the two variables exerts a negative and statistically significant effect. These results confirm that a higher level of financial literacy does not obligatorily promote the inclusive capacity of Fintechs. These findings may be due to some structural barriers, informal financial practices, or institutional quality that limit the financially literate people's capacity to translate digital skills into effective inclusion.

Keywords: Financial inclusion; FinTech; Financial literacy; MENA region; Panel data.

1. Introduction

Numerous empirical studies have examined the factors that promote financial inclusion (FI) and assessed its social and economic implications. This concept has gained significant attention in recent literature with the rise of financial technologies, also known as fintechs (FT), and the increasing emphasis on financial literacy.

On the one hand, FI is when individuals and businesses, especially those who are underserved or excluded from traditional banking institutions, have access to affordable and useful financial services and products that satisfy their requirements and are provided in an ethical and sustainable manner (Demirgüç-Kunt et al., 2022). It is now one of the most important indicators developed and disseminated by international authorities to reflect the level of financial development system.

On the other hand, over the past decade, FT has emerged as a revolution in the financial sector; it refers to the innovation in financial services made possible by technology that could lead to new procedures, business models, or products that have a substantial impact on financial markets, institutions, and the provision of financial services (Dimler et al., 2018; Glavanits, 2020). Providing innovative digital solutions such as mobile banking, peer-to-peer lending, digital wallets, and blockchain-based services has the potential to reach underserved people by avoiding the conventional banking infrastructure and reducing transaction costs.

The need to increase digital financial inclusion (DFI) has been emphasized by the Covid-19 pandemic through the use of digital technologies for the majority of financial transactions. Dadoukis et al., (2021) argued that financial market innovations and technological advancements can boost banks' resilience and performance, promoting financial stability. However, this quick and often unregulated democratization of access to digital financial services has been accompanied by new and sometimes poorly controlled risks. Thus, the increase in users without proper training has made digital escroqueries (unauthorized access to mobile accounts, identity theft fraud, etc.) easier. Therefore, this has led to instability and the emergence of distrust toward the fintech system, which could negate the benefits of FI; hence, the emergence of the notion of financial literacy (FL), which becomes essential to support this digital inclusion in order to promote responsible and secure use of FT, increase people's ability to assess the risks associated with digital financial products, lessen their vulnerability to fraud, and boost their trust in digital financial systems. The OECD[1] (2012) defines FL as a mix of knowledge, attitude, skill, and behavior required to make prudent financial decisions and

[1] Organisation de coopération et de développement économiques.

eventually attain individual financial well-being. Thus, according to the Global Fintech Index Report 2020, there is a 66% annual growth of financial services data connections, and 60% of the world's GDP will be digitalized in every industry.

To create a more resilient and inclusive financial sector and increase FI through fintechs, policymakers in numerous MENA countries are enacting financial reforms in reaction to several crises. This study contributes to the literature on the link between FT and FI while emphasizing the role of FL, addressing a major gap in the literature where both dimensions are rarely examined together using robust multidimensional measures. It is the first study to employ a financial inclusion index (FII) constructed following the methodology of Sarma (2008) as a dependent variable and to measure financial literacy using the innovative Financial Knowledge Index (FKI) developed by Oliver-Márquez et al. (2021), which provides a composite and multidimensional assessment of financial literacy at the country level. The study concerns 13 countries that are both oil-exporting and oil-importing parts of the MENA region.

2. Literature review

Financial inclusion is essential for economic development, poverty reduction, and improving the overall well-being of communities (Demirgüç-Kunt et al., 2018).

2.1.Impact of fintechs (FT) on financial inclusion (FI)

A wide range of theories have been introduced by researchers to explain the relationship between FT and FI. Davis in 1989 (Davis, 1989) introduced the Technology Acceptance Model (TAM) to explain individual adoption of information technologies via perceived ease and perceived usefulness of use that are the main factors influencing technology adoption. The author argued that the perceived ease is the perception that using FT services involves little effort, which is especially relevant in rural areas where digital literacy is lower, while the perceived usefulness indicates how much an individual believes utilizing FT services can improve financial activities, including credit availability, transactions, and savings. By including social impact, adding social influence, and moderating factors (such as age, gender, and experience), the Unified Theory of Acceptance and Usage of Technology (UTAUT) expands on TAM to understand user acceptance and usage of a technology (Venkatesh et al., 2003).

Based on its three main components, which are perceived behavioral control, subjective norms, and attitude, the theory of planned behavior (TPB) claims that the positive or negative opinion on the use of FT services mainly depends on the individual's attitude (Ajzen, 1991). In addition, several studies have investigated the factors improving FI (Ediagbonya & Tioluwani, 2023;

Anagreh et al., 2024; El Yamani & Betane, 2025). The use of mobile payments contributes significantly to driving FI, although it needs to be carefully considered.

Numerous researchers argued that FT innovations may aggravate social and digital inequality, despite the fact that they are often hailed as powerful enhancers of FI, especially through digital payments, mobile banking, and online lending. According to studies conducted by Ozili (2018) and Demirgüç-Kunt et al. (2022), FT reduces transaction costs, increases outreach, and enhances accessibility for the unbanked population, particularly in developing economies. Therefore, by bypassing traditional banking infrastructures, FT like mobile money platforms allow users to conduct transactions via mobile phones (Omarini, 2018). Additionally, according to Ediagbonya and Tioluwani's research (2023), FT can play a big part in driving FI in developing and emerging markets. But, in order to fully realize their potential, it is necessary to address challenges like education, infrastructure development, and regulatory support. However, Young and Young (2022) and Xiao et al., (2025) argued that FT can unintentionally exclude rural, low-income, or elderly populations lacking internet access, digital literacy, or trust in technology.

2.2.Role of financial literacy (FL) in financial inclusion (FI)

Hastings et al., (2013), in their study suggested that a higher level of FL can help make good financial decisions, which may encourage individuals to use formal financial services and enhance financial well-being. Miller et al., (2015) argued that FI is improved thanks to the programs for FL that enable users to effectively use financial tools. In addition, financially literate people are more likely to use financial products and adopt them safely, avoiding excessive debt and fraud. In this case, FL improves perceived usage and reduces perceived complexity of financial services. Grohmann and Menkhoff (2021) confirmed that FL enhances individuals' understanding of financial services and products (credit, savings, insurance), enabling them to engage in formal financial systems and decisions and make prudent financial decisions. Using both OLS[2] and instrumental variable (IV) regressions, the study conducted by Grohmann et al., (2018) investigates the relationship between FL and FI across various countries, finding that FL generally improves FI, but its interaction with access to sophisticated financial technologies can be negative in low-income environments. According to Morgan and Long (2020), the budgets are mostly created by financially literate people; this can avoid excessive debt and promote responsible usage of financial services, promoting sustainable inclusion.

[2] Ordinary Least Squares.

The study conducted by Hasan and Hoque (2021), using binary estimation, concluded that the promotion of FI via the access and the use of various financial services and products, particularly in rural areas in Bangladesh, is due to the rise of FL. Ozili (2025), in his research about the FL theory of FI, highlighted that despite already being financially included, financially illiterate people might not be able to fully maximize their welfare within the formal financial system. This is due to their low level or lack of FL, which prevents them from the optimal use of the available financial services.

Nevertheless, if financial transactions lack robust security, the improvement of the level of FL cannot automatically translate into safe FI (Chawla & Mokhtari, 2025), or behavioral barriers persist or strong structural, a low social capital, and technology access (Thomas et al., 2024).

According to the preceding, FL plays a crucial role in facilitating FI by encouraging responsible behavior, empowerment, and promoting informed participation. However, complementing factors, including focused financial infrastructure, policy design, and institutional quality, determine its impact. Without these, FL might not be sufficient to guarantee full FI and might even exacerbate already-existing inequalities.

2.3.Combined impact of fintechs (FT) and financial literacy (FL)

The current debate revolves around whether FT innovation can replace low FL (by promoting access) or if both are necessary together for sustainable inclusion. Several scholars (Lusardi & Mitchell, 2014; Jünger & Mietzner, 2020) have argued that FT and FL reinforce each other, technology provides access, and literacy ensures effective and safe usage. Moreover, by providing low-cost accounts and on-demand services, FT reduces entry barriers. Users with basic digital and FL are more likely to finish onboarding, keep active accounts, and use services for savings and transactions than let accounts sit inactive. Using a cross-sectional design with a sample of 218 individuals from different areas of China, Shen et al., (2018) suggested that improving FL of residents and popularizing internet usage can promote the use of digital financial services and achieve the goal of advancing FI. Additionally, the findings of the study performed by ur Rehman et al., (2023) supported a high positive correlation between banking access and FT use thanks to the moderating role of FL. An important component of the interaction between FT, banking access, and FI is the mediating role of FL. People with higher FL levels tend to gain more from technological improvements and banking services, which promote FI outcomes. Also, the results found by Amnas et al. (2024) reveal that FL serves as a significant mediator, indicating that FT promotes FI partly by enhancing users' digital financial capabilities. Similarly, perceived regulatory support moderates the FT–FL correlation, such that

the relationship is stronger when regulatory frameworks are viewed as supportive and trustworthy. The integrated moderated–mediated approach highlights that FT, FL, and regulatory assistance jointly reinforce FI outcomes. Which further justifies the necessity of the coexistence of both FT and FL to improve FI, as FT creates digital footprints (mobile money flows, transaction histories) that can be converted into insurance underwriting and alternative credit scoring. These products are more likely to be adopted by financially literate consumers who understand data use and consent, widening sustainable access to credit and risk-sharing (Ha & Nguyen, 2025). On the contrary, when FL is low, FT can produce superficial FI, with many people opening accounts but rarely making transactions (dormant accounts), failing to use credit productively, or misunderstanding fees, which increases the risk that FI indicators improve on paper but not in terms of well-being (World Bank, 2021; Kodongo, 2024). According to Mandić (2025), rapid FT expansion associated with low literacy creates consumer protection issues: users who are unable to spot risks are disproportionately harmed by phishing, predatory digital credit, fraud, and data privacy breaches; these harms are exacerbated by weak regulation. As a result, literacy reduces but does not eliminate systemic risks that need regulation and platform design fixes. Also, program design must actively target underserved subgroups because FT can widen inequality if literacy programs preferentially educate or reach urban or male users. Advantaged groups capture the productivity and credit benefits, while disadvantaged groups remain superficially included or excluded (Kodongo, 2024).

3. Methodology and analysis

This study aims to examine the effect of FT on FI with a particular emphasis on the moderating role of FL.

3.1.Variables and Measurements

The dependent variable, financial inclusion, is measured by the financial inclusion index (FII), which is calculated using the methodology introduced by Sarma (2008), which enables us to calculate a three-dimensional synthetic index of financial inclusion (FII) including three dimensions: banking penetration (access), availability of financial services, and the use of financial services.

The key explanatory variable: Based on the research of Demirgüç-Kunt et al., (2022), mobile phone users as a proportion of the total population is used to measure fintechs (FT).

The moderating variable, financial literacy (FL), measured by the novel Financial Knowledge Index (FKI) introduced by Oliver-Márquez et al. (2021), provides a composite and multidimensional measure of financial literacy at the country level. The FKI is built on four main dimensions, each represented by standardized indicators: Economic capacity to invest and

save, educational training (which is crucial to understanding financial issues), technology management skills (as a key factor motivating agents to participate in financial markets), and longevity play significant roles in this sub-index since longer life expectancy increases the probability of spending more time in retirement.

The control variables:

Income (INCM): Wage and salaried employees.

Internet users (NET): are individuals who have used the Internet in the last 3 months (from any location).

In light of this, we specify our model using the following equation:

$$FII_{it} = \beta_0 + \beta_1 FT_{it} + \beta_2 FL_{it} + \beta_3 (FT \times FL)_{it} + \beta_4 INCM_{it} + \beta_5 NET_{it} + \varepsilon_{it}$$

where FI is measured by the financial inclusion index (FII); mobile banking is used to measure financial technology (FT); financial literacy (FL) is proxied by the Financial Knowledge index; wage and salaried workers measure the income (INCM); and the Internet users (NET). Furthermore, the moderating effect of financial literacy is captured by the interaction term $FT \times FL$.

Note that the intercept and the parameters of the equation are indicated by β_0 and β_k (1, 2, ..., 5) respectively. The ε_{it} is the error term.

The empirical works on panel data from 13 different MENA countries[3], diversity of economic structures These countries range from oil-dependent economies (example: Qatar, Saudi Arabia, and UAE) to diversified economies (example: Egypt, Morocco, Tunisia, and Turkey). The objective is to capture the varying roles of FT and financial literacy in shaping financial inclusion across diverse economic contexts. During the period 2004-2022, explained by the availability of indicators for calculating the FII starting in 2004. Consequently, countries without complete data on FI indicators are excluded from the study to guarantee the validity and accuracy of our analysis.

3.2. Estimation approach

The empirical analysis of this study is conducted using the Robust Weighted Least Squares (RWLS) method because of its robustness when dealing with non-normally distributed data and outliers. Numerous considerations and an examination of the methods employed in previous studies lend credibility to this choice.

According to Huber and Ronchetti (1981), RWLS reduces the impact of outliers on the outcome. Parameter estimates may be skewed by outliers' excessive influence on OLS findings.

[3] Algeria; Egypt; Iran; Iraq; Jordan; Lebanon; Morocco; Oman; Qatar; Saudi Arabia; Tunisia; Turkey; United Arab Emirates.

To address this issue, RWLS attributes smaller weights to observations with higher residuals and larger weights to those with small residuals; that reduces their effect on the final estimates (Huber and Ronchetti, 1981; Rousseeuw and Leroy, 1987). Furthermore, Rousseeuw et al., (1986) argued that RWLS decreases the impact of outliers via preventing them from affecting parameter estimates, thereby improving robustness compared to the OLS method. This aspect further improves the robustness and reliability of our estimates, which justify the use of RWLS.

4. Results and discussion

This study aims to test the two main hypotheses that examine how FT impacts FI, with a particular emphasis on the moderating role of FL.

- H_1: Financial inclusion may be impacted by FinTechs, but financial literacy is a key factor that moderates this effect.
- H_2: Financial literacy has a moderating effect, but it depends on the economy's development level.

To deal with assumption violations, we conducted a robust regression method. The following results provide insight into the relationship between FT and FI with an emphasis on the moderating impact of FL.

4.1.Descriptive Analysis

The distribution of FI among MENA countries is slightly right-skewed and mildly leptokurtic, according to the positive skewness (0.99) and kurtosis (0.01), while the standard deviation of FII is 0.14, reflecting a moderate degree of variability in FI across countries. This means that the majority of MENA countries have FI levels that are lower than the regional average, while a small number of countries have significantly higher inclusion levels, which pull the distribution's tail to the right.

The positive skewness (0.99) indicates a longer right tail, suggesting that a few high-value observations (outliers) pull the distribution to the right. In the meantime, the near-zero kurtosis (0.01) suggests that the overall shape of the distribution is close to normal, with a typical peak around the mean. This combination implies moderate asymmetry without excessive tail thickness. The Jarque-Bera test rejects the null hypothesis of normality at the 1% significance level due to the skewness.

The FinTechs (FT) show a skewness value close to 0 (0.07) and a kurtosis value close to 3 (2.85), indicating that the distribution of FT is approximately symmetric and close to a normal distribution, suggesting no significant deviation from normality.

The skewness value close to 1 and the kurtosis value close to 0 indicate a moderately right-skewed distribution with light tails compared to the normal distribution. The Jarque-Bera test (p-value = 0.000) confirms the non-normality of the financial literacy (FL), income (INCM), and network (NET) distributions, leading to the rejection of the null hypothesis of normality of all these variables at the 1% significance level. The Jarque-Bera test (43.25) confirms the acceptance of the null hypothesis of a normal distribution.

Table 1. Descriptive Statistics

	FII	FT	FL	INCM	NET
Mean	0.28	102.67	0.16	75.99	48.99
Min	0.14	2.08	0.01	50.79	.90
Max	0.56	220.41	0.27	99.60	100
Std. Dev.	0.14	45.02	0.15	15.82	29.56
Skewness	0.99	0.07	1.01	0.89	0.94
Kurtosis	0.01	2.85	0.03	0.07	0.08
Jarque-Bera	13.30***	43.25	36.83***	37.25***	22.46***
Probability	0.00	0.19	0.00	0.00	0.00

Note: *** indicate a significant level at 1%.
Source: Author

The Robust Weighted Least Squares (RWLS) estimate method can be considered suitable given the non-normal distribution and potential heterogeneity resulting from outliers. The empirical results can be trusted since RWLS can successfully manage heteroscedasticity and non-normality and generate more reliable parameter estimates when outliers are present (Rousseeuw & Leroy, 1987).

4.2.Correlation Matrix Analysis

The links between the independent variables in this study are illustrated by the correlation matrix shown in Table 2.

The FT reveals a weak positive correlation with FL (0.08) and a moderate correlation with both INCM (0.58) and NET (0.58), which is consistent with the hypothesized positive relationship between FinTechs and financial literacy, income, and network. Furthermore, financial literacy shows a weak positive correlation with income (0.29) and network (0.21).

Regarding network, it exhibits a moderate positive correlation with income (0.43).

Table 2. Correlation analysis

	FT	FL	INCM	NET
FT	1			
FL	0.08* (0.07)	1		
INCM	0.58***	0.29***	1	

	(0.00)	(0.00)		
NET	0.68*** (0.00)	0.21*** (0.00)	0.43 (0.00)	1

Note: *, *** indicate a significant level at 10% and 1% respectively. (.) : Probalilities.
Source : Author

In conclusion, the correlation analysis highlights the complex relationship between FT, FL, and the control variable variables (INCM and NET), indicating a strong correlation between independent variables (multicollinearity). These findings support the need for an estimating method that considers this issue. RWLS can mitigate the effects of multicollinearity by assigning varying weights to observations. This method helps to provide more reliable coefficient estimates (Gujarati & Porter, 2009).

4.3.Regression Analyses

This section presents two distinct estimation results about how FT and FL affect FI in the MENA countries. FT and FL have different effects on FI, as Table 3 of the findings makes clear. Table 4 displays the results of the impact of the interaction between FT and FL (moderating effect) on FI in the studied countries.

The results of Table 3 show that FI is negatively impacted by FT and FL. Because it ignores the synergistic effect whereby FL increases the adoption of FT services, and exposure to FT further reinforces financial knowledge. Analyzing FT and FL separately may underestimate their true impact on FI. These results are consistent with those found by Lusardi and Mitchell (2014); the authors confirmed that FL is alarmingly low across populations, even in developed economies, and that deficits in basic financial knowledge negatively impact financial behaviors, including retirement planning, saving, and borrowing decisions. Also, Mandić (2025) identified the main risks related to the adoption of FT that can decrease the promotion of FI. These include low digital literacy, regulatory barriers, and socio-cultural challenges. The author argued that, without proper safeguards, FT adoption might increase exclusion, especially among populations that lack the trust or skills needed to adopt FT. On the other hand, FI is positively influenced by income (INCM) and network (NET).

Table 3. The effect of FinTechs and Financial Literacy on Financial Inclusion

Variables	FT	FL	INCM	NET	Cons
FII	-0.001* (-1.95)	-0.25*** (-5.35)	0.02*** (3.05)	0.003*** (7.52)	0.11*** (2.91)
F statistics	28.09***				
R-squared	0.3171				
Adj R-squared	0.3058				

Notes: FII, FT, FL, INCM, and NET denote financial inclusion index, finTechs, financial literacy, income, and network.
The t-statistics are in parentheses. * and *** indicate 10% and 1% significance level, respectively.
Source : Author' estimates

Table 4 shows the moderating role of FL in the effect of FT on FI. In this table the variable of interest is (FT×FL), indicating the interaction between financial literacy and FinTechs.

As a result, the model demonstrates an adjusted R^2 of 31.26%. This degree of explanatory power is accepted given the complex nature of financial inclusion, which is determined by a wide range of variables outside the model, such as macroeconomic conditions, cultural norms, institutional quality, informal financial practices, and regulatory environments (Sarma & Pais, 2011; Zins & Weill, 2016; Eldomiaty et al., 2020). Therefore, even while the model captures key factors like FT and FL, a significant portion of variation in FI remains attributable to unobserved or difficult-to-measure external variables, as is typical in empirical studies on FI. Additionally, the model's robustness is increased by the highly significant F statistics at the 1 percent level.

Table 4. FinTechs' impact on financial inclusion, with an emphasis on financial literacy's moderating role

Variables	FT	FL	FT × **FL**	INCM	NET	Cons
FII	-0.002 (-1.22)	-0.21 (0.15)	-0.003*** (-2.24)	0.02*** (2.90)	0.003*** (7.71)	0.09** (2.17)
F statistics	21.92***					
R-squared	0.3126					
Adj R-squared	0.2983					

Notes: The t-statistics are in parentheses. ** and *** indicate 5% and 1% significance level, respectively.
Source : Author' estimates

Table 4 above demonstrates that neither FinTechs nor financial literacy alone have a significant effect on FI in the MENA countries. Their interaction (FT×FL), however, reveals a negative coefficient (-0.003), suggesting that the impact of FT adoption on FI is not necessarily improved by greater FL. This could be the consequence of institutional imperfections, limitations on digital access, or disparities between user expertise and FinTech products (Lusardi & Mitchell, 2014; Grohmann et al., 2018).

Results shown in Table 4 are in line with those in Table 3 for the control variables. Income (INCM) has a notable impact on FI; table 4 shows that the INCM coefficient is positive and significant (0.02). indicating that increased FI in the MENA region is associated with higher income levels. Since higher income increases the capacity to save, invest, and interact with formal financial institutions. Also, the coefficient of the internet users (NET) is positive and

significant (0.003), which means that higher internet penetration contributes to greater FI in the MENA region.

4.4.Discussion

This section addresses the findings of our study on the impact of fintechs on financial inclusion, with an emphasis on the moderating role of financial literacy in a panel of 13 MENA economies. We provide a clear and succinct interpretation of the main findings in light of the body of existing research.

The estimation results indicate that neither FT nor FL alone has a significant impact on financial inclusion in the MENA region. These findings are supported by Ozili (2018), who highlighted that infrastructure and regulatory barriers prevent digital financial services from automatically turning into inclusion. The author also argued that new risks can be generated because of the rapid expansion of digital financial services, such as inadequate regulatory oversight, cybersecurity threats, and operational vulnerabilities, which may compromise financial stability if not improperly managed. Even though digital finance is a crucial factor for inclusion, authorities must fortify regulatory frameworks and risk-management procedures to guarantee that the expansion of digital financial services leads to a stable financial system. Lusardi and Mitchell (2014) also noted that FL alone does not guarantee access to formal financial services without complementary institutional and technological support. However, the coefficient associated with the interaction (FT × FL) is negative (-0.003) and significant, suggesting that higher FL does not automatically promote the effect of FT adoption. These findings are consistent with those found by Grohmann et al. (2018) supported that FL generally improves FI, but its interaction with access to sophisticated financial technologies can be negative in low-income environments. These could be due to a mismatch between users' financial knowledge and available FinTech services because of institutional and structural barriers like weak regulation, limited digital infrastructure, or low trust in digital financial systems, which leads financially literate people to prefer traditional banking channels. This suggests that FT × FL interaction increases the exclusion, rather than reducing it. Lusardi and Mitchell (2014) confirmed that FL is very low across populations, even in developed economies, and that deficits in basic financial knowledge negatively impact financial behaviors, including retirement planning, saving, and borrowing decisions.

Regarding the impact of per capita income (INCM), the findings show that it has a positive and significant effect (0.02), meaning that higher income encourages access to financial services. The result is consistent with previous studies that argued that FI is more strongly and consistently impacted by income than by FL (Adetunji & David-West, 2019). The result

suggests that people with better literacy but low income are nonetheless excluded because of accessibility and affordability issues.

Additionally, the coefficient of internet users (NET) is positive and significant (0.003), highlighting the crucial role of internet penetration in promoting FI via FT development. The finding suggests that digital connectivity facilitates access to financial services, probably through the use of FT like online banking and mobile money, thereby improving people's and businesses' capacity to engage in the formal financial system (Evans, 2018; Ozili, 2018; Zhang et al., 2023).

In summary, the results demonstrate the complex and context-dependent nature of FI in the MENA region. Neither FT adoption nor FL alone significantly affects inclusion, but their combination has a negative effect, suggesting that higher FL does not automatically increase the advantages of FT. Indicating that structural, institutional quality, and infrastructural factors play an important role in enabling financial inclusion in the MENA region, and that promoting FT and FL must be accompanied by supportive institutional frameworks and accessible digital infrastructure.

5. Conclusion and policy implications

The main purpose of this study is to examine the impact of FT adoption, fl, and their interaction on FI in 13 MENA countries. The findings show that neither FT nor FL alone significantly affects FI, while their interaction exhibits a negative effect, suggesting that higher FL does not automatically enhance the benefits of FT adoption. At the same time, income per capita (INCM) and internet penetration (NET) positively contribute to FI, highlighting the importance of economic capacity and internet penetration in improving FI. These findings underscore that FI is context-dependent and shaped by structural, institutional quality, and infrastructural factors.

Based on these results, policymakers in the MENA region should consider several policy implications. First, to develop FT adoption, it is necessary to encourage transparency and trust in digital financial services. Second, integrate access to appropriate financial products with financial education programs to ensure that literacy is translated into actual usage. Third, improve governance, regulatory frameworks, and consumer protection to ensure that FT solutions and FL efforts effectively translate into inclusion. Fourd, invest in digital infrastructure to reduce the digital gap between urban and rural areas and provide FT services that are user-friendly, easily accessible, and customized to local needs, especially for those with different levels of FL. Fifth, recognize that the MENA region is heterogeneous; policies should

adapt to country-specific economic, institutional, and technological contexts to optimize the impact of FT and FL initiatives.

Despite these valuable findings, this study has some limitations. First, the conclusions are restricted to the MENA economies, which can reduce their generalization to other regions. Second, regulatory and institutional differences across the region complicate generalization. Third, data quality differs significantly among MENA countries, and our proxies for FI, FT adoption, and FL may contain measurement error; therefore, results should be interpreted as associations rather than conclusive causal estimates. Lastly, the model does not account for omitted variables that may have an impact on FI, such as sector-specific legislation, informal financial practices, or cultural perspectives.

Future research could address some of these limitations by employing richer and more granular datasets, particularly those combining household surveys with administrative or transaction-level FT records to reduce measurement error. In addition, studies could examine country-specific factors, such as regulatory frameworks, institutional quality, and digital infrastructure, to better understand the heterogeneity in FI across MENA countries. To provide a more comprehensive understanding of the mechanisms promoting inclusion, research might also investigate the impact of nonlinear effects of FT and FL.

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