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Financial Technology (FINTECH) and Financial Inclusion: Micro-Level Evidence from Ethiopia Using 2018/2019 Ethiopian Socio-economic Survey Data

Meskerem Bogale Gebre[1], Abbi M. Kedir[2], and Alem Hagos[3]

KEY WORDS
FINTECH, Financial Inclusion, Iddir, Multivariate Probit , Ethiopia

ABSTRACT

As the banking system evolves toward a cashless economy, digital transactions are rapidly increasing. In today's financial landscape, cashless systems are no longer just a convenience but a necessity. As a result Financial Technology (FINTECH) is adopted to help companies, business owners and consumers better manage their financial operations. This paper investigates whether or not FINTECH contributes to financial inclusion at the household level in Ethiopia. The research analyzed 2018/19Ethiopian Socio Economic Survey (ESS) data using a multivariate Probit model. A new evidence is presented to show that FINTECH or mobile payments have a significant effect on Iddir which is an informal finance mechanisms. Additionally, it is disclosed that FINTECH significantly enhances formal savings and insurance uptake, though it shows no statistically significant effect on household account ownership or borrowing behavior. These findings suggest that policy makers should leverage the positive influence that FINTECH has on informal financial systems. That could be made possible by integrating digital payment solutions into platforms like Iddir. Expanding access to FINTECH services through promotion of savings and insurance among underserved populations can also advance financial inclusion. FINTECH does not appear to influence account ownership or household borrowing. Therefore, policy efforts should address structural barriers that are beyond access. Strengthening consumer protection measures could also further enhance inclusive access to financial services.

[1] PhD Candidate in Finance at Addis Ababa University, Addis Ababa, Ethiopia; email: meskibg1@gmail.com.
[2]A Director of Research, African Economic Research Consortium, Nairobi, Kenya. E-mail: abbi.kedir@aercafrica.org.
[3]Assistant professor at Addis Ababa University, Addis Ababa, Ethiopia; email: alem.hagos@aau.edu.et.

1. Introduction

Financial technology (FINTECH) has fundamentally reshaped the global financial landscape through four major phases of transformation (Arner et al., 2019; Leong & Sung, 2018). The first phase, FINTECH 1.0 (1866–1967), saw the advent of foundational technologies such as the telegraph and credit cards, though financial systems remained largely analogue. FINTECH 2.0 (1968–2008) marked a period of bank-led digitalization, with innovations such as ATMs, NASDAQ's electronic trading platform, and SWIFT's cross-border payment systems (Arner et al., 2019). Following the 2008 global financial crisis, FINTECH 3.0 (2008–2014) emerged and it was characterized by the entry of non-bank innovators leveraging mobile technology platforms like Apple Pay. During FINTECH 3.5 (2014–2018), the momentum shifted to emerging markets. In Kenya, for example, mobile money service M-Pesa processed transactions valued at over 43% of the country's GDP(World Bank, 2014). Today, FINTECH 4.0 (2018–present) is driven by block chain, artificial intelligence, and open banking, with technology firms at the forefront and regulators focusing on digital identity, cyber security, and ethical artificial intelligence (Arner et al., 2020).

The convergence of finance and technology is not new. Today's FINTECH ecosystem is, however, marked by an unprecedented influx of start-ups and non-traditional players. Tech and e-commerce companies which have disrupted and fragmented the traditional financial services market are included in this group (Schueffel, 2016). FINTECH has proven capable of lowering costs, increasing transaction speed, and expanding access to tailored financial services. Over the past decade, it has played a key role in expanding financial inclusion, enabling 1.2 billion adults to access financial services and reducing the global unbanked population by 35%. It was largely due to mobile money adoption (Demirgüç-Kunt et al., 2018). Nevertheless, 1.7 billion adults remain unbanked. That shows the continued relevance of FINTECH in addressing access gaps (World Bank, 2018).

Financial inclusion has become a global development priority since the early 2000s, particularly following the 2010 G20 Summit in Seoul, where it was formally integrated into international policy agendas. Empirical evidence has linked financial access to poverty alleviation, economic resilience, and inclusive growth (Beck et al., 2007; Bruhn & Love, 2014). Financial inclusion encompasses access to a range of services, that include savings, credit, insurance, pensions, and remittances offered by both banking and non-banking institutions. It empowers households and businesses to manage daily transactions, invest in education or health, absorb financial shocks, and plan for long-term goals (Demirgüç-Kunt et al., 2018) . Mobile phone penetration has emerged as a strong predictor of financial inclusion. That is because households with mobile money accounts are more likely to receive remittances, save more, and obtain bank credit (Jack & Suri, 2011). FINTECH is therefore widely recognized as a key enabler of inclusive finance and a potential equalizer in the global financial system (Sahay et al., 2020).

Despite these global advancements, financial inclusion in Africa remains low and there are notable disparities across countries (Demirgüç-Kunt et al., 2018). Ethiopia, in particular, lags behind its neighbors. According to the World Bank's Global Findex data, the share of adults in Ethiopia with a bank account rose from 22% in 2014 to 35% in 2017—an improvement, but still below Kenya's 82% and Rwanda's 50% (World Bank, 2018). In Ethiopia, 26% of adults are reported to save at a financial institution. Only 11% borrowed formally, however. Informal financial mechanisms like *Iddir* remain the dominant means of managing financial needs (Hoddinott et al., 2005).

Several structural and socio-economic barriers continue to hinder financial inclusion in Ethiopia. These include limited geographic coverage of financial institutions, a small number of commercial banks, lack of disposable income, and weak trust in formal financial institutions (Demirgüç-Kunt et al., 2018). The digital divide further exacerbates these challenges. While mobile phone ownership is high with more than 45 million mobile subscribers and 17 million smart phone users, adoption of digital financial services remains limited (Central Statistical Agency, 2016). For instance, in 2017, only 0.3% of adults held mobile money accounts, and 99% of utility bill payments were still made in cash (World Bank, 2018). In comparison, the regional average for mobile money account ownership was 43%, and only 12% of Kenyans paid utility bills in cash.

Recent reforms, however, have begun to unlock new opportunities. The Ethiopian government launched the Digital Ethiopia 2025 strategy and introduced regulatory changes through the National Bank of Ethiopia. This strategy allows non-bank entities to offer mobile money services (National Bank of Ethiopia 2017) . Local companies like M-Birr started providing mobile-based payments, transfers, and

wallet services (GSMA, 2019). Additionally, the National Financial Inclusion Strategy (NFIS), introduced in 2017, set targets to increase account ownership to 60% and electronic payment usage to 40% by 2020 (National Bank of Ethiopia 2017) . Despite these efforts, Ethiopia still faces significant challenges in outreach and infrastructure. On average, a bank branch serves nearly 17,000 people, and 35% of all branches are located in the capital, Addis Ababa (World Bank, 2018).

Importantly, most studies of financial inclusion focus on supply-side factors, such as availability of financial services. This study, however, emphasizes the demand side. Therefore, it investigates how households in Ethiopia use mobile payments to save, invest, make payments, borrow, and manage risk. It also explores how FINTECH affects both formal and informal financial systems by focusing on traditional institutions like *Iddir* (Hoddinott et al., 2005). While FINTECH has been shown to increase savings and insurance uptake (Batista & Vicente, 2020; Suri & Jack, 2016), its impact on account ownership and borrowing remains limited. This highlights the need for a broader strategy that addresses deeper structural barriers through enhancement of digital literacy, and fostering trust in digital finance (Ozili, 2022).

To fully realize the potential of FINTECH in promoting financial inclusion, Ethiopia needs to integrate digital solutions with informal finance systems. It also needs to support partnerships between FINTECH providers and microfinance institutions, and invest in consumer protection and financial education (Ozili, 2022; World Bank, 2018). As FINTECH continues to evolve, its ability to combine innovation with robust regulation will be critical to achieving inclusive and sustainable growth (Arner et al., 2020; Zetzsche et al., 2020).

There are also significant regional differences in FINTECH-supported financial inclusion within Ethiopia. Cities like Addis Ababa and Dire Dawa have strong mobile- money utilization. The Somali, Gambela, Amhara, and much of Oromia however, significantly trail behind. The region-level account ownership rate is as low as 6% compared to the 75% for Addis Ababa (National Bank of Ethiopia, 2024). These disparities are brought about by limited digital infrastructure, poor financial literacy, and utilization of informal financial systems in rural areas. In response to this, the National Financial Inclusion Strategy II (2021–2025) established regional task forces and consultation forums in Gambela, Somali, Oromia, and Dire Dawa to agent outlets and rendering FINTECH interventions responsive to underprivileged communities (National Bank of Ethiopia, 2024) . As progress is achieved, bridging these gaps requires coordinated efforts in digital infrastructure, literacy programs, and region-specific FINTECH environment (Afircanenda, 2024).

In light of this context, the study seeks to address a significant empirical gap. While most previous works have focused on supply-side factors for e.g., bank outreach, regulatory reforms, or networks coverage, this study shifts the focus towards demand-side behavior. It specifically investigates how Ethiopian households use mobile payments for saving, investing, borrowing, and insurance. It also looked into how digital finance interacts with informal institutions like Iddir. This is a timely and policy-relevant strategy. For example, early evidence from the Ethiopian Socioeconomic Survey (ESS4, 2018/19) suggests that households who utilize mobile money are more likely to have reported insurance and savings coverage. Aggregate take-up is still low. Understanding these behavioral dynamics will be important to design interventions that move beyond infrastructure. Such interventions include addressing resistance to change, trust, and leveraging community-based platforms for digital financial services.

Generally, this study fills in three important gaps in FINTECH and financial inclusion literature:

1. The limited empirical evidence of FINTECH's effect on various aspects of financial inclusion in Ethiopia (saving, credit, account holding and insurance)
2. The yet-to-be-tested connection between FINTECH and informal finance institutions like *Iddir*.
3. The lack of micro-level-evidence on household-level behavior toward digital financial products in a low-inclusion environment.

Using new empirical evidence of Ethiopian Socioeconomic Survey wave four data (ESS4), the present study offers valuable contributions to the role of FINTECH in pursuing inclusive growth by enhancing access to both formal and informal finance. The remainder of this paper follows this structure. Section 2 is a literature review covering the theoretical framework, empirical studies, and conceptual framework on which analysis is founded. Section 3 discusses

the sources of data and introduces the research methodology employed for the study. Section 4 discusses and displays the study findings. Section 5 sums up the study by identifying significant policy implications. Finally, section 6 discusses the study limitations and proposes areas for future study.

2. Review of Related Literature

2.1 Theoretical Framework

The Diffusion of Innovation (DOI) Theory, developed by Rogers in 1962, constitutes a solid theoretical foundation for understanding the influence of financial technology (FINTECH) on financial inclusion. The theory explains how new ideas and technologies spread among a population over time. It emphasizes the roles played by communication channels, social systems, and perceived benefits in adoption. In the Ethiopian context, FINTECH innovations such as mobile money services, digital savings products, and micro-insurance products represent financial innovations that must diffuse across various socioeconomic and geographical segments (GSMA, 2019). DOI assumes that early adopters influence others in their communities (Rogers, 2003). For instance, mobile-based financial services such as M-Birr and Hello Cash can improve account ownership and savings behavior by reducing physical and administrative barriers (GSMA, 2019). Similarly, digital credit offerings can improve access to borrowing through alternative credit scoring and collateral-free aspects. Mobile–enabled micro–insurance products, however, allow individuals to manage risks in a convenient and affordable way. The adoption, on the other hand, tends to slow among low-income and rural communities due to law awareness, trust, and digital literacy challenges. DOI factors that lie at the heart of late adopter and laggard obstacles. As such, the application of DOI theory explains the asymmetric FINTECH adoption and provides an insight into the demand-side determination of financial inclusion results (Ozili, 2022; World Bank, 2018). By analyzing behavior at the household level, this study takes advantage of the DOI model in understanding how FINTECH diffusion affects formal financial participation in

in four primary dimensions of inclusion: account ownership, savings, credit, and insurance.

2.2 Empirical Literature

Research consistently highlights FINTECH as a key driver of financial inclusion(Gosavi, 2018; Jack & Suri, 2014; Tchamyou et al., 2019). A strong correlation exists between mobile phone penetration and financial inclusion both across and within countries (Andrianaivo & Kpodar, 2012). Mobile money usage, in particular, has been positively associated with greater financial access for households and firms. Households with mobile money accounts are more likely to be banked, receive and send remittances more frequently, and accumulate higher savings (Jack & Suri, 2014; Morawczynski & Pickens, 2009; Ouma et al., 2017). Mobile money also promotes financial inclusion among small and medium-sized enterprises (SMEs) by improving their access to bank credit(Gosavi, 2018). In a study of 25 African countries, (Chinoda & Mashamba, 2021) found that FINTECH significantly contributes to financial inclusion, especially in terms of bank account ownership and the expansion of bank branch networks.

Mobile payments generally fall into two broad categories: daily transactions and payments for bills or credit obligations(Lu, 2019). By enabling faster, more efficient payment platforms, FINTECH reduces transaction costs and enhances access to financial services for underserved populations, including low-income groups, rural communities, and the unbanked (Kedir & Kouame, 2022). As such, FINTECH plays a transformative role in expanding access to formal finance, despite facing persistent challenges such as the digital divide(Odei-Appiah et al., 2022).

The literature on financial inclusion distinguishes between access to and usage of both formal and informal financial services. Formal services are offered by institutions such as banks, insurance companies, microfinance institutions, cooperatives, post offices, and money transfer operators. Financial inclusion is a multidimensional concept. It encompasses the ability of individuals and firms to save, borrow, obtain credit, purchase insurance, and access various payment systems, including digital platforms (Geraldes et al., 2022; Kabakova & Plaksenkov, 2018; Zins & Weill, 2016). In essence, financial inclusion means ensuring that individuals and businesses can access useful, affordable financial products, such as savings, credit, payments, and insurance, delivered responsibly and sustainably. Full financial inclusion also implies providing customers with the education and support needed to make informed financial decisions (Aduda & Kalunda,

2012).The following chart indicates the scope of financial inclusion.

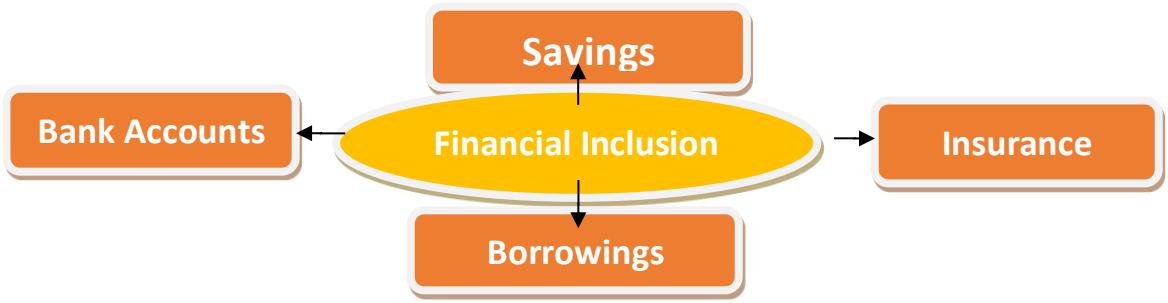

Fig 1. Scope of Financial Inclusion
Source: Adopted from (Aduda & Kalunda, 2012)

Using a critical approach to the above literature, several important research implications can be highlighted. First, the relationship between FINTECH and financial inclusion is likely to vary depending on the specific financial service in question-such as formal savings, borrowing, insurance, or bank account ownership. This highlights the importance of incorporating diverse financial inclusion indicators into econometric models to capture the nuanced impacts of FINTECH across different financial activities. Second, regional disparities in socioeconomic and demographic characteristics may influence how FINTECH affects financial inclusion. Therefore, analyzing FINTECH's role at the national level is essential to account for these potential variations. This study contributes to the literature by exploring the FINTECH–financial inclusion link within Ethiopia, considering all nine regional states and two city administrations. In doing so, it provides a more granular understanding of how FINTECH interacts with financial inclusion across different socioeconomic contexts.

Based on the above tangible empirical facts that reflect a positive and strong relationship between FINTECH and financial inclusion, the present study proposes the following four hypothesis to examine the mechanisms through which FINTECH promotes inclusive growth via formal and informal channels.

H1: There is a significant and positive relationship between FINTECH and Bank Account Ownership

H2: There is a significant and positive relationship between FINTECH and Formal Savings

H3: There is a significant and positive relationship between FINTECH and Formal Borrowings

H4: There is a significant and positive relationship between FINTECH and Formal Insurance

2.3 Conceptual Framework

The rapid evolution of Financial Technology (FINTECH) has extensively reshaped the financial inclusion phenomenon, particularly among emerging economies, FINTECH innovations ranging from mobile money services to digital insurance firms and credit, have emerged as powerful tools for enhancing access to formal financial services (Demirgüç-Kunt et al., 2018; Ozili, 2018). This theoretical framework for enhancing access to formal financial services This theoretical framework examines the avenues through which FINTECH affects significant dimensions of financial inclusion, including bank account holding, formal saving, formal borrowing, and formal insurance (Zins & Weill, 2016). By lowering transaction costs, convenience, geographical, and bureaucratic barriers, FINTECH enhances individuals' ability to access use, and derive benefits from formal financial services.

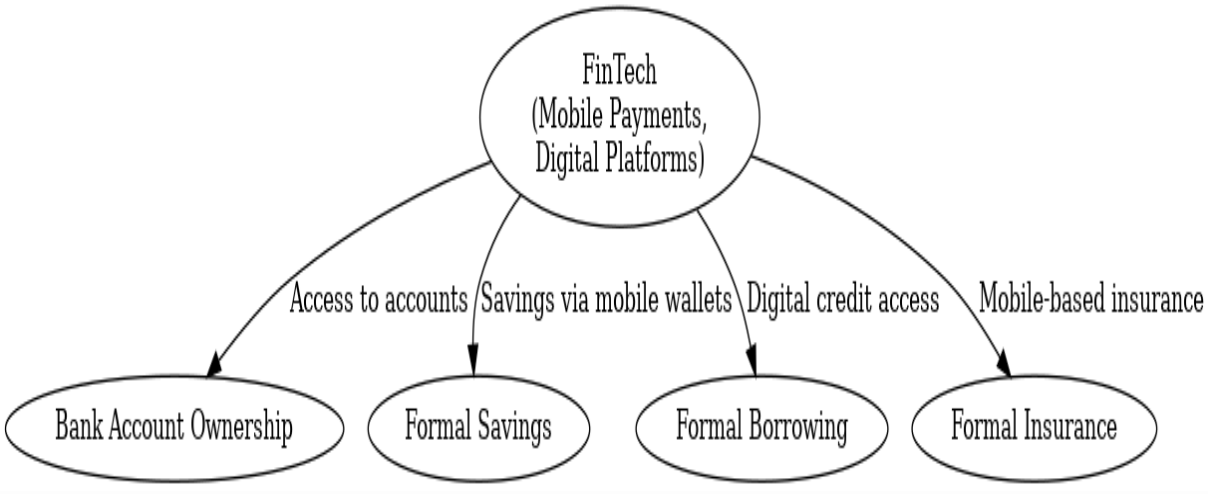

Fig. 2 Conceptual Model

Source: Author's own elaboration based on literature review, including works by (Demirgüç-Kunt et al., 2018; Ozili, 2018; Zins & Weill, 2016).

Conceptual model illustrates how FINTECH, through using digital platforms and mobile payment, achieves financial inclusion through having a favorable influence on formal insurance, formal borrowing, savings in a formal setting, and bank account ownership. FINTECH reduces the distance, cost, and documentation barrier, enhancing access to formal financial services, especially among underserved populations. Empirically, the relationship can be tested with a multivariate probit model, capturing the interdependencies of household financial decisions. Empirical studies such as (Demirgüç-Kunt et al., 2018; Ozili, 2018; Suri & Jack, 2016) substantiate these relationships by proving how digital finance enhances access, usage, and financial resilience.

3. Data and Methodology

3.1 Data Sources

To achieve the objective of the study, the data was obtained from the 2018/ 2019 Ethiopian Socio-Economic Survey wave4 (ESS4) (https://microdata.worldbank.org/index.php/ catalog /3823). The 2018/19 Ethiopian Socio-Economic Survey data contains detailed information on demographic and socio-economic characteristics of all surveyed households, including information on access to and use of formal, informal and mobile money/digital financial services. The data covers all economic sectors. It is nationally representative household survey conducted by the Central Statistics Agency (CSA) of Ethiopia and the World Bank as part of the Living Standards Measurement Study. By capturing household-level and individual-level information across rural and urban areas, the survey allows for disaggregated analysis by region, gender, income level, and other socio-demographic variables. ESS4 is conducted in 565 EAs (Enumeration Areas) of which 316 are rural and 219 are urban. ESS4 planned to interview 7,527 households from 565 enumeration areas (EAs) (Rural 316 EAs and Urban 249 EAs). Households that total 6770 from 535 EAs participated in the interview for both the agriculture and household modules. Because of security related reasons the household module was not implemented in 30 EAs.

3.2 Data Sampling and Cleaning

A random sample of 4,498 of household heads was included (67%) in our study after managing missing values. Missing values were treated using mean imputation (for the continuous variable distance to the nearest financial institution) and mode imputation (for a binary variable education). The total imputation rate is less than 5% which is acceptable in most research writings. According to (Dong & Peng, 2013; Schafer, 1999), when the proportion of missing data is below 5%, the bias introduced by imputation is typically negligible, and simple imputation methods can be used without significantly compromising data integrity.

3.3 Variable Descriptions and Summary Statistics

Table 1 provides variable descriptions and summary data for the variables utilized in this investigation. The dependent variable is financial inclusion measured by four indicators namely bank account ownership, formal savings, formal borrowings, and formal insurance. The primary variable of interest or our Independent variable is FINTECH adoption, as assessed by mobile payments for financial transactions. The control variables include demographic and socioeconomic factors and we specify a multivariable probit model to capture their effect on FINTECH adoption. The variables descriptions are given below in Table 1 while the summary statistics are presented in Table 2.

Table 1: Variables Descriptions

S.N	Variable Name	Definition	Category	Measurement
1	Formal Insurance (INSU)	Using formal insurance product	Dependent	=1 if the household head uses formal insurance , and 0 otherwise
2	Formal Saving (SAV)	Saving habit in formal Institution	Dependent	= 1 if the household head is saving in any way, and 0 otherwise
3	Formal Borrowing (BORW)	Borrowing from the formal institutions	Dependent	= 1 if the household head borrowed at least 150 birr , and 0 otherwise
4	Formal Bank Account Ownership (BAC)	Opening an account at bank	Dependent	=1 if the household head opened an account at formal financial institution , and 0 otherwise
5	Informal Insurance (*Iddir*)	Participation in traditional community – based insurance system	Control	=1 if the household head is an *IDDIR* member, and0 otherwise
6	FINTECH	Use of mobile phones to access digital financial services such as paying bills	Independent	=1 if the household uses mobile phone to pay bills; and 0 otherwise
7	Financial Literacy (FLT)	Knowledge and understating of financial services	Control	=1 if the household knows how to open a bank account; and 0 otherwise
8	Urban/ rural	The geographic location where the household resides, either urban or rural	Control	=1 if the household lives in urban area; and0 if the household lives in rural area
9	Household members (HHS)	The total number of individuals living in the household	Control	Number of people living in the household or household size
10	Gender (GDR)	Gender of the household head	Control	=1 if the individual in the household is male =0 if the individual in the household is female
11	Marital status (MART)	Whether the household head is married or not	Control	=1 if the household head is married =0 otherwise (single, divorced, widowed, separated)
12	Age (AG)	The age of the household head	Control	The age of the household head between 17 to 99
13	Education (EDU)	Whether the individual in the household has some education level	Control	=1 if the household has attended any school =0 if otherwise (no schooling at all)
14	Distance (DIST)	The distance between the living area of the household and the financial institution	Control	Distance in kilometers
15	Financial Capability (FINCAP)	Household's ability to manage financial matters like borrowings	Control	=1 if the household try to borrow & was turned down in the last 12 months; and0 otherwise
16	Religion (RLG)	Religion of the household head	Control	= 1 if the household is Christians and others = 0 if the head is a Muslim

Source: Ethiopian Socio-economic Survey 2018/2019

Table 2: Summary Statistics

Variables	Obs	Mean	Std. Dev.	Min	Max
Bank Account Ownership	4498	.618	.486	0	1
Formal Saving	4498	.531	.499	0	1
Formal Borrowing	4498	.116	.321	0	1
Formal Insurance	4498	.062	.242	0	1
FINTECH (i.e. mobile payments)	4498	.109	.312	0	1
Household Size	4498	4.191	2.28	1	19
Distance to the nearest Financial Institution	4498	17.219	99.702	0	6000
Marital Status	4498	.688	.464	0	1
Financial Literacy	4498	.691	.462	0	1
Gender	4498	.713	.453	0	1
Urban/ Rural	4498	.295	.456	0	1
Iddir Membership	4498	.442	.497	0	1
Age	4498	40.331	14.15	17	99
Religion	4498	.659	.474	0	1
Financial Capability	4498	.414	.493	0	1
Education	4498	.703	.457	0	1

Source: Authors' Computations using Ethiopian Scio -economic survey data 2018/2019

The dataset comprises 4,498 observations and includes a range of socio-economic and financial inclusion variables. Approximately 62% of respondents own a bank account, while 53.1% report formal savings and 11.6% formal borrowing—indicating higher engagement in saving than borrowing. Formal insurance coverage remains low at just 6.2%. Use of FINTECH, measured by mobile phone bill payments, is also limited, with only 10.9% of individuals using this service. The average household size is 4.19, ranging from 1 to 19 members. Access to financial institutions varies significantly, with an average distance of 17.2 km and a maximum of 6,000 km. Marital status and financial literacy have mean values of 0.688 and 0.068, respectively, while 71.3% of respondents are male and 29.5% reside in urban areas. Informal insurance (*Iddir*) is common, with 44.2% participation. The average age is 40.3 years, ranging from 17 to 99, and 65.9% identify with a religion. Additionally, 41.4% report being financially capable of borrowing from formal institutions, and 70.3% has received some level of education.

3.4 Econometric Model

To examine the effect of FINTECH use on financial inclusion, we estimate a Multivariate Probit (MVProbit) model where the dependent variables are binary indicators for four financial inclusion outcomes:

$$FIji = \alpha j + \beta j\ FINTECHi + \gamma jXi + \delta jD_{j,i} + \epsilon ji \ ; \ j=1,2,3,4 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (1)$$

Where:

- FIji is a latent variable indicating household i's likelihood of financial inclusion in dimension j
  - FI1: Bank account ownership
  - FI2: Formal saving
  - FI3: Formal borrowing
  - FI4: Formal insurance
- FINTECHi is a dummy for mobile phone payment
- Xi is a vector of household controls (age, education, gender , household size, etc)
- $D_{j,i}$ is the regional dummy variable for a household head $_i$ and region J.
- ϵji are jointly normally distributed error terms

The observed outcome FIji=1 if Fiji >0 , and 0 otherwise.

The model is estimated using maximum simulated likelihood (MSL) with the Geweke-Hajivassiliou-Keane (GHK) simulator**,** a well-established method for approximating high-dimensional multivariate normal probabilities (Geweke, 1991; Hajivassiliou et al., 1996; Keane, 994). The likelihood function involves integrals over correlated latent variables that lack closed-form solutions, necessitating simulation-based approximations.

4 Results and Discussions

4.1 Diagnostic test result

The multivariate probit (MVProbit) model was estimated using a sample of 4,497 observations to estimate four correlated binary outcomes: bank account ownership, formal saving, formal borrowing, and formal insurance. The model fitted reasonably well, as evidenced by a log-likelihood value of -6590.31 and a highly significant Wald chi-square test statistic of 2327.06 (88 degrees of freedom, $p < 0.001$), which significantly rejects the null hypothesis that all the coefficients are collectively zero. Importantly, the model corrects for correlations between the four equations' error terms, given the interdependence of these financial inclusion measures. There were strong positive correlations between bank account ownership and formal savings ($\rho = 0.661$, $p < 0.01$), bank account ownership and formal borrowings ($\rho = 0.092$, $p < 0.01$), and bank account ownership and formal insurance ($\rho = 0.077$, $p < 0.1$), indicating that the missing factors influencing one outcome are associated with others. Saving and borrowing ($\rho = 0.021$, $p > 0.05$) and borrowing and insurance ($\rho = -0.010$, $p > 0.05$) correlation were not significant. Likelihood ratio tests also determined significance of the above correlations for using joint model approach. Standard errors given are standard, as standard for maximum likelihood estimation of the MVProbit model. All these diagnostics are aimed at collectively confirming the relevance and reliability of the MVProbit model in quantifying the interlinked complexities of different dimensions of formal financial inclusion.

To assess the possible multi-collinearity among explanatory variables, a Variance Inflation Factor (VIF) diagnostic test was undertaken. From the output, it is evident that most of the variables provide VIF estimates far from the critical value of 10, with the estimates varying from 1.01 for FINTECH to a record high of 9.64 for the gender variable. Some of the local dummy variables have comparatively higher VIFs, such as Addis Ababa (8.59) and Diredawa (5.75), but those are also below acceptable values. The mean VIF for all the regressors is 3.15, which further supports the suggestion that no serious multicollinearity exists in the model. Thus, the test and evidence prove that multicollinearity is not a matter of concern in the model, and the estimated coefficients are reliable and unbiased.

4.2 Estimation Results

The multivariate probit regression results in Table 5 provide strong evidence on the role of FINTECH and other factors in shaping financial inclusion across Ethiopia. Nationally, FINTECH has a significant positive impact on both formal saving and formal insurance uptake. Specifically, it increases the likelihood of formal saving ($\beta = 0.192$, $p < 0.01$) and insurance usage ($\beta = 0.200$, $p < 0.05$), indicating its potential to enhance access to these services. However, FINTECH's influence on bank account ownership ($\beta = 0.0422$) and formal borrowing ($\beta = 0.0246$) is positive but statistically insignificant, suggesting that additional barriers beyond digital access may hinder broader financial participation.

Our result are consistent with previous single country studies that have found a positive relationship between FINTECH and financial inclusion in African countries ((Gosavi, 2018; Mbiti & Weil, 2011) and previous cross –country results (Demir et al., 2022).Beyond FINTECH, various household characteristics are important determinants of financial inclusion. Larger household size is associated with lower likelihoods of owning bank accounts and saving formally(Soumaré et al., 2016). Greater distance from financial institutions significantly reduces access to accounts, savings, and insurance(Abel et al., 2018); Mossie, 2022) Financial literacy emerges as a strong, positive predictor of financial inclusion across nearly all indicators except borrowing.(Abel, Mutandwa, and Le Roux 2018; Akileng, Lawino, and Nzibonera 2018; Akudugu 2013; Evans 2016). Gender also plays a role, with women more likely to engage in formal saving(Soumaré et al., 2016). Urban residents enjoy higher levels of financial inclusion than rural populations, underscoring persistent geographic disparities (Soumaré et al., 2016). Participation in informal financial mechanisms like *Iddir* has a consistently positive effect across all inclusion metrics, highlighting their complementary role alongside formal systems. Education (Abel et al., 2018; Mossie, 2022; Soumaré et al., 2016)and financial capability further boost inclusion, especially in areas like account ownership and saving.

Regionally, FINTECH's impact does not significantly differ from Tigray (the base category), though some trends are observed. The SNNP region shows a higher probability of saving, while urban areas like Addis Ababa, Dire Dawa, and Harar demonstrate modest, but statistically insignificant, positive associations with financial inclusion. Conversely, Oromia and Benishangul show slightly negative effects on

borrowing and insurance. Regions such as Amhara, Afar, Somali, and Gambella exhibit no substantial deviation from Tigray in FINTECH's effect, though Amhara trends toward higher savings and borrowing. Overall, FINTECH plays a meaningful role in promoting formal savings and insurance, contributing to financial inclusion in Ethiopia. However, its influence on account ownership and borrowing remains limited, likely due to structural and regional disparities in infrastructure, financial access, and digital literacy.

4.3 Robustness Test Result

To ensure the validity of the univariate probit estimates presented in Table 4, robust standard errors were employed to correct for potential heteroscedasticity in the error terms. Such a diagnostic correction enhances the validity of the coefficient estimates and p-values by considering the possibility of any non-constant variance among the residuals. Particularly, the significance, magnitude, and statistical relevance of the key coefficients, especially for FINTECH, are largely consistent between the univariate models and the multivariate probit model (Table 5). In both specifications, FINTECH has a positive and significant effect on formal saving and formal insurance, but an insignificant effect on formal borrowing or bank account ownership. That such results hold robust across the universal models is indicative that heteroscedasticity is not a concern issue in the univariate models. Further, the Multivariate Probit model, which simulates all four results collectively and also deals with the potential correlations in unobserved variables, confirms the robustness of the findings. Although the Multivariate Probit model maximizes statistical efficiency by the assumption of correlated errors (with significant correlations such as $\rho 21 = 0.661$, $p < 0.01$), the evidence that significant coefficients are stable across models indicates that findings are not a result of misspecification or heteroscedasticity bias. Therefore, the application of robust standard errors for the univariate models along with joint estimation for the multivariate model provides solid evidence for the validity and reliability of empirical findings.

Despite similar results across the two models, the Multivariate Probit model is a better fit for this study since it detects possible interdependence between financial inclusion indicators. For example, individuals who engage in one type of formal finance, such as saving, are more likely to participate in others, such as borrowing or insurance. By modeling these indicators together, multivariate probit gives more efficient and accurate estimations. Hence, it is the preferred to estimate the main study.

Table 3. Pair wise Pearson's Correlation Matrix

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
(1) BAC	1.000																	
(2) SAV	0.601	1.000																
(3) BORW	0.039	0.009	1.000															
(4) INSU	0.059	0.070	0.001	1.000														
(5) FINTECH	0.052	0.078	0.004	0.034	1.000													
(6) HHS	-0.205	-0.171	-0.015	0.028	-0.048	1.000												
(7) DIST	-0.107	-0.091	-0.003	-0.023	-0.008	0.029	1.000											
(8) MART	-0.042	-0.008	-0.005	0.039	0.002	0.359	-0.006	1.000										
(9) FLT	0.611	0.479	0.006	0.067	0.064	-0.216	-0.090	-0.006	1.000									
(10) AOWN	0.176	0.142	0.017	-0.015	0.030	-0.096	-0.015	-0.054	0.135	1.000								
(11) GDR	0.037	0.078	0.006	0.038	0.028	0.208	-0.016	0.507	0.092	0.021	1.000							
(12) Urban/Rural	-0.352	-0.240	0.003	0.035	-0.017	0.262	0.095	0.164	-0.382	-0.066	0.149	1.000						
(13) *IDDIR*	0.059	0.067	0.026	0.084	-0.031	0.157	-0.030	0.105	0.033	-0.038	0.059	0.066	1.000					
(14) AG	-0.133	-0.134	-0.052	0.030	-0.031	0.303	0.022	0.000	-0.213	-0.083	0.001	0.070	0.271	1.000				
(15) RLG	0.268	0.232	0.034	0.078	0.027	-0.214	-0.081	-0.095	0.262	0.056	-0.064	-0.196	0.150	-0.034	1.000			
(16) FINShock	0.034	-0.003	0.065	-0.011	-0.032	-0.065	-0.011	-0.064	0.047	0.000	-0.061	-0.117	0.046	0.000	0.131	1.000		
(17) FINCAP	0.243	0.333	-0.017	0.041	0.062	-0.051	-0.026	0.029	0.246	0.052	0.095	-0.148	0.011	-0.111	0.075	-0.090	1.000	
(18) EDU	0.401	0.343	0.009	0.015	0.045	-0.196	-0.058	0.056	0.474	0.100	0.155	-0.298	-0.009	-0.344	0.242	0.025	0.226	1.000

Source: Author's Computations using Ethiopian Socio-economic Survey Data 2018/2019

The Pearson's Correlation Matrix provides essential information about the relationships between financial inclusion, financial technology (FINTECH), and socio-economic variables in Ethiopia. Bank account ownership (BAC) is highly linked with formal savings (SAV) (0.601) and financial literacy (FLT) (0.611). This result shows that financial knowledge plays a vital role to support formal financial activities. Education (EDU) also has a positive association with financial literacy (0.474) and bank account ownership (0.401). This portrays that higher education levels improve financial inclusion. The role of financial technology (FINTECH) is weakly correlated with formal finance variables, such as bank account ownership (0.052) and financial literacy (0.064).This indicates that when digital finance tools are rising, their direct impact on financial inclusion remains limited. On the other hand, household size (HHS) and urban-rural residence negatively affect bank account ownership (-0.205, -0.352) and savings (-0.171, -0.240). Both, Borrowing (BORW) and insurance (INSU) show weak correlations with bank account ownership (0.039, 0.059). This result indicates that to own a bank account does not necessarily lead to borrowing or insurance uptake. The weak relationship between financial shocks (FINShock) and bank account ownership (0.034) reveals that individuals may rely on informal financial mechanisms such as *Iddir*, which itself has low correlations with formal finance indicators. Religious affiliation (RLG) has a moderate positive correlation with bank account ownership (0.268).

Table 4. Effects of FINTECH on Financial Inclusion Univariate Probit Estimation Result

VARIABLES	Bank Account Ownership	Formal Savings	Formal Borrowing	Formal Insurance
FINTECH	0.0526	0.201***	0.0267	0.200**
	(0.0749)	(0.0671)	(0.0784)	(0.0886)
Household Size	-0.0377***	-0.0424***	0.00375	0.0180
	(0.0117)	(0.0113)	(0.0131)	(0.0155)
Distance to the nearest FI	-0.00184***	-0.00234***	3.32e-05	-0.00381*
	(0.000530)	(0.000573)	(0.000151)	(0.00218)
Marital Status	-0.0592	-0.0333	-0.0554	0.0793
	(0.0597)	(0.0561)	(0.0639)	(0.0789)
Financial Literacy	1.443***	1.029***	-0.0239	0.366***
	(0.0552)	(0.0550)	(0.0647)	(0.0881)
Gender	-0.0466	0.0481	0.128	0.207
	(0.148)	(0.145)	(0.164)	(0.235)
Urban/ Rural	-0.375***	-0.0815	-0.00310	0.317***
	(0.0546)	(0.0542)	(0.0618)	(0.0809)
Iddir	0.163***	0.175***	0.138***	0.219***
	(0.0491)	(0.0459)	(0.0528)	(0.0658)
Age	0.00373*	0.000102	-0.00906***	0.00317
	(0.00192)	(0.00176)	(0.00213)	(0.00238)
Religion	0.300***	0.278***	0.124**	0.318***
	(0.0496)	(0.0479)	(0.0571)	(0.0785)
Financial Capability	0.325***	0.679***	-0.0849	0.133**
	(0.0474)	(0.0435)	(0.0518)	(0.0620)
Education	0.430***	0.327***	-0.0570	-0.102
	(0.0591)	(0.0559)	(0.0672)	(0.0791)
Base Region: Tigray				
Afar	0.183	0.0396	-0.0988	0.190
	(0.115)	(0.105)	(0.123)	(0.158)
Amhara	0.247**	-0.0237	-0.0417	0.0724
	(0.108)	(0.0999)	(0.115)	(0.159)
Oromia	0.0887	0.0261	0.0123	-0.136
	(0.144)	(0.137)	(0.156)	(0.232)
Somali	0.180	-0.00620	-0.130	-0.163
	(0.183)	(0.174)	(0.200)	(0.280)
Benishangul	0.173	0.0903	-0.0547	-0.139
	(0.190)	(0.183)	(0.206)	(0.288)
SNNP	0.0924	0.0257	-0.180	0.0607
	(0.182)	(0.175)	(0.200)	(0.275)
Gambella	0.267	0.0793	-0.112	-0.0632
	(0.184)	(0.174)	(0.200)	(0.277)
Harar	0.269	0.236	0.0262	-0.104
	(0.181)	(0.172)	(0.195)	(0.276)
Addis Ababa (City)	0.160	0.0377	-0.137	-0.129
	(0.173)	(0.166)	(0.189)	(0.267)
DireDawa (City)	0.293	0.204	-0.198	-0.0681
	(0.180)	(0.171)	(0.196)	(0.274)
Constant	-1.322***	-1.284***	-0.878***	-2.583***
	(0.130)	(0.121)	(0.139)	(0.206)
Observations	4,497	4,497	4,497	4,497

Robust standard errors in parentheses

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

Table 5. The Effect of FINTECH and other explanatory variables on Financial Inclusion: A mvprobit Regression Result

VARIABLES		**Bank Account Ownership**	**Formal Saving**	**Formal Borrowing**	**Formal Insurance**
FINTECH		0.0422	0.192***	0.0246	0.200**
		(0.0752)	(0.0696)	(0.0789)	(0.0898)
Household Size		-0.0364***	-0.0415***	0.00340	0.0171
		(0.0117)	(0.0110)	(0.0129)	(0.0160)
Distance to the nearest FI		-0.00179***	-0.00243***	2.60e-05	-0.00378**
		(0.000585)	(0.000561)	(0.000243)	(0.00150)
Marital Status		-0.0614	-0.0411	-0.0554	0.0809
		(0.0607)	(0.0556)	(0.0652)	(0.0861)
Financial Literacy		1.446***	1.032***	-0.0208	0.370***
		(0.0554)	(0.0542)	(0.0649)	(0.0868)
Gender		-0.0587	0.0282	0.125	0.213
		(0.157)	(0.145)	(0.165)	(0.240)
Iddir		0.160***	0.173***	0.138***	0.218***
		(0.0492)	(0.0453)	(0.0532)	(0.0651)
Age		0.00368**	-0.000151	-0.00900***	0.00317
		(0.00186)	(0.00173)	(0.00211)	(0.00253)
Religion		0.287***	0.279***	0.122**	0.320***
		(0.0504)	(0.0474)	(0.0572)	(0.0752)
Education		0.429***	0.326***	-0.0577	-0.104
		(0.0579)	(0.0554)	(0.0663)	(0.0835)
Financial Capability		0.318***	0.676***	-0.0845	0.132**
		(0.0479)	(0.0435)	(0.0525)	(0.0642)
Urban /Rural		-0.370***	-0.0667	-3.32e-05	0.320***
		(0.0555)	(0.0535)	(0.0621)	(0.0773)
Base region : Tigray					
Afar		0.206*	0.0654	-0.0935	0.192
		(0.111)	(0.103)	(0.123)	(0.160)
Amhara		0.253**	-0.0441	-0.0404	0.0706
		(0.106)	(0.0980)	(0.115)	(0.160)
Oromia		0.125	0.0442	0.0165	-0.147
		(0.146)	(0.136)	(0.156)	(0.235)
Somali		0.202	0.00763	-0.129	-0.168
		(0.187)	(0.174)	(0.199)	(0.283)
Benishnagul		0.218	0.0972	-0.0521	-0.140
		(0.195)	(0.179)	(0.205)	(0.289)
SNNP		0.107	0.0361	-0.178	0.0559
		(0.187)	(0.173)	(0.200)	(0.277)
Gambella		0.302	0.115	-0.107	-0.0679
		(0.189)	(0.174)	(0.200)	(0.281)
Harar		0.302	0.246	0.0296	-0.109
		(0.186)	(0.172)	(0.195)	(0.279)
Addis Ababa (City)		0.190	0.0525	-0.134	-0.135
		(0.178)	(0.165)	(0.189)	(0.271)
DireDawa (City)		0.316*	0.218	-0.190	-0.0742
		(0.185)	(0.171)	(0.197)	(0.277)
Constant		-1.337***	-1.286***	-0.881***	-2.585***
		(0.129)	(0.121)	(0.138)	(0.190)
Observations		4,497	4,497	4,497	4,497
atrho21	atrho31	atrho41	atrho32	atrho42	atrho43
0.661***	0.0920***	0.0769*	0.0206	0.0728*	-0.00967
(0.0304)	(0.0332)	(0.0409)	(0.0312)	(0.0384)	(0.0430)
Log likelihood = -6590.3141					

Wald chi2(88) = 2327.06	Prob > chi2 = 0.0000
Likelihood ratio test of rho21 = 0.000 ; rho31 =0.005 ; rho41 =0.059 ; rho32 =0.511; rho42 =0.057 ; rho43 = 0.822	
Standard errors in parentheses	
*** p<0.01, ** p<0.05, * p<0.1	

5 Conclusion and Policy Implications

Our findings demonstrate that FINTECH plays a vital role in advancing financial inclusion in Ethiopia, particularly by boosting formal saving and insurance usage. However, its influence on bank account ownership and formal borrowing is not statistically significant, suggesting that barriers to credit and financial services persist. Key drivers of financial inclusion include financial literacy, education, financial capability, and informal networks such as *Iddir*, which shows a consistently strong positive effect across all indicators. The study also highlights the persistent urban–rural divide, with rural populations facing greater access challenges due to geographic distance and limited infrastructure. While regional differences in FINTECH's impact exist, none show a statistically significant deviation from Tigray, the reference region. In light of these findings, the following policy implications are proposed for key stakeholders:

The commercial banks in Ethiopia have to become more actively involved and engaging in leveraging FINTECH to expand access to financial services. The inclusion of digital channels such as mobile banking and agent banking can break geographical constraints, mainly in underserved rural areas. Secondly, banks have to design more inclusive credit products that are customized for low income households and informal sector employees, thereby bridging the observed shortfall for formal borrowing. Collaborations with informal community based institutions like *Iddir* can enhance outreach, build trust, and promote financial inclusion form the grassroots level.

FINTECH operators must look beyond insurance and savings products offered digitally by developing offerings that facilitate formal account holding and borrowing. Investment in robust digital security platforms, schemes for user protection and customer education initiatives must also be made to instil confidence and cause large-scale adoption. Expansion of mobile and agent-based services in rural areas will be critical to narrowing the rural–urban divide. Specific focus must be given to the usability and accessibility of the electronic channels to individuals with poor literacy.

Policy makers must provide the highest priority to digital infrastructure development and interoperability of the financial system so as to facilitate a robust and inclusive digital finance system. Increasing national level financial literacy campaigns particularly in rural and women will be crucial in order to empower citizens to fully utilize financial services. Additionally, integrating informal financial institutions such as *Iddir* into the national policy of financial inclusion can make financial participation broader and more culturally suitable. Regionally , variations was not relevant at a statistical level, but region – tailored policy interventions can still optimize the effectiveness and local feasibility of FINTECH implementation. Thus, fostering trust in FINTECH through strong consumer protection and digital security measures, alongside region-specific strategies, bridging the rural–urban gap and integrating informal financial systems like *Iddir* will ensure more equitable access across Ethiopia.

Future researchers are encouraged to investigate the underlying barriers that limit the effect of FINTECH on formal borrowing and account ownership. Qualitative and behavioral research may provide more detailed insights into trust relationships, technology adoption, and financial choice among population groups. Longitudinal and cross county studies also are needed to quantitatively assess the evolving role of FINTECH and identify best practices for growth. There is also plenty of scope for experimenting with blended financial architectures that integrate formal digital service with conventional informal services to conceptualize inclusive financial systems adapted to the Ethiopia scenario.

6 Limitations and future research directions

This study examines FINTECH's role in promoting financial inclusion in Ethiopia using a cross-sectional household dataset from the World Bank. While insightful, the use of cross-sectional data limits the ability to draw causal conclusions, offering only a snapshot in time. Data limitations also restrict deeper exploration of informal financial systems like *Iddir*. Additionally, factors such as financial literacy trust in digital services, and regulatory environments may influence the results. The findings, therefore, may not be fully generalizable beyond Ethiopia. Future research should consider longitudinal or panel data for several African countries to better assess FINTECH's

impact over time and across many countries. Comparative analyses across Sub-Saharan Africa, behavioral studies of FINTECH adoption, and evaluations of regulatory frameworks would further enhance knowledge on how FINTECH advances financial inclusion.

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Statement of declaration

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Authors' contributions

All authors contributed equally to the development of this research article. The corresponding author led the drafting and coordination of the manuscript. The principal advisor and co-advisors provided critical guidance, academic supervision, and valuable input throughout the research design, data analysis, and interpretation stages. All authors reviewed and approved the final version of the manuscript.

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