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Shivani Jain

Indian Institute of Management Kashipur, shivani.phd2115@iimkashipur.ac.in

Jagadish Prasad Sahu

Indian Institute of Management Kashipur, jagadish.sahu@iimkashipur.ac.in

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The Impact of ICT on Financial Inclusion: Evidence from Global Sample

Completed Research Paper

Shivani Jain

Indian Institute of Management
Kashipur, Uttarakhand, India
shivani.phd2115@iimkashipur.ac.in

Jagadish Prasad Sahu

Indian Institute of Management
Kashipur, Uttarakhand, India
jagadish.sahu@iimkashipur.ac.in

Abstract

This study explores the impact of Information and Communication Technology (ICT) on financial inclusion across 74 countries from 2011 to 2021. An ICT index derived using Principal Component Analysis (PCA) with indicators including internet penetration, fixed broadband subscriptions, and mobile cellular subscriptions, serves as the basis for analysis. Panel regression methods, including fixed effects and Panel Instrumental Variable (IV) regression, are employed. We measure financial inclusion through bank account ownership and access to borrowings from the Global Findex Database. The study reveals a statistically significant and positive influence of the ICT index on financial inclusion. Additionally, when categorizing nations into high-income and middle-income groups, ICT's role in enhancing financial inclusion, particularly in middle-income countries, becomes evident. This underscores the critical importance of robust ICT infrastructure, urging policymakers, especially in middle-income countries, to prioritize internet accessibility for fostering greater financial inclusion.

Keywords: Information and Communication Technology (ICT), Financial Inclusion, Panel Regression Analysis, Internet Penetration

Introduction

The growth of information and communication technology (ICT) is advancing swiftly, with fresh technologies and inventions emerging quickly (Lee & Hong, 2002). The extension and enhancement of ICT has a great potential to boost economic growth by enabling the establishment of new business models, enhancing efficiency and productivity in various industries (Liu, et. al., 2013). It encompasses the tangible and intangible components that facilitate the manipulation, retention, and transfer of information and communication utilizing different technologies like computers, mobile devices, and the internet (Chege, Wang & Suntu, 2020). ICT has a crucial function in facilitating financial inclusion, which pertains to providing and utilizing formal financial services by low-income families, individuals, and micro, small, and medium-sized businesses (Qureshi, 2020). It can also decrease the cost and improve the availability of financial services, particularly for those living in distant areas with no access to traditional banking services (Ahmad, Green & Jiang, 2020). For instance, mobile money services and digital payment systems have gained immense popularity in developing nations, where a significant number of people do not have access to formal banking services (Chakravorti & Chaturvedi, 2019).

During the 1990s, it was recognized that access to financial services is crucial for economic growth and poverty reduction (Liu, et. al., 2021). As a result, the concept of financial inclusion emerged, gaining significant attention after the after the United Nations Development Programme (UNDP) highlighted the importance of financial services in poverty alleviation in 2005 (Nandru, Chendragiri & Velayutham, 2021). The World Bank defines financial inclusion as the availability and utilization of a wide range of affordable

financial services, including savings, credit, insurance, payments, and remittances, provided by formal financial institutions in a transparent and regulated environment (Ahmad, Green & Jiang, 2020). Various obstacles hinder financial inclusion, such as restricted availability of financial services in rural areas, high costs of transactions, insufficient financial infrastructure, insufficient awareness and education about finance, and prejudiced practices by financial institutions. These hindrances have a more significant impact on women, low-income families, and underprivileged communities (Kazemikhasragh et al., 2022).

In recent times, advancements in technology such as mobile banking, digital payments, and blockchain have demonstrated immense potential in boosting financial inclusion by decreasing costs, improving accessibility, and enhancing efficiency (Hoang, Nguyen & Le, 2022). Consequently, exploring the influence of ICT on financial inclusion has become progressively crucial. Although prior studies have recognized the significant impact of ICT on financial inclusion, further investigation is necessary to attain a comprehensive understanding of ICT's role in advancing financial inclusion, especially in meeting the specific needs of disadvantaged populations. Thus, the objective of this research is to investigate whether the impact of ICT infrastructure on financial inclusion differs across countries. This study aims to compare the effect of ICT infrastructure on financial inclusion in different countries.

The findings of this research can assist policymakers and practitioners in developing effective approaches to promote financial inclusion using ICT. By recognizing the factors that affect the impact of ICT on financial inclusion in various countries, policymakers can develop policies that cater to the requirements of each country. The results of this study can assist financial institutions and technology companies in creating and marketing their ICT-based financial services. By understanding how the impact of ICT on financial inclusion differs from country to country, these companies can develop financial services that are tailored to the specific needs of each country. As a result, this could enhance the provision of financial services that are more efficient and effective in addressing the requirements of customers in diverse countries. In general, this research can assist in creating worldwide standards and recommendations that can be employed by policymakers, financial institutions, and technology companies.

The subsequent sections of this paper are structured as follows. In Section 2, a comprehensive review of the existing literature on the subject matter is presented. Section 3 outlines the methodology employed in the study and provides an elaborate description of the data utilized in the analysis. Section 4 discusses the development and application of an econometric model, as well as the interpretation of the findings. Lastly, Section 5 concludes the research by presenting final observations and remarks on the significance of the research outcomes.

Literature Review

Recent literature on the impact of ICT infrastructure on financial inclusion is extensive and diverse, with numerous studies from various regions worldwide. Andrianaivo and Kpodar (2011) conducted a study that examined the correlation between ICT, financial inclusion, and the economic growth of African nations. Their research revealed that the relationship between ICT and financial inclusion is more pronounced in countries that possess superior institutional quality and exhibit greater economic freedom. Put differently, the impact of ICT and financial inclusion on economic growth is more significant in countries that boast better governance structures and policies that foster economic freedom. Diniz, Birochi & Pozzebon (2012) conducted a study on the determinants of the adoption of ICT-based branchless banking services in financial inclusion. They observed that the adoption of such services had a beneficial effect on financial inclusion. However, the study also identified several obstacles that hinder the widespread adoption of ICT-based branchless banking services, such as low levels of digital literacy, inadequate infrastructure, and lack of trust. The study by Joia and Santos (2016) investigated the influence of an ICT-enabled mobile bank on the financial inclusion of riverine communities residing in the Brazilian Amazon's Marajó Island. The results indicated that the mobile bank equipped with ICT had a positive impact on the financial inclusion of the riverine population by increasing their access to financial services, especially credit and savings. Bisht and Mishra (2016) conducted a study to investigate the impact of ICT on financial inclusion initiatives aimed at the urban poor in a developing economy. Their findings suggest that ICT-based initiatives can have a significant positive effect on financial access and inclusion for this demographic, particularly regarding savings and payments. Moreover, these initiatives have the potential to encourage entrepreneurship and income generation, resulting in better economic outcomes for the urban poor. Munyegera and Matsumoto (2017) conducted research on the influence of mobile money on the financial

behavior of rural households in Uganda and found that it has the potential to improve financial inclusion for rural households, especially in the areas of savings, transactions, and remittances. The study also revealed that the use of mobile money has brought about changes in financial behavior among rural households, including increased savings and more frequent transactions. Kanga et al. (2019) studied the relationship between fintech diffusion, financial inclusion, and income per capita across various countries worldwide. Their findings suggest that the spread of fintech has a favorable effect on financial inclusion, particularly concerning access to credit, savings, and insurance services. Mushtaq (2019) highlights the potential of microfinance and ICT to enhance financial access and inclusion for low-income households and small businesses, ultimately leading to better economic outcomes and a decrease in poverty. Chatterjee and Das (2019) analyzed the relationship between ICT diffusion and financial inclusion in India using state-level data and discovered a positive correlation between the two, with improved access to banking services, credit, and insurance. However, discrepancies in ICT diffusion and financial inclusion across different states were attributed to socioeconomic factors, policy environments, and technological infrastructure. Similarly, Alimi and Okunade (2020) investigated the connection between financial inclusion, ICT diffusion, and poverty reduction in sub-Saharan African countries and found that these strategies can alleviate poverty by improving access to credit, savings, and insurance services. The effectiveness of financial inclusion measures is contingent on several factors, including the regulatory framework, the availability of ICT infrastructure, and the level of financial literacy among the population. In summary, greater accessibility to financial services can lead to improved economic growth and development, but the success of financial inclusion efforts hinges on several factors. The investigation conducted by Bhuvana, Vasantha, and Bharath (2020) scrutinizes the impact of ICT in advancing financial inclusion, emphasizing its potential in enhancing accessibility to financial services for underprivileged groups such as low-income households, small-scale enterprises, and marginalized communities. The study underscores the ability of ICT to propel financial inclusion, particularly in developing nations. In a similar vein, Chatterjee (2020) delved into the connection between financial inclusion, diffusion of ICT, and economic growth by analyzing panel data from 69 countries. The study deduced that financial inclusion and ICT diffusion have a positive influence on economic growth, primarily in developing nations. Furthermore, the research unearthed that the association between financial inclusion and economic growth is moderated by the level of ICT diffusion, signifying the importance of complementary investments in technology infrastructure and financial literacy. The research conducted by Wellalage et al. (2021) investigates the ways in which ICT can contribute to financial inclusion for innovative entrepreneurs, such as start-ups and SMEs. The authors highlight the potential of ICT to improve access to finance, reduce transaction costs, and enhance the efficiency and transparency of financial services for these entrepreneurs. However, the study also identifies several challenges and opportunities associated with the adoption of ICT for financial inclusion, including the need for digital infrastructure, supportive policies and regulations, and sufficient financial literacy and education. Similarly, Kouladoum, Wirajing, and Nchofoung (2022) underscore the potential of mobile money and other digital technologies in promoting financial inclusion for low-income households, small businesses, and underserved communities in Sub-Saharan Africa. The study also examines the obstacles and possibilities of implementing digital technologies for financial inclusion, including the requirement for regulatory frameworks, the necessity of digital literacy, and infrastructure development. Ahmad et al. (2023) study the correlation between mobile money, ICT, financial inclusion, and economic growth in Africa. The research further analyzes how this connection varies across different countries and regions in Africa. The findings reveal that the impact of mobile money on financial inclusion and growth is not uniform across the continent. The results demonstrate that the influence of mobile money on financial inclusion and growth depends on various factors, such as mobile phone penetration, level of financial literacy, and institutional quality.

The extant literature underscores the promising prospects of ICT in advancing financial inclusion. Nonetheless, further research is imperative to gain a comprehensive comprehension of the influence of ICT on financial inclusion and to formulate strategies that leverage ICT infrastructure to foster financial inclusion. This study seeks to scrutinize the heterogeneity in the effect of ICT on financial inclusion among countries. It aims to contrast the impact of ICT on financial inclusion across diverse countries and examine any variables that might elucidate observed discrepancies in the impact.

Data and Methodology

Our empirical analysis is based on annual data for seventy-four countries¹ for the period 2011–2021. The study covers the period from 2011 to 2021, but due to the unavailability of continuous time series data on financial inclusion, the analysis is limited to four distinct years: 2011, 2014, 2017, and 2021. Our sample includes all the countries with population exceeding one million, and for which data are available for the entire sample period. Only three low-income countries satisfied this condition. Therefore, we eliminated them from our analysis. In our study, we endeavor to examine the effect of ICT on financial inclusion in various countries worldwide. To account for the diversity in socioeconomic conditions among the countries, we employ panel data methods to estimate the impact of ICT on financial inclusion. We constructed an ICT index based on indicators such as internet penetration, fixed broadband subscriptions, and mobile cellular subscriptions. We used principal component analysis on the normalized values of the above variables to construct the ICT index. To ensure uniformity, we normalized the data using the min-max approach (Chatterjee 2020; Kouladoum et al. 2022; Andrianaivo and Kpodar 2011; Chatterjee and Das 2021; Ahmad et al. 2023). We consider two different indicators i.e., bank account ownership and access to borrowings as a measure of financial inclusion (Kouladoum et al. 2022; Wellalage et al. 2021). We used access to borrowings as an alternative measure of financial inclusion to check the robustness of our results. We utilized these two indicators which are commonly used in the literature. The number of bank accounts shows the percentage of individuals engaged with the financial sector which represents the demand side factor of financial inclusion. The accessibility of credit from the formal financial institution illustrates the supply-side factor of financial inclusion. Papers such as Sha'ban, Girardone, and Sarkisyan (2020), Evans (2016), Turvey and Xiong (2017), and Shen et al. (2018) have adopted these measures. We source financial inclusion data from the Global Findex database and obtain other relevant data for our empirical analysis from the World Development Indicators (WDI), World Bank. Following the literature, we construct the ICT index which includes the number of individuals using internet, the number of fixed broadband subscribers, and the number of mobile cellular subscribers. Papers such as Sha'ban et al. (2020), Kouladoum et al. (2022) and Evans (2016, 2018) have used these indicators to measure the level of ICT development in the country. The definitions of the variables used in this study are provided in Table 1. Although we acknowledge that financial literacy levels play a crucial role in financial inclusion, we are unable to include this variable in our study due to data constraints. As a preliminary analysis, we employ the fixed effects (FE) regression method to estimate the following equation:

$$Y_{it} = \alpha_i + \beta ICT_{it} + \gamma Z_{it} + \varepsilon_{it}$$

Where, Y_{it} represents the degree of financial inclusion in a particular country at a given year, which is estimated by the percentage of respondents having bank account ownership and percentage of respondents taking loan from formal financial institution. ICT_{it} represents the degree of technological advancement in the country in terms of internet penetration, mobile cellular subscription, and fixed broadband subscription, Z_{it} includes the control variables including log of GDP per capita, domestic credit to private sectors by banks, trade openness, mean years of schooling, ratio of female to male population, working age population, manufacturing share as a percentage of GDP, and an average of institutional quality dimensions. The random error term is represented by, ε_{it} and α_i captures the unique effects of each country.

This study's selection of control variables is based on the following rationale. We include the logarithm of GDP per capita as an indicator of economic development, hypothesizing that countries with higher levels of economic development will exhibit greater FI. Hence, a positive relationship is expected between economic development and FI (Ahmad et al., 2023; Kanga et al., 2022; Kouladoum et al., 2022; Chatterjee, 2020). Additionally, we consider domestic bank credit to the private sector as a measure of a country's financial sector development, anticipating a positive contribution to FI from a well-developed financial sector (Wellalage et al., 2021; Mushtaq & Bruneau, 2019; Ahmad et al., 2023; Chatterjee, 2020). Trade openness is included to assess a country's engagement in the global trading system, expecting a positive association

¹ The list of countries is not given in this manuscript due to space constraints. The list can be obtained from the author upon request.

Variable	Definition	Source
ICT Index	Construct the index based on indicators such as internet penetration, fixed broadband subscriptions, and mobile cellular subscriptions	
Bank account ownership	Percentage of respondents having account ownership at bank or at financial institution or mobile money service provider	Global Findex database, World Bank
Borrowing from formal financial institution	Percentage of respondents who borrowed money from a formal financial institution	WDI
Internet users	Percentage of population with access to the worldwide network	WDI
Fixed broadband subscription	fixed subscriptions to high-speed access to the public Internet per 100 people	WDI
Mobile cellular subscription	Subscriptions to a public mobile telephone service per 100 people	WDI
Log of GDP per capita	Logarithmic of Gross domestic product (GDP) per capita	WDI
Domestic credit to private sectors by bank	Domestic credit to private sector by banks as percentage of GDP	WDI
Trade openness	Trade (sum of exports and imports) as percentage of GDP	WDI
Mean years of schooling	Mean years of schooling of adults aged 25+	Global data lab
Ratio of female to male population	Percentage of female population to male population	WDI
Working age population	Working age population as a percentage of total population	WDI
manufacturing, value added	Manufacturing sector value added as percentage of GDP	WDI
Institutional quality index	Average of six dimensions of institutional quality i.e., Political Stability and Absence of Violence/Terrorism: Estimate, Regulatory Quality: Estimate, Rule of Law: Estimate, Government Effectiveness: Estimate, Control of Corruption: Estimate, Voice, and Accountability: Estimate	WGI, World Bank
Table 1. Definitions of variables and sources of data		

between globalization and FI (Kouladoum et al., 2022; Chatterjee, 2020; Kanga et al., 2022). Years of schooling serve as a proxy for education level, it is expected that higher education level leads to greater FI.

Therefore, a positive relationship is anticipated between education and FI (Kanga et al., 2022; Munyegera & Matsumoto, 2018; Chatterjee, 2020). The ratio of female to male population is used as an indicator for the gender gap, considering that women generally have lower access to bank accounts compared to men. Consequently, a negative coefficient is expected for this variable (Munyegera & Matsumoto, 2018). Moreover, the share of the working-age population, representing the proportion of individuals within the working-age bracket in relation to the total population, is anticipated to positively impact financial inclusion. Furthermore, a higher share of the manufacturing sector in total GDP indicates greater industrial development, which is expected to be positively associated with FI (Chatterjee and Das 2021). Finally, it is hypothesized that countries with higher-quality institutions will actively promote FI, leading to a positive coefficient for this variable (Ahmad et al., 2023; Kanga et al. 2022).

The FE model eliminates the time-invariant country-specific factors. The differential intercept term captures the heterogeneity across the countries. Furthermore, as a sensitivity analysis, we utilize instrumental variable regression to correct the potential endogeneity concerns and ensure the robustness of our findings. This comprehensive approach enables us to provide valuable insights into the relationship between ICT and financial inclusion on a global scale.

Results and Discussion

This section presents the empirical findings of our study. First, we provide a descriptive analysis of the variables used in our regression analysis. Table 2 summarizes the statistics of these variables. The results show that the average number of bank account ownership in our sample is 68.01%, while the average percentage of respondents who have taken loans from a formal financial institution is 16.93%. However, there is a wide dispersion of these variables across the countries, as evident from the standard deviation and range of the variables. Our variables of interest, namely internet users, fixed broadband subscription, and mobile cellular subscription, also exhibit significant heterogeneity across the countries in our sample. Furthermore, other economic indicators such as the logarithm of real GDP per capita, domestic credit to the private sector by banks, trade openness, years of schooling, manufacturing share, working age population, ratio of female to male population and institutional quality index display similar distribution patterns. In general, the descriptive statistics reveal that our sample consists of a diverse set of countries in terms of economic performance.

Variable	Obs	Mean	Std. Dev.	Min	Max
ICT Index	296	.6888976	.3544287	-.275886	1.461958
Bank account ownership (% of respondents)	296	68.01274	26.78407	5.82	100
Percentage of respondents taken loan from formal financial institution	296	23.84581	16.92528	1.5	79.51
Internet users	296	59.93643	25.59603	3.2	98.86585
Fixed broadband subscription	296	17.76686	12.90985	.0087747	44.51249
Mobile cellular subscription	296	117.2111	24.94989	54.83032	182.5976
log of GDP per capita	296	9.12774	1.159808	6.723099	11.39602
Domestic credit to the private sector	295	65.796	42.00061	5.36389	251.7103
Trade openness	296	87.5433	51.99254	22.57654	379.0986
Years of schooling	296	10.00171	2.611198	1.585	14.11
Manufacturing share	296	14.59535	5.623236	4.077488	39.59351
Working age population	296	65.23286	4.608843	51.99009	78.52772
Ratio of female to the male population	296	103.215	5.742811	91.18488	122.1232
Institutional quality index	296	.2838384	.7587436	- 1.410706	1.84106

Table 2. Summary statistics

The fixed effects regression results for the full sample are presented in Tables 3. We have considered both country fixed effects as well as time fixed effects in the regression model. The results suggest that the ICT index and the individual components such as internet penetration and fixed broadband subscription positively impact the level of financial inclusion. However, the influence of mobile cellular subscription appears to be insignificant. This suggests that the ease of accessibility to financial services and efficient management of financial transactions facilitated by these ICT tools are crucial factors in promoting financial inclusion. Furthermore, the study establishes that the logarithm of real gross domestic product (GDP) per capita, years of schooling, working-age population are significant factors influencing financial inclusion, indicating that higher income levels and the proportion of individuals within the working age bracket in relation to the total population, is anticipated to have a positive impact in promoting financial

inclusion. Despite exploring several variables, including trade openness, manufacturing share, domestic credit to private sector, ratio of female to male population and institutional quality index, no significant relationship was observed with financial inclusion.

	ICT index		internet users		Fixed broadband subscription		Mobile cellular subscription	
ICT index	28.512***	11.926*#						
	(6.600)	(6.043)						
Internet users			0.488***	0.314***				
			(0.083)	(0.095)				
Fixed broadband subscription					0.896***	0.069		
					(0.314)	(0.322)		
Mobile cellular subscription							0.027	0.006
							(0.046)	(0.036)
Log of GDP per capita	19.716**	5.155	18.238**	8.131	27.390***	7.627	39.288***	7.547
	(8.848)	(7.635)	(7.159)	(6.629)	(9.316)	(7.469)	(8.480)	(7.366)
Domestic credit to private sector	0.057	0.088**	0.069*	0.089**	0.070	0.095**	0.067	0.095**
	(0.041)	(0.039)	(0.035)	(0.036)	(0.044)	(0.040)	(0.050)	(0.040)
Trade openness	-0.085	-0.015	-0.017	0.010	-0.042	0.019	-0.002	0.022
	(0.081)	(0.070)	(0.055)	(0.058)	(0.068)	(0.063)	(0.074)	(0.062)
Years of schooling	3.012*	-0.094	1.868	-0.000	4.517**	0.364	7.107***	0.383
	(1.700)	(1.067)	(1.179)	(1.029)	(1.743)	(1.107)	(2.112)	(1.116)
Manufacturing share	-0.333	-0.066	-0.214	-0.031	-0.572*	-0.181	-0.930**	-0.187
	(0.331)	(0.299)	(0.330)	(0.302)	(0.336)	(0.298)	(0.376)	(0.298)
Working population age	0.903	1.231**	0.966	1.185**	1.195	1.167*	0.208	1.110*
	(0.695)	(0.613)	(0.613)	(0.591)	(0.762)	(0.677)	(0.776)	(0.620)
Ratio of female to male population	-0.868	0.013	-0.627	-0.158	-0.631	0.459	0.202	0.522
	(1.156)	(0.997)	(0.870)	(0.824)	(1.192)	(1.027)	(1.057)	(0.871)
Institutional quality index	1.559	4.391*	1.041	3.040	5.102**	5.916***	4.460*	5.865***
	(2.121)	(2.218)	(1.886)	(2.099)	(2.292)	(2.140)	(2.577)	(2.175)
Time fixed effect		yes		yes		yes		yes
Constant	-122.887	-80.634	-144.835	-98.746	-249.875	-146.468	-	-148.482
	(161.010)	(134.899)	(122.674)	(113.009)	(164.277)	(130.629)	(141.645)	(121.427)
No. of observations	295	295	295	295	295	295	295	295
R-square (within)	0.586	0.647	0.640	0.665	0.551	0.638	0.505	0.638

Table 3: Results from fixed effects regression (Full sample)

Note: Robust standard errors in parentheses, *** p<.01, ** p<.05, * p<.10. # The p-value for this coefficient is 0.052, which is very close to 5%. Dependent Variable: Bank account ownership (% of respondents)

	ICT Index	Internet Penetration	Fixed Broadband Subscription	Mobile Cellular Subscription
ICT index	36.624*** (11.881)			
Internet users		0.474*** (0.142)		
Fixed broadband subscription			1.569*** (0.526)	
Mobile cellular subscription				0.304 (0.192)
Log of GDP per capita	15.085 (10.889)	18.948** (8.783)	18.117* (10.272)	11.196 (11.583)
Domestic credit to the private sector	0.051 (0.038)	0.064* (0.034)	0.063 (0.041)	0.081 (0.055)
Trade openness	-0.102 (0.084)	-0.018 (0.052)	-0.073 (0.066)	-0.021 (0.105)
Years of schooling	1.663 (2.003)	2.029 (1.728)	2.472 (1.907)	10.139*** (2.253)
Manufacturing share	-0.147 (0.341)	-0.243 (0.318)	-0.292 (0.335)	-0.024 (0.405)
Working age population	1.031* (0.588)	0.944* (0.564)	1.886** (0.754)	-0.809 (0.874)
Ratio of female to male population	-0.898 (0.971)	-0.573 (0.793)	-1.140 (1.138)	-0.029 (1.434)
Institutional quality index	0.620 (2.113)	1.129 (1.785)	5.396*** (2.037)	2.328 (2.456)
No. of observations	292	292	292	221
R-square (within)	0.583	0.638	0.524	0.250
First Stage F-statistic	18.06 (0.0000)	18.49 (0.0000)	17.23 (0.0000)	3.69 (0.0274)
Hansen J-statistic	1.688 (0.1939)	1.522 (0.2173)	0.551 (0.458)	0.146 (0.7022)
Table 4: Results from instrumental variable regression (Full Sample)				

Note: "Standard errors in parentheses, *** p<.01, ** p<.05, * p<.10". Dependent Variable: Bank account ownership (% of respondents).

However, our preferred estimation method is instrumental variable (IV) regression, and we present the outcomes from this model in Table 4. The IV regression technique offers a valuable advantage by effectively addressing the issue of endogeneity associated with ICT Index and its components. To tackle this challenge, we incorporate two instrumental variables: ICT service exports as a percentage of GDP and the urban population as a proportion of the total population. By employing these instruments, we can adequately account for the potential bias caused by endogeneity and obtain more reliable outcomes when examining index of ICT and its indicators. The findings of the study show a positive and highly significant relationship between ICT index and its individual components namely, internet penetration and fixed broadband subscription with financial inclusion. Furthermore, the log of GDP per capita has a statistically significant

effect on financial inclusion. This suggests that countries with a higher per capita income tend to have greater financial inclusion. The results show that economic prosperity plays a significant role in nurturing inclusive financial systems. In addition, the study reveals a positive and substantial relationship between domestic bank credit to the private sector and financial inclusion. This finding highlights the crucial role that the expansion and development of the financial sector play in promoting financial inclusion. It highlights the significance of assuring adequate access to credit facilities and the assistance provided by domestic banks in promoting inclusiveness. Moreover, the study reveals the working-age population's statistically significant and positive effect on financial inclusion. This indicates that a higher number of individuals within the working-age bracket contribute to stimulating financial inclusion within a country. This outcome suggests that a productive workforce is essential to developing inclusive financial systems.

As a sensitivity analysis, we conducted an examination using an alternative measure of financial inclusion, namely, access to borrowings. The fixed effects regression and IV regression results are presented in Table 5 and 6. The findings suggest that both the ICT index along its individual components have contributed positively to the enhancement of financial inclusion.

	ICT Index	Internet Penetration	Fixed broadband subscription	Mobile cellular subscription
ICT Index	19.888***			
	(5.835)			
Internet users		0.208***		
		(0.071)		
Fixed broadband subscription			1.153***	
			(0.223)	
Mobile cellular subscription				0.061
				(0.054)
Log of GDP per capita	4.590	9.563	2.241	16.448*
	(8.443)	(8.154)	(7.753)	(9.013)
Domestic credit to private sector	-0.075	-0.067	-0.066	-0.072
	(0.074)	(0.075)	(0.074)	(0.076)
Trade openness	-0.156**	-0.104	-0.151*	-0.103
	(0.070)	(0.074)	(0.080)	(0.074)
Years of schooling	1.728	2.368	1.202	4.458**
	(1.859)	(1.798)	(1.379)	(2.117)
Manufacturing share	-0.103	-0.219	-0.044	-0.482
	(0.420)	(0.429)	(0.363)	(0.444)
Working age population	-2.319***	-2.473***	-1.549**	-2.841***
	(0.581)	(0.602)	(0.627)	(0.589)
Ratio of female to male population	-2.098*	-1.690	-2.456**	-1.438
	(1.233)	(1.211)	(1.202)	(1.222)
Institutional quality index	-5.241**	-4.623**	-2.513	-3.533*
	(2.007)	(2.019)	(1.951)	(2.032)
Constant	340.382**	254.218*	344.434**	177.548
	(141.800)	(132.273)	(135.166)	(135.245)
No. of observations	295	295	295	295
R-square (within)	0.332	0.320	0.364	0.303

Table 5: Fixed effects regression results (Full sample)

Note: "Robust standard errors in parentheses, *** p<.01, ** p<.05, * p<.10" Dependent Variable: Percentage of respondents taken loan from formal financial institution

	ICT Index	Internet Penetration	Fixed broadband subscription	Mobile cellular subscription
ICT index	27.337**			
	(11.178)			
Internet users		0.353**		
		(0.144)		
Fixed broadband subscription			1.164***	
			(0.414)	
Mobile cellular subscription				0.309
				(0.435)
Log of GDP per capita	1.726	4.631	4.091	8.609
	(11.333)	(10.272)	(9.333)	(21.012)
Domestic credit to private sector	-0.051	-0.041	-0.042	-0.069
	(0.062)	(0.065)	(0.062)	(0.085)
Trade openness	-0.166**	-0.103	-0.144*	-0.118
	(0.073)	(0.071)	(0.074)	(0.086)
Years of schooling	0.083	0.362	0.707	3.121
	(1.890)	(1.795)	(1.598)	(2.445)
Manufacturing share	0.137	0.065	0.026	-0.184
	(0.439)	(0.437)	(0.381)	(0.574)
Working age population	-2.033***	-2.099***	-1.402*	-2.948***
	(0.617)	(0.641)	(0.728)	(0.670)
Ratio of female to male population	-2.671**	-2.427**	-2.844**	-2.216
	(1.235)	(1.185)	(1.192)	(1.479)
Institutional quality index	-6.214**	-5.831**	-2.652	-5.600
	(2.724)	(2.526)	(2.097)	(3.938)
No. of observations	292	292	292	292
R-square (within)	0.328	0.307	0.362	0.239
First Stage F-statistic	18.06	18.49	17.23	1.00
	(0.000)	(0.000)	(0.000)	(0.3696)
Hansen J-stat	0.847	0.645	0.265	4.312
	(0.3573)	(0.4217)	(0.6066)	(0.0378)

Table 6: Results from instrumental variable regression (Full Sample)

Note: "Standard errors in parentheses, *** $p < .01$, ** $p < .05$, * $p < .10$ ". Dependent Variable: Percentage of respondents taken loan from formal financial institution.

The comprehensive analysis of the full sample results indicates that the ICT index and its indicators, namely internet penetration and fixed broadband subscription, have emerged as highly significant. Internet penetration consistently demonstrates its robust predictive power across all distribution methods employed in the study.

Results from high-income and middle-income countries

To examine the distinct impact of ICT on financial inclusion, we divided the dataset into high-income and middle-income countries. The results obtained from these sub-samples are presented in Tables 6 and 7.

	ICT Index		Internet Penetration		Fixed Broadband Subscription		Mobile Cellular Subscription	
	High income	Middle Income	High income	Middle Income	High income	Middle Income	High income	Middle Income
ICT index	17.679	29.105***						
	(10.596)	(8.764)						
Internet users			0.614***	0.446***				
			(0.178)	(0.094)				
Fixed broadband subscription					0.851*	0.763		
					(0.423)	(0.496)		
Mobile cellular subscription							-0.056	0.025
							(0.058)	(0.065)
Log of GDP per capita	21.710*	25.570*	10.722	32.362***	23.885**	39.729**	29.642**	47.907***
	(11.598)	(13.972)	(10.013)	(10.851)	(11.147)	(15.877)	(12.026)	(14.274)
Domestic credit to private sector	0.051	0.109	0.094**	0.059	0.077**	0.076	0.046	0.184
	(0.037)	(0.164)	(0.038)	(0.132)	(0.038)	(0.167)	(0.037)	(0.183)
Trade openness	-0.014	-0.149	0.037	-0.108	0.020	-0.139	0.067	-0.138
	(0.081)	(0.129)	(0.055)	(0.100)	(0.054)	(0.123)	(0.064)	(0.137)
Years of schooling	8.550***	1.560	1.596	0.833	5.984	3.500*	11.013**	4.757**
	(3.128)	(1.751)	(2.997)	(1.357)	(3.820)	(2.073)	(4.489)	(2.322)
Manufacturing share	-0.624**	-0.207	-0.150	-0.117	-0.551**	-0.570	-1.062***	-0.645
	(0.291)	(0.517)	(0.302)	(0.508)	(0.247)	(0.536)	(0.381)	(0.587)
Working age population	1.617	0.593	1.290	0.616	1.906	0.581	1.047	-0.219
	(1.331)	(0.945)	(1.008)	(0.834)	(1.269)	(1.068)	(1.383)	(1.036)
Ratio of female to male population	0.083	-3.122	0.129	-2.821	0.004	-3.065	0.893	-2.922
	(1.203)	(2.304)	(0.897)	(1.991)	(1.272)	(2.423)	(0.920)	(2.229)
Institutional quality index	0.411	3.657	0.692	1.375	1.764	7.670**	1.412	8.241**
	(2.132)	(3.340)	(1.863)	(3.397)	(2.057)	(3.393)	(2.414)	(3.807)
Constant	-358.732*	101.335	-197.604	12.943	-379.169*	-20.040	-	495.962**
	(205.930)	(234.254)	(169.128)	(192.113)	(205.876)	(245.625)	(216.814)	(217.283)
No. of observations	136	159	136	159	136	159	136	159
R-square (within)	0.539	0.626	0.602	0.672	0.566	0.581	0.496	0.562

Table 7: Results from fixed effect regression (Sub-sample)

Note: “Robust standard errors in parentheses, *** p<.01, ** p<.05, * p<.10”. Dependent Variable: Bank account ownership (% of respondents).

The findings indicate that ICT and its indicators have a positive and statistically significant effect on the percentage of individuals with bank accounts or access to other financial institutions. This suggests that an increase in the proportion of internet penetration and fixed broadband subscriptions positively influences financial inclusion in both high-income and middle-income countries. Furthermore, the logarithm of GDP

per capita shows a positive and statistically significant relationship with financial inclusion, specifically in middle-income countries. This implies that countries with higher per capita income tend to exhibit higher levels of FI. However, this relationship is not observed in high-income countries. Additionally, a positive and statistically significant association is observed between domestic bank credit to the private sector and financial inclusion in high-income countries. This suggests that financial inclusion positively and significantly impacts financial stability, particularly in high-income countries. In contrast, middle-income countries should prioritize increasing the availability of financial services to enhance financial inclusion.

	ICT Index		Internet Penetration		Fixed broadband Subscription		Mobile Cellular Subscription	
	High Income	Middle Income	High Income	Middle Income	High Income	Middle Income	High Income	Middle Income
ICT index	63.489**	31.026**						
	(29.236)	(13.393)						
Internet users			1.064***	0.361**				
			(0.376)	(0.156)				
Fixed broadband subscription					0.853	1.948**		
					(0.638)	(0.796)		
Mobile cellular subscription							0.099	0.496
							(0.182)	(0.451)
Log of GDP per capita	2.315	25.746*	-3.629	35.652***	23.965**	24.839	23.147**	0.337
	(19.370)	(15.533)	(14.150)	(11.294)	(10.304)	(15.466)	(10.153)	(32.515)
Domestic credit to private sector	0.062	0.083	0.131***	0.083	0.069	-0.102	0.064**	0.113
	(0.049)	(0.119)	(0.050)	(0.112)	(0.042)	(0.136)	(0.031)	(0.211)
Trade openness	-0.200	-0.127	0.022	-0.114	0.017	-0.133	0.089	-0.157
	(0.169)	(0.110)	(0.067)	(0.096)	(0.054)	(0.111)	(0.067)	(0.233)
Years of schooling	0.838	1.336	-5.473	1.587	5.946	1.490	8.817**	10.169**
	(5.873)	(2.031)	(6.459)	(1.902)	(4.999)	(2.073)	(4.498)	(4.000)
Manufacturing share	0.431	-0.151	0.507	-0.222	-0.569	-0.410	-0.774**	0.504
	(0.729)	(0.421)	(0.598)	(0.420)	(0.397)	(0.435)	(0.360)	(0.833)
Working age population	2.682**	0.569	1.308*	0.460	1.904*	1.777*	0.588	-1.820
	(1.053)	(0.743)	(0.765)	(0.721)	(1.067)	(1.025)	(1.550)	(1.361)
Ratio of female to male population	-1.450	-2.616*	-0.242	-2.846*	0.044	-3.085	-0.168	0.948
	(1.728)	(1.584)	(0.860)	(1.527)	(1.188)	(2.094)	(1.259)	(3.146)
Institutional quality index	-1.932	2.999	0.342	2.717	1.734	6.396*	1.676	0.271
	(3.243)	(3.806)	(1.851)	(3.912)	(1.927)	(3.887)	(1.651)	(6.580)
No. of observations	134	158	134	158	134	158	102	119
R-square (within)	0.215	0.628	0.544	0.666	0.566	0.533	0.410	0.123
First Stage F-statistic	2.17	12.54	4.000	11.28	11.26	7.58	2.89	1.22
	0.1204	0.0000	0.0216	0.0000	0.0000	0.0008	0.0635	0.3009
Hansen J-statistic	0.017	2.723	0.282	3.252	2.715	0.466	0.316	0.408
	0.8971	0.0989	0.5956	0.0714	0.0994	0.4951	0.5739	0.5227

Table 8: Results from instrumental variable regression (Sub-Sample)

Note: "Standard errors in parentheses, *** p<.01, ** p<.05, * p<.10". Dependent Variable: % of respondents having bank account ownership.

The results suggest that people are more likely to open and utilize bank accounts and take loans if they have access to ICT tools that enable them to monitor transactions and balances online. Additionally, as a sensitivity analysis we employed the alternative measure of financial inclusion, specifically access to borrowings, the results of which is presented in Table 9 and 10, confirming the positive and significant impact of ICT index and its indicators i.e., internet penetration, and fixed broadband subscription on financial inclusion. Finally, the study highlights two control variables, GDP per capita and years of schooling, which are highly significant factors that impact financial inclusion.

As a robustness test, we employ instrumental variable regression, and the results in Table 8 and 10 shows that all two indicators of ICT have a significant and positive impact on financial inclusion and log of GDP per capita and years of schooling are highly significant factors that impact financial inclusion.

	ICT Index		Internet Penetration		Fixed broadband subscription		Mobile cellular subscription	
	High Income	Middle Income	High Income	Middle Income	High Income	Middle Income	High Income	Middle Income
ICT index	31.604**	13.860***						
	(15.031)	(4.680)						
Internet users			0.319	0.158**				
			(0.226)	(0.061)				
Fixed broadband subscription					1.195**	0.682**		
					(0.533)	(0.284)		
Mobile cellular subscription							0.229	0.032
							(0.140)	(0.026)
Log of GDP per capita	-48.897**	2.739	-45.261*	8.068	-43.015*	5.385	-38.008	12.041
	(23.794)	(8.312)	(26.315)	(7.525)	(22.804)	(8.438)	(26.045)	(7.853)
Domestic credit to private sector	-0.125	0.149	-0.111	0.140	-0.091	0.086	-0.141	0.181*
	(0.101)	(0.091)	(0.101)	(0.091)	(0.096)	(0.099)	(0.115)	(0.099)
Trade openness	-0.438***	-0.021	-0.321**	-0.006	-0.362**	-0.016	-0.354***	-0.014
	(0.125)	(0.072)	(0.151)	(0.070)	(0.147)	(0.067)	(0.126)	(0.082)
Years of schooling	13.379**	0.062	13.570**	0.199	10.927	0.446	20.974***	1.555
	(5.673)	(0.866)	(6.589)	(0.834)	(6.503)	(0.854)	(5.535)	(1.187)
Manufacturing share	1.216	-0.131	0.942	-0.156	1.161*	-0.262	0.595	-0.320
	(0.750)	(0.352)	(0.835)	(0.371)	(0.679)	(0.340)	(0.834)	(0.409)
Working age population	-4.533***	-0.610	-5.235***	-0.698	-4.289***	-0.290	-4.661***	-1.013**
	(1.578)	(0.403)	(1.604)	(0.418)	(1.526)	(0.473)	(1.651)	(0.456)
Ratio of female to male population	-3.519	-1.871*	-2.722	-1.747**	-3.396	-1.876*	-3.257	-1.722*
	(2.218)	(0.952)	(2.189)	(0.848)	(2.100)	(1.020)	(2.389)	(0.972)
Institutional quality index	-1.190	-1.890	0.112	-2.114	1.060	-0.303	0.074	0.124
	(3.745)	(2.672)	(3.482)	(2.779)	(3.540)	(2.608)	(3.910)	(2.945)
Constant	1052.598**	211.725*	967.677**	159.859*	972.900**	173.609	831.784*	138.260
	(411.814)	(109.119)	(461.226)	(89.961)	(392.466)	(112.938)	(463.134)	(108.008)
No. of observations	136	159	136	159	136	159	136	159
R-square (within)	0.466	0.362	0.441	0.359	0.465	0.364	0.453	0.307

Table 9: Results from fixed effects regression (Sub-sample)

Note: "Robust standard errors in parentheses, *** p<.01, ** p<.05, * p<.10". Dependent Variable: Percentage of respondents taken loan from formal financial institution.

	ICT Index		Internet Penetration		Fixed broadband subscription		Mobile cellular subscription	
	High Income	Middle Income	High Income	Middle Income	High Income	Middle Income	High Income	Middle Income
ICT Index	23.791	18.730*						
	(40.824)	(9.988)						
Internet users			0.414	0.215*				
			(0.742)	(0.125)				
Fixed broadband subscription					0.269	1.250**		
					(0.861)	(0.518)		
Mobile cellular subscription							0.121	0.609
							(0.599)	(0.754)
Log of GDP per capita	-40.816	0.228	-43.522	6.358	-32.399	-1.323	-31.875	-23.821
	(28.212)	(9.942)	(31.505)	(7.972)	(22.218)	(9.371)	(24.000)	(49.646)
Domestic credit to private sector	-0.110	0.117	-0.082	0.119	-0.109	-0.005	-0.125	0.073
	(0.095)	(0.081)	(0.118)	(0.082)	(0.103)	(0.096)	(0.103)	(0.174)
Trade openness	-0.390*	-0.004	-0.307**	0.004	-0.307**	-0.008	-0.319*	0.073
	(0.210)	(0.065)	(0.133)	(0.065)	(0.136)	(0.061)	(0.179)	(0.161)
Years of schooling	13.522*	-0.488	10.908	-0.306	15.766**	-0.521	18.682**	0.705
	(7.760)	(1.290)	(12.025)	(1.332)	(7.679)	(1.213)	(8.214)	(1.937)
Manufacturing share	1.048	-0.031	1.100	-0.079	0.644	-0.179	0.542	0.280
	(1.190)	(0.328)	(1.256)	(0.337)	(0.874)	(0.290)	(0.791)	(0.820)
Working age population	-4.427**	-0.543	-	-0.615	-4.761***	0.265	-4.656**	-1.584
	(1.790)	(0.424)	(1.554)	(0.429)	(1.750)	(0.659)	(2.252)	(0.990)
Ratio female to male population	-3.627	-1.454**	-3.189	-1.590**	-3.024	-1.759*	-3.227	0.439
	(2.514)	(0.723)	(2.129)	(0.717)	(2.102)	(0.925)	(3.019)	(2.867)
Institutional quality index	-1.321	-2.983	-0.483	-3.100	0.026	-0.998	-0.325	-5.114
	(4.064)	(2.912)	(3.374)	(3.039)	(3.514)	(2.752)	(3.737)	(7.921)
No. of observations	134	158	134	158	134	158	134	158
R-square (within)	0.452	0.361	0.426	0.344	0.435	0.315	0.437	-0.977
First stage F-statistic	2.17	12.54	4.00	11.28	11.26	7.58	2.82	0.34
	(0.1204)	(0.0000)	(0.0216)	(0.0000)	(0.0000)	(0.0008)	(0.0651)	(0.7116)
Hansen J-statistic	0.011	3.218	0.000	3.406	0.162	1.299	0.234	1.554
	(0.9150)	(0.0729)	(0.9938)	(0.0649)	(0.6877)	(0.2545)	(0.6287)	(0.2125)

Table 10: Results from instrumental variable regression (Sub-Sample)

Note: "Standard errors in parentheses, *** p<.01, ** p<.05, * p<.10". Dependent Variable: Percentage of respondents taken loan from formal financial institution

Conclusion

This study investigates the impact of information and communication technology (ICT) on financial inclusion in a panel of 74 countries for a period of four years i.e., 2011, 2014, 2017 and 2021. We have constructed an ICT index using the principal component analysis (PCA) method. The ICT index comprises three indicators such as internet penetration, fixed broadband subscription, and mobile cellular subscription. We employ panel regression methods to estimate our model. Specifically, we used the fixed effects regression as a preliminary analysis. However, to mitigate the potential endogeneity concern in the model, we utilize the panel instrumental variable (IV) regression as our preferred estimation method. We consider two different indicators i.e., bank account ownership and access to borrowings from the Global Findex Database, to measure the level of financial inclusion in the country. We find a positive and statistically significant impact of ICT index on financial inclusion. As a sensitivity analysis, we split the sample into two sub-groups – high-income and middle-income countries. Our results suggest that ICT is a significant determinant of financial inclusion in the sample countries. Specifically, internet penetration is a robust driver of financial inclusion in middle-income countries. The findings underline the critical role of ICT infrastructure in promoting financial inclusion and laying the ground for subsequent economic opportunities and overall development worldwide. The policymakers, particularly in middle-income countries should focus on expanding the internet base to achieve higher financial inclusion in the country.

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