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Measuring Digital Financial Inclusion in Emerging Market and Developing Economies: A New Index

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Measuring Digital Financial Inclusion in Emerging Market and Developing Economies: A New Index

Short running title: A Novel Digital Financial Inclusion Index

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Research Highlights:

- Our novel cross-country digital financial inclusion index provides a comprehensive and more accurate measurement of financial inclusion by incorporating the impact of digitalization along various dimensions.
- Digital financial services have been a key driver of financial inclusion in recent years, even where traditional financial inclusion retreated.
- There is wide variation in digital financial inclusion across countries and regions, with Africa and Asia leading the progress.
- Policy efforts are needed to narrow the digital divide, safeguard trust in financial services, and ensure sustainable financial inclusion.

Abstract: Adoption of technology in the financial services industry has been accelerating in recent years. To assess its contribution to financial inclusion, we develop a novel digital financial inclusion index covering 52 emerging market and developing economies. We find that (i) the adoption of digital financial services has been a key driver of financial inclusion; and (ii) there is wide variation across countries and regions, with the greatest progress recorded in Africa and Asia. Given the accelerated adoption of digital payments during the COVID-19 pandemic, policies are needed to close the digital divide to ensure continued progress in financial inclusion and safeguard trust in financial services.

Keywords: digital financial services; electronic money; financial inclusion; fintech; mobile money

JEL codes: C38, G10, G20, O30

1. Introduction

The rapid adoption of digital technology in finance offers a large potential to increase financial inclusion, namely, access to and usage of financial services by a wide section of the population. Digital financial services (DFSs), enabled by fintech (technological innovation in the financial sector), can help overcome the often-cited obstacles in accessing traditional financial services such as cost, geographical barriers, and information asymmetry. Recognizing this potential, the United Nations, Sustainable Development Goals include targets both on traditional and digital inclusion measures (Target 8.10). There are several anecdotal evidence, including country-based case studies (Jack and Suri, 2011; 2014; Tarazi and Breloff, 2010) and regional studies (Sy et. al., 2019; Berkmen et. al., 2019; Loukoianova et al, 2019, Lukonga, 2018, and Blancher et al., 2019), that show how fintech is increasing access to financial services, especially for those previously unbanked or underserved.

Existing literature primarily focuses on financial inclusion facilitated by financial institutions such as banks, i.e. traditional financial inclusion. This is measured by indicators related to access to and/or usage of traditional financial services, such as the number of bank account per capita and ATM per capita, or combining these indicators into a composite index (Beck, Demirguc-Kunt and Martinez Peria, 2007, Honohan, 2008). Some recent studies have quantified the degree of digital financial inclusion by looking at relevant indicators, such as mobile money accounts and financial transactions using mobile phone (Sy et al., 2019; Loukoianova et al., 2019; Camara and Tuesta, 2017). However, these measures capture a single aspect of digital financial inclusion at a time, and do not present a comprehensive picture combining multiple aspects.

This paper aims to fill this gap in the existing literature by incorporating both measures of access to and usage of DFSs into the measurement of financial inclusion. The key contribution of this paper is the construction of a digital financial inclusion index, covering 52 emerging markets and developing economics (EMDEs) for 2014 and 2017.[2] The index is composed of indicators related to access to and usage of financial services provided through digital means, taking advantage of the new and expanded data coverage of the World Bank Global Findex Database and IMF's Financial Access Survey (FAS) data series on mobile money and other means of online financial services. We exclusively focus on the payment aspects of financial inclusion,[3] reflecting the fact that payments are often the first step and the gateway to gaining access to financial services. Other aspects of financial services, such as credit and insurance, tend to come later with financial development and deepening, for which cross-country comparable data related to financial inclusion are still scarce.

[2] The index was originally developed for and presented in Sahay et. al (2020).

[3] The index does not cover wider topics related to financial inclusion such as cross-border payments, and the impact of central bank digital currency.

We employ a three-stage principal component analysis (PCA), a commonly used objective weighting methodology in the literature. The first stage computes the access and usage sub-indices. Access is primarily captured by indicators related to availability of means to access payments services (e.g., accessibility to the internet and mobile phone). Usage focuses on demand-side elements, such as account ownership and making/receiving payments through these accounts. At the second stage, we combine the access and usage sub-indices into the digital financial inclusion index. An index of traditional financial inclusion similar to those in existing literature is constructed following the same methodology. At the third stage, the digital and traditional financial inclusion indices are aggregated into a comprehensive measure of financial inclusion.

Our financial inclusion indices have several advantages over past measures. First, it provides a more comprehensive picture of financial inclusion by incorporating the digital channel. Second, instead of relying on a single indicator, such as mobile money account ownership, combining data from a variety of sources allows us to capture DFSs' contribution to financial inclusion from a multi-dimensional perspective. Third, the granular view along the usage/access and digital/traditional aspects allow for more detailed understanding of the relative contribution and drivers of changes in financial inclusion in recent years. This would help inform policymakers in developing appropriate approaches in promoting financial inclusion.

Our measure indicates that fintech has had a significantly positive impact on financial inclusion in payments. Digital financial inclusion increased between 2014 and 2017 across all countries, even where traditional financial inclusion was stalling or declining. Most countries saw an increase in both the access and usage dimensions. However, there are noticeable regional differences, with countries in Africa and Asia and the Pacific in the lead.

Our index offers a useful analytical tool for researchers and policy makers. Khera et al. (2021a) use these indices to conduct a cross-country examination of the impact of digital financial inclusion on economic growth, and explore its key drivers. Using the methodology in this paper, Khera et al. (2021b, forthcoming) compute gender-based digital financial inclusion indices – i.e., female versus male digital financial inclusion index – and use it to understand the determinants of gender gaps in digital financial inclusion across countries.

While our index should offer a useful analytical tool for researchers and policy makers, the analyses in this paper has limitations primarily driven by data constraints. First, the index lacks long time-series, and the size of the sample of countries is relatively small and excludes advanced economies. Second, the databases used for the construction of the index do not differentiate between the providers of DFSs. In other words, the digital financial inclusion index would capture services provided by fintech companies as well as banks (such as mobile banking) including in partnerships with DFSs. Similarly, the databases do not provide granular information on the range of financial services a user has access to (e.g., only banks, only DFS, or both). This limits the understanding of whether DFSs are broadening financial inclusion, or providing alternative means of access to those already financially included.

The remainder of the paper is organized as follows: Section 2 presents literature review; Section 3 lays out the methodology; Section 4 discusses underlying data and stylized facts; Section 5 presents the index and findings; and Section 6 concludes.

2. Literature Review

Existing measures of financial inclusion in the literature focus on financial services primarily provided by banks. Initial studies relied on single measures of financial inclusion by using different banking-service indicators such as: the number of branches and/or ATMs per adult population, and bank accounts per capita (e.g., Beck, Demirgüç-Kunt, and Martinez Peria, 2007; Honohan, 2008). But Sarma (2008) points out that the use of an individual indicator to assess the extent and impact of financial inclusion can be misleading. More recent studies have constructed more comprehensives measures of financial inclusion that combine different dimensions of financial inclusion, taking into account various aspects of access and usage by household and firms (Amidžić, Massara, and Mialou, 2014; Dabla-Norris et al, 2015; Camara and Tuesta, 2017). The papers generally find improved access over the last ten years. However, women, the poor, the young, and rural population are found to be disproportionally excluded (Demirguc-Kunt, Klapper and Singer, 2013; Aslan et al., 2017).

These measures, however, do not fully capture the contribution from the increasingly important role of technology in financial services. Mobile money operators and other fintech companies are newly entering the financial sector at varying pace across geographical regions and countries. At the same time, banks and existing financial institutions are starting to adopt technology in delivering services. While the latter may be partially reflected in the traditional measures of financial inclusion, improved access and usage of financial services enabled by fintech companies are yet to be fully captured and quantified. Therefore, incorporating financial inclusion through digital means could present a more comprehensive, and potentially a very different, understanding of the progress across time and country. Some recent studies quantify the degree of digital financial inclusion by looking at relevant indicators, such as mobile money accounts and financial transactions using mobile phone (Sy et al., 2019; Loukoianova et al., 2019; Camara and Tuesta, 2017).

There is a rapidly growing body of literature on DFSs and financial inclusion, largely focused on experiences in specific countries or regional developments in fintech activities. Jack and Suri (2011, 2014) survey the rapid adoption of mobile phones and mobile money in Kenya, and find that mobile money has a significant impact on households' ability to share risks. Tarazi and Breloff (2010) reviews the regulatory approaches taken in light of the increasing role of mobile network operators in providing financial services, including to safeguarding and isolating funds. Others follow regional development in fintech activities, for example, Sy et al. (2019), on Sub-Saharan Africa; Berkmen et al. (2019) on Latin America and the Caribbean; Loukoianova et al. (2019) on Pacific Islands; and Lukonga (2018) and Blancher et al. (2019) on Middle-East and Central Asia. IMF (2019) takes stock

of the fintech developments by geographical regions, and discusses key policy issues such as balancing competing policy priorities, addressing infrastructure constraints, developing legal and regulatory framework, and data and cybersecurity issues.

3. Methodology[4]

We construct a composite measure of financial inclusion ("comprehensive financial inclusion index") consisting of both financial inclusion through financial institutions such as banks ("traditional financial inclusion index") and through DFSs and digital means ("digital financial inclusion index"). Digital financial inclusion index reflects digital delivery of financial services, including mobile money operators, fintech companies, others newly entering the financial sector, as well as internet and mobile banking offered by traditional banks.

The indices cover 52 EMDEs for which comprehensive data on financial inclusion related variables is available. Data on access and usage aspects of financial inclusion are compiled using global data sources, including IMF's Financial Access Survey (IMF FAS),[5] the World Bank Global Findex, International Telecommunication Union, and the GSMA Mobile Money Dataset. The indices are constructed for 2014 and 2017, as the Global Findex survey data is only available every three years since 2011, and that its coverage of data related to DFSs is relatively limited for 2011. The focus on payments reflects its role as an entry point to financial inclusion, and the greater role mobile money payment services play in low-income and lower middle-income countries. While mobile money payment service providers have also started to extend credit and insurance services to their users in many of these countries, it is still at an early stage and their sizes remain miniscule. For example, total outstanding alternative finance was less than 0.1 percent of GDP in 2017 for most countries in our sample, except China (the Cambridge Centre for Alternative Finance).[6] In contrast, the value of mobile money transactions ranged from around 20 percent of GDP in Bangladesh and Senegal to over 140 percent of GDP in Zimbabwe in 2018.

A three-stage PCA is used to construct this new measure,[7] to capture different aspects of financial inclusion at each stage: in the first stage, the supply-side ("access") and demand-

[4] See Appendix I for a detailed overview of the methodology, underlying indicators and the weights assigned to each for constructing the indices.

[5] See Espinosa-Vega et. al, (2020) for an overview of the database.

[6] See Bazarbash and Beaton (2020) for developments in marketplace lending.

[7] The approach is similar to the methodology used in the existing literature on traditional financial inclusion (Sahay et. al., 2015b; Loukoianova et. al., 2018; Blancher et. al., 2019; and Camara and Tuesta, 2017). It is a

side ("usage") aspects of financial inclusion; in the second stage, the financial inclusion through financial institutions ("traditional") and enabled by technology ("digital"); and on the third and final stage, a comprehensive index encompassing all these sub-components. The weights assigned to the underlying indicators using PCA are biased towards those that are highly correlated to each other. Estimating the sub-indices in separate stages, rather than estimating the comprehensive index in one stage, helps address this bias. The three indices (traditional, digital and comprehensive) are constructed and normalized separately based on data for both 2014 and 2017. While their respective levels can be compared over time but are not directly comparable across indices, they give a sense of where a country stands relative to the sample (e.g., most advanced in digital inclusion but around average on traditional).

Indicators for digital financial inclusion index broadly mirror the components of traditional financial inclusion indices in existing literature. For instance, supply-side measures are represented by accessibility to digital infrastructure (i.e., mobile subscription and access to internet) and to mobile agents for digital financial inclusion, and by accessibility to ATMs and bank branches is used for traditional financial inclusion. Similarly, demand-side measures encompass account holdings (mobile money for digital and at a financial institution for traditional financial inclusion index) and active use of the services (e.g., use of mobile money and financial institutions accounts, respectively, for payments and receipt of wages).[8]

Mobile money agents play an important complementary role in enabling access to financial services for people who don't own mobile phone or don't have direct access to internet. They provide cash-in and cash-out services, converting physical cash to digital value and vice-versa, and for onboarding new customers. While regional aggregates and country-specific data on mobile money agents is available from the GSMA and IMF FAS respectively, this data is not complete (for instance, for 2017 the IMF FAS only has data for 22 countries in our sample). We supplemented the missing data by estimates based on various data sources, including mobile money service providers, GSMA, IFC Mobile Money Scoping country reports, and articles and reports including from the Consultative Group to Assist the Poor (CGAP).

4. Findings

We find countries in Africa and Asia and the Pacific regions in our sample to have high degrees of digital financial inclusion compared to other regions (Figure 1, Appendix Table

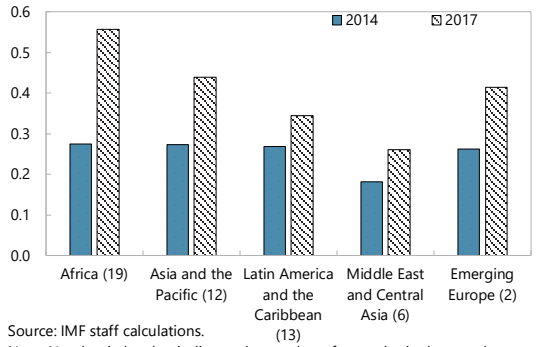
statistical procedure which allows reducing the dimension of a large number of interrelated variables while preserving as much information in the data as possible.

[8] It should be noted that mobile-related variables have the same weights as traditional bank-related variables in the final index, as we are using weights coming from first principal component. This could lead to some bias in the final results in countries especially where DFSs have smaller presence compared to traditional financial services.

I.8). African countries, led by Ghana, Kenya and Senegal, account for majority of the countries with the top quartile of the index in 2017, as well as China, Bangladesh and Malaysia. Countries in Latin America and the Caribbean rank around the middle, with Dominican Republic, Chile and Argentina among the highest for the region.

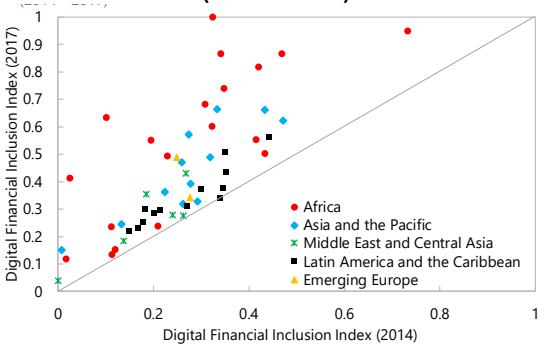
Most countries saw an increase in digital financial inclusion index between 2014 and 2017, and the improvement was particularly large in African countries (Figure 2). Ghana, Benin, and Senegal were among the highest gainers. On the other hand, the index level did not see significant increase for some of the countries in Latin America and the Caribbean, and Middle East and Central Asia. Most countries saw an increase in both the access and usage dimensions, while for a small number of countries, the improvement was driven by the increase in usage.

Figure 1. Digital financial inclusion index



Source: IMF staff calculations.
Note: Number in bracket indicates the number of countries in the sample.

Figure 2. Progress in digital financial inclusion (2014 – 2017)

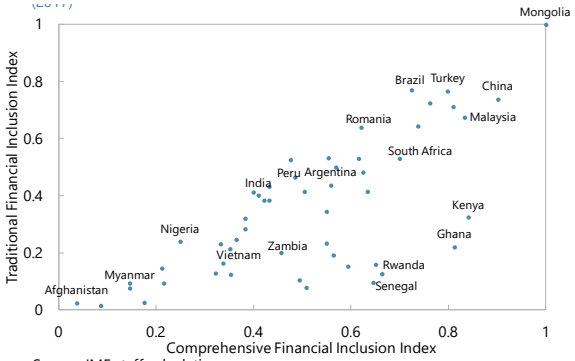


Source: IMF staff calculations.

Incorporating digital financial inclusion indicators results in significant changes in relative ranking of overall financial inclusion for some countries (Figure 3). In specific, countries with high digital but low traditional inclusion see improvements in the ranking of comprehensive financial inclusion index compared that based on traditional financial inclusion index. On the other hand, countries with well-developed bank infrastructure and high bank penetration but low adoption of fintech may see declines in their overall rankings. While most countries stay at similar position measured by both traditional and comprehensive index, we see notable improvements in countries that are leading in digital financial inclusion. This means that people in countries that have similar levels of traditional financial inclusion (as typically captured in existing literature) indeed could have very different experiences in accessing and using financial services when digital measures of inclusion are taken into account. For example, Kenya, Botswana and Jordan rank similar in terms of traditional financial inclusion index. While Botswana remains at a similar rank in terms of comprehensive financial inclusion index, Kenya ranks in the top group and Jordan around the bottom 1/3 of the countries in our sample. Similarly, Uganda ranks among the top quartile and Togo in the bottom quartile in the comprehensive measure, while both Uganda and Togo are in the bottom quartile in terms of traditional financial inclusion.

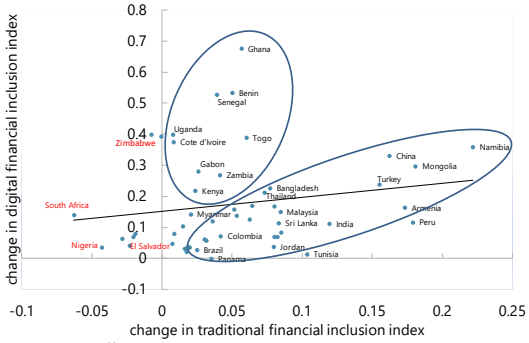
Looking at progress in comprehensive financial inclusion, we find that improvements are entirely driven by the progress in digital financial inclusion in some countries (Figure 4). Most countries saw improvements in both traditional and digital financial indices between 2014 and 2017. There are, however, eight countries where the increase in digital inclusion index was accompanied by a fall in traditional inclusion index. Sub-components of traditional index indicate that this is driven more by the fall in demand (usage) rather than the access (supply). This could reflect substitution by technology-related financial services away from traditional financial institutions, and/or banks themselves shifting towards technology-based delivery of services as opposed to physical presences.

Figure 3. Comprehensive vs. traditional F.I Index (2017)



Source: IMF staff calculations.

Figure 4. Changes in financial inclusion indices (from 2014 – 2017)



Source: IMF staff calculations.

5. Conclusion

This paper relies on a broad set of indicators to build a new measure of digital financial inclusion. This is used to identify countries where DFSs have played a significant role in expanding both the access to and usage of financial services to a wider population. We take advantage of the new data and expanded coverage of the World Bank's Global Findex Database on usage of mobile money and online financial services, and the IMF FAS data series on access to mobile money accounts, and supplement it by data on access to mobile money agents put together using various data sources. Three-stage principal component analysis (PCA) is employed to determine the weight on each indicator, where the first stage computes the access and usage sub-indices; the second stage then combines these sub-indices into traditional and digital financial inclusion indices, and a weighted combination of these forms a comprehensive measure of overall financial inclusion at the third stage.

Our indices indicate that most of the 52 EMDEs in our sample saw improvements in digital financial inclusion between 2014-17, particularly in countries in Africa and Asia and the Pacific on average. Comprehensive financial inclusion, taking into account both traditional and digital measures, improved in most of the countries over the same period, however in some countries, the improvement was entirely driven through digital means. Incorporating digital financial inclusion indicators in the overall measure of financial inclusion gives a more accurate estimate of differences in financial inclusion across countries.

The growing role and rapid adoption of DFSs, including during the COVID-19 pandemic, pose important policy implications. First, there is risk that digital divide could lead to financial exclusion. While mobile subscription increased sharply, including in LICs since mid-2000s, there are persistent gaps in mobile ownership among population (e.g., male/female, rural/urban, and different age groups). Second, financial and digital literacy is key in facilitating sustainable financial inclusion. Some DFSs are expanding their businesses from payments to credit, leveraging new sources of data. While this has helped broaden the access to credit to those who were previously difficult to conduct assessment of creditworthiness on, there are instances where it has led to overborrowing and high delinquency. Third, a loss of trust in digital technology, for example stemming from concerns on cyber security and data privacy, could have spillover effect on confidence in broader financial services and set back financial inclusion. The public sector has a significant role to play in addressing these challenges, by investing in digital infrastructure, promoting education, and strengthening and adapting regulatory frameworks to address challenges and risks to financial integrity, consumer protection, and financial stability.

Comprehensive measurement of financial inclusion would serve as a useful tool in understanding main drivers and obstacles, and inform policy making for advancing financial inclusion (Khera et al. (2021a, 2021b). While there are challenges in constructing the index, mainly due to data coverage limitations, this paper attempted to contribute towards this effort. We strive to continue improving the digital financial inclusion indices by addressing some of its limitations as new data becomes available.

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Appendix I: Construction of the Financial Inclusion Index

1. Coverage:

Appendix Table I.1. Breakdown of Countries by Region

Asia and the Pacific	Africa	Latin America and the Caribbean	Middle East and Central Asia	Emerging Europe
Bangladesh	Benin	Argentina	Afghanistan	Romania
Cambodia	Botswana	Bolivia	Armenia	Turkey
India	Cameroon	Brazil	Tunisia	
Indonesia	Democratic Republic of Congo	Chile	Jordan	
Malaysia	Republic of Congo	Colombia	Mauritania	
Mongolia	Cote d'Ivoire	Dominican Republic	Pakistan	
Myanmar	Gabon	El Salvador		
Philippines	Ghana	Guatemala		
Sri Lanka	Kenya	Honduras		
Thailand	Madagascar	Mexico		
Vietnam	Namibia	Nicaragua		
China	Nigeria	Panama		
	Rwanda	Peru		
	Senegal			
	South Africa			
	Togo			
	Uganda			
	Zambia			
	Zimbabwe			

2. Data and data sources: Appendix Table I.2 list the variables used for each dimension of the index.

Appendix Table I.2. Selected variables for constructing financial inclusion indices

Overall Financial Inclusion Index					
Traditional Financial Inclusion Index	**Data Source**	**Weight**	**Digital Financial Inclusion Index**	**Data Source**	**Weight**
Access[9]			**Access**		
Access to bank infrastructure		0.25	**Access to digital infrastructure**		0.125
Number of ATMs per 100,000 adults	IMF FAS		Mobile subscription per 100 people	ITU	
Number of Branches per 100,000 adults			% of population who have access to internet		
			Number of registered mobile money agents per 100,000 adults	IMF FAS GSMA Auth. est.	0.25

[9] For missing data from IMF's FAS on ATM per 100,000 adults and commercial bank branches per 100,000 adults, we use proxy variables (i.e. ATM per 10,000 km^2 and bank branches per 10,000 km^2) to interpolate the missing data. When data on proxy variable is also not available, missing data is filled with the general past trend in the variable.

Usage	0.25	**Usage**[10]	0.125
% of adults with a financial institution account		% of adults who have a mobile account	
% of adults who save at a financial institution		% of adults who use internet to pay	
% of adults with debit cards	WB Findex	% of adults who use mobile phone to receive salary or wages	WB Findex
% of adults who received wages through a financial institution account		% of adults who use mobile phone to make utility payments	
% of adults who use a financial institution account for utility			

Note: 'Weight' is the weight of the variable in the overall index of financial inclusion

The data on mobile money agents' density primarily draws on country-specific data from IMF's FAS which has data for 38 countries in our sample starting in 2009 until 2018. To fill in the many missing datapoints in the FAS and for the remaining 14 countries in our sample, we drew on publicly available data from respective country's mobile money service providers, IFC Mobile Money Scoping country reports, and articles and reports including from the Consultative Group to Assist the Poor (CGAP). Overall, sum of mobile money agents across the country-specific data in each region is checked against the regional aggregate data that is publicly available from the GSMA to ensure consistency.[11] The point-in-time data collected for each country is used to estimate time series for 2013-17, based on the real GDP growth and adjusted for the year of the launch of services. The dataset is then trimmed by the 2nd and 98th percentile to avoid having extreme values driving the highest and lowest scores. Appendix Table I.3 reports the summary statistics of the selected variables for the traditional financial inclusion index and digital financial inclusion index.

Appendix Table I.3. Summary statistics of selected variables for the indices

	Obvs.	Mean	Standard Deviation	Range
Access (Traditional)				
ATM per 100,000 population	104	32.17	29.49	109.31
Bank branches per 100,000 population	104	11.47	7.84	32.66
Usage (Traditional)				
Account at a F.I. (%)	104	40.57	21.25	75.56

[10] FAS also includes annual data on mobile money transactions and volumes. However, it is not comprehensive in terms of its country coverage which is why we do not include it in our index.

[11] The GSMA has aggregate data for the following regions: Europe and Central Asia, Middle East & North Africa, Sub-Saharan Africa, East Asia & Pacific, South Asia, Latin American & Caribbean, spanning from 2011 to 2018.

Saving at a F.I. (%)	104	15.31	9.34	35.52
Debit card (%)	104	24.87	18.25	65.05
F.I account for wages (%)	104	7.03	6.15	25.35
F.I account for utility (%)	104	6.27	6.42	25.02
Access (Digital)				
Mobile subscription per 100 ppl.	104	105.16	31.03	130.48
Internet (%)	104	33.00	18.76	66.26
Usage (Digital)				
Mobile account (%)	104	11.11	13.63	50.42
Use internet to pay (%)	104	8.11	7.77	35.82
Mobile for wages (%)	104	1.81	2.73	11.59
Mobile for utility (%)	104	3.22	4.25	18.50
Mobile Money Agents				
Registered mobile money agents	104	138.14	192.72	743.52

Note: F.I. is financial institutions.

3. Weighting of variables: A three-stage principal component analysis (PCA) is used to construct the comprehensive financial inclusion index for each country.[12] In the first stage of the PCA, we estimate the two sub-indices: 'access' and 'usage', separately for traditional and digital financial inclusion. In the second stage, we estimate the traditional and digital financial inclusion indices by using the access and usage dimensions, computed in the first stage, as explanatory variables. In the third stage we compute the comprehensive financial inclusion measure by using the two types of financial inclusion, estimated in stage two, as explanatory variables.

3.1 First-stage PCA

In the first stage, the sub-indices for 'access' and 'usage' categories in both traditional (FI_T^a, FI_T^u) and digital component (FI_F^a, FI_F^u) are constructed based on selected variables listed in Table 1.

Access component (FI_T^a) of traditional financial inclusion is determined by: ATMs per 100,000 population (X_1) and bank branches per 100,000 population (X_2); whereas the usage component (FI_T^u) is determined by: percentage of adults with a financial institution account (Y_1), percentage of adults who saves at a financial institution (Y_2), percentage of adults with debit cards (Y_3), percentage of adults who received wages through a financial institution

[12] PCA is a statistical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables (see Jolliffe, 1986).

account (Y_4), and percentage of adults who use a financial institution account to make utility payments (Y_5).

$$(FI_T^a)_{it} = \sigma_1(X_1)_{it} + \sigma_2(X_2)_{it} + d_{it}$$

$$(FI_T^u)_{it} = \theta_1(Y_1)_{it} + \theta_2(Y_2)_{it} + \theta_3(Y_3)_{it} + \theta_4(Y_4)_{it} + \theta_5(Y_5)_{it} + n_{it}$$

where *i* denotes the country and $t \epsilon (2014, 2017)$ corresponds to each of the two years. The total variation in the access and usage dimensions is represented by two orthogonal parts: variation due to the explanatory variables and variation due to error, $d(i)$ and $n(i)$ respectively. If the model is well specified, then E(e) = 0 and E(μ)= 0, and the variance of the error term is relatively small compared to the variance of the latent variables, the latter being 'access' and 'usage' of traditional payment services, respectively.

Similarly, for dimensions of digital financial inclusion, the access component (FI_F^a) is determined by mobile subscription per 100 people (K_1) and percentage of population with access to the internet (K_2). The usage component (FI_F^u) is determined by percentage of adults with a mobile account (P_1), percentage of adults who use internet to pay (P_2), percentage of adults who use a mobile phone to receive wages (P_3), and percentage of adults who use a mobile phone to make utility payments (P_4).

$$(FI_F^a)_{it} = \rho_1(K_1)_{it} + \rho_2(K_2)_{it} + u_{it}$$

$$(FI_F^u)_{it} = \tau_1(P_1)_{it} + \tau_1(P_2)_{it} + \tau_3(P_3)_{it} + \tau_4(P_4)_{it} + v_{it}$$

For each dimension-related sub-index, PCA produces linear combinations of the underlying variables to generate principal components. Principal components are ordered so that the first component accounts for the largest possible amount of variation in the explanatory variables. The first principal component, PC_1, explains more than 70 percent of the explanatory variables' total variation (Appendix Table I.4).

Appendix Table I.4. First-stage PCA: Cumulative variance explained by principal components

Access (Traditional)		**Access (Digital)**	
PC_1	0.7982	PC_1	0.7884
PC_2	1.0000	PC_2	1.000
Usage (Traditional)		**Usage (Digital)**	
PC_1	0.7759	PC_1	0.7495
PC_2	0.8986	PC_2	0.9311
PC_3	0.9623	PC_3	0.9774
PC_4	0.9849	PC_4	1.0000
PC_5	1.0000		

To calculate the sub-indices for each country and year, underlying explanatory variables (x) and their respective absolute loadings (L) are needed. In the equation, the explanatory

variables are standardized such that standard deviation equals to 1 and mean equals to 0. The absolute loadings are taken from the first principal component (Appendix Table I.5: column 3). The index score (PC_{score}) is hence defined as:

$$PC_{score} = \sum_{i=1}^{n} L_i x_i$$

where PC_{score} equals to the sum of all standardized explanatory variables, denoted by x, weighted by absolute loadings of each variable (L). n specifies the number of explanatory variables within each category. The index scores are then normalized between 0 (lowest) and 1 (highest) across all countries and both years within each category, using a global min-max procedure across all countries and both years – 2014 and 2017:

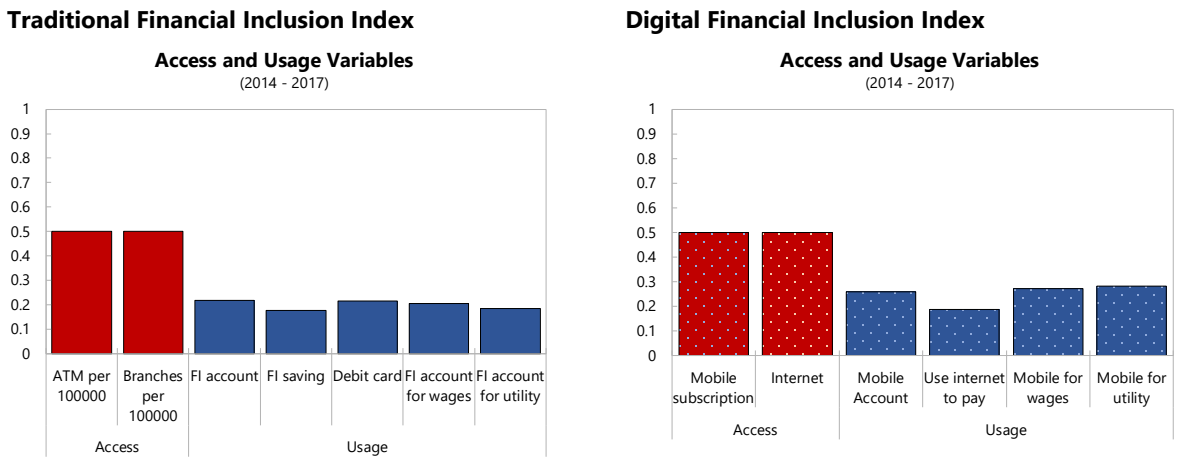
$$x_{normalised} = \frac{x - x_{min}}{(x_{max} - x_{min})}$$

Appendix Table I.5. First-stage PCA: Loadings

Access (Traditional)						
	Notation	PC_1	PC_2			
ATM per 100,000 population	X_1	0.7071	0.7071			
bank per 100,000 population	X_2	0.7071	-0.7071			
Usage (Traditional)						
	Notation	PC_1	PC_2	PC_3	PC_4	PC_5
Account at an F.I (%)	Y_1	0.4842	0.1934	0.0217	-0.5796	-0.6259
Saving at an F.I (%)	Y_2	0.3954	0.7556	0.2523	0.4328	0.1473
Debit Card (%)	Y_3	0.4820	-0.0465	-0.3747	-0.3772	0.6948
F.I account for wages (%)	Y_4	0.4551	-0.3382	-0.5087	0.5736	-0.3012
F.I account for utility (%)	Y_5	0.4120	-0.5245	0.7326	0.0735	0.1140
Access (Digital)						
	Notation	PC_1	PC_2			
Electricity (%)	K_1	0.7071	0.7071			
Internet (%)	K_2	0.7071	-0.7071			
Usage (Digital)						
	Notation	PC_1	PC_2	PC_3	PC_4	
Mobile account (%)	P_1	0.5130	-0.4231	0.5674	0.4857	
Use internet to pay (%)	P_2	0.3722	0.8911	0.1412	0.2181	
Mobile for wages (%)	P_3	0.5356	-0.1541	-0.7974	0.2315	
Mobile for utility (%)	P_4	0.5580	-0.0575	0.1496	-0.8142	

To know the relative importance of each explanatory variable in the sub-indices, we can derive the weighting, which is the percentage contribution of each variable to the sub-indices, from the loadings results in the first principal component. Weightings are shown in Appendix Figure I.2.

Appendix Figure I.2. First stage principal components analysis: Weights



Note: FI in the chart refers to financial institution.

3.2 Second-stage PCA

A second stage PCA then combines these access and usage sub-indices derived in the first stage, separately into the index for traditional and digital financial inclusion.

$$(FI_T)_{it} = \beta_1(FI_T^a)_{it} + \beta_2(FI_T^u)_{it} + e_{it}$$

$$(FI_F)_{it} = \alpha_1(FI_F^a)_{it} + \alpha_2(FI_F^u)_{it} + \mu_{it}$$

$\propto$ and β are the weights assigned to each sub-component (Appendix Figure I.3, left chart). Cumulative variance explained by principle component in the second and the third stage is reported in Appendix Table I.6.

Note that for the digital financial inclusion index, the digital access variable 'mobile money agents (per 100,000 adults)' is added at the second stage PCA, as opposed to including it in the first stage with the other digital access variables. The mobile money agent density is negatively correlated with the access to internet and mobile subscription (Appendix Table I.9), which is consistent with its role in facilitating access to digital payments services to those who don't have access to digital infrastructure themselves. As a result, including it in the first stage PCA assigns a negative weight to mobile money agents. This would imply that higher accessibility to mobile money agents leads to lower access to DFSs, which is counter-intuitive.

Appendix Table I.6. Second and Third-stage PCA: Cumulative variance

Traditional financial inclusion index		Digital financial inclusion index[1]	
PC_1	0.8448	PC_1	0.5435
PC_2	1.0000	PC_2	1.0000
Overall Financial Inclusion Index			
	PC_1	0.6083	
	PC_2	1.0000	

[1]Mobile money agents (per 100,000 adults) are added in this stage.

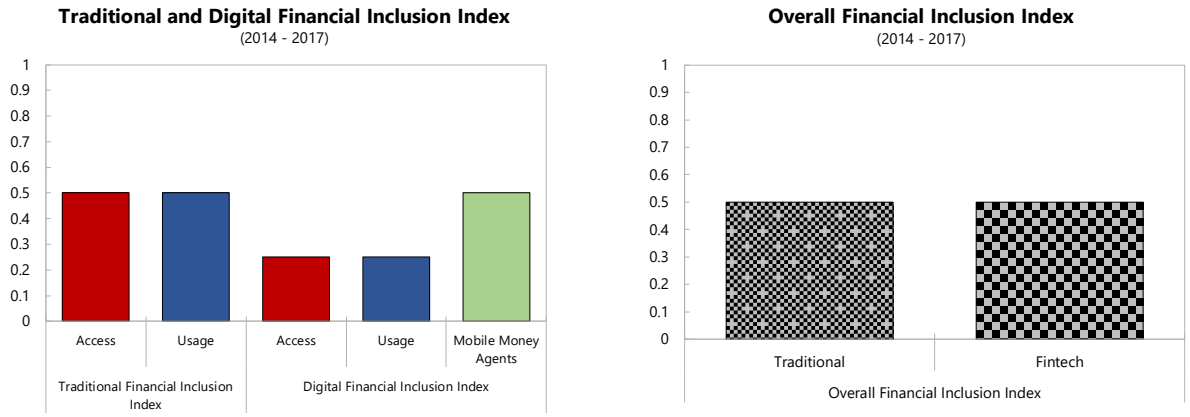
3.3 Third-stage PCA

Finally, the comprehensive financial inclusion index (FI) is computed by applying PCA on the traditional and digital financial inclusion indices, in the last stage, where ω is the weight assigned to each of the two subcomponents (Appendix Figure I.3, right chart).

$$FI_{it} = \omega_1(FI_T)_{it} + \omega_2(FI_F)_{it} + \omega_{it}$$

Similar to the sub-indices, overall financial inclusion index is normalized between 0-1.

Appendix Figure I.3. Second- and third-stage principal components analysis: Weights



4. Results: Summary statistics of the overall financial inclusion index and financial inclusion sub-indices are included in Appendix Table I.7 below. Appendix Table I.8 shows the ranking of countries in the sample according to the value of the overall financial inclusion index, traditional financial inclusion index and digital financial inclusion index.

Appendix Table I.7. Summary Statistics of Financial Inclusion Indices

No. of countries	Category	Observations	Mean	Standard Deviation	Min	Max
Traditional Financial Inclusion Index						

52	Access	104	0.296	0.233	0	1
52	Usage	104	0.34	0.247	0	1
52	Traditional	104	0.324	0.226	0	1
Digital Financial Inclusion Index						
52	Access	104	0.527	0.267	0	1
52	Usage	104	0.196	0.218	0	1
52	Digital	104	0.349	0.204	0	1
Comprehensive Financial Inclusion Index						
52	Overall	104	0.433	0.216	0	1

Appendix Table I.8. 2017 Ranking: Financial Inclusion Indices

	Comprehensive	Index	versus 2014	Traditional	Index	versus 2014	Digital	Index	versus 2014
1	Mongolia	1.00	1	Mongolia	1.00	0	Ghana	1.00	15
2	China	0.90	6	Brazil	0.77	0	Kenya	0.95	-1
3	Kenya	0.84	1	Turkey	0.77	2	Senegal	0.87	10
4	Malaysia	0.83	-1	China	0.74	5	Uganda	0.87	-1
5	Ghana	0.81	25	Thailand	0.72	-1	Rwanda	0.82	2
6	Namibia	0.81	12	Namibia	0.71	6	Zimbabwe	0.74	5
7	Turkey	0.80	3	Malaysia	0.67	1	Cote d'Ivoire	0.68	12
8	Thailand	0.76	1	Chile	0.64	-1	China	0.66	7
9	Chile	0.74	-3	Romania	0.64	-6	Bangladesh	0.66	-3
10	Brazil	0.72	-9	Panama	0.53	0	Benin	0.64	38
11	South Africa	0.70	-6	South Africa	0.53	-5	Malaysia	0.62	-9
12	Uganda	0.66	10	Armenia	0.53	8	Gabon	0.60	5
13	Rwanda	0.65	10	Guatemala	0.53	-2	Mongolia	0.57	11
14	Senegal	0.65	22	Sri Lanka	0.50	1	Dominican Republic	0.56	-10
15	Dominican Republic	0.63	-3	Indonesia	0.48	-1	South Africa	0.55	-7
16	Indonesia	0.62	-1	Peru	0.47	9	Namibia	0.55	21
17	Romania	0.62	-10	Argentina	0.44	-4	Chile	0.51	-7
18	Armenia	0.62	2	Bolivia	0.43	3	Botswana	0.50	-13
19	Zimbabwe	0.59	10	Dominican Republic	0.42	-2	Zambia	0.50	13
20	Sri Lanka	0.57	-4	Colombia	0.41	-2	Indonesia	0.49	-2
21	Bangladesh	0.56	4	Honduras	0.41	1	Turkey	0.49	9
22	Argentina	0.56	-8	India	0.40	5	Thailand	0.47	7
23	Panama	0.55	-12	Tunisia	0.38	5	Argentina	0.43	-14
24	Botswana	0.55	-11	Mexico	0.38	-8	Armenia	0.43	2
25	Gabon	0.55	2	Botswana	0.34	-6	Togo	0.41	24
26	Cote d'Ivoire	0.51	14	Kenya	0.32	-2	Sri Lanka	0.39	-4
27	Colombia	0.51	-10	Jordan	0.32	2	Brazil	0.37	-15
28	Benin	0.49	19	El Salvador	0.28	-5	Colombia	0.37	-8
29	Peru	0.49	6	Philippines	0.25	1	Cambodia	0.36	4
30	Guatemala	0.48	-11	Nigeria	0.24	-4	Pakistan	0.35	8
31	Zambia	0.46	8	Gabon	0.23	0	Romania	0.34	-8
32	Bolivia	0.43	-4	Nicaragua	0.23	5	Panama	0.34	-18
33	Mexico	0.43	-12	Ghana	0.22	1	Vietnam	0.33	-12
34	Tunisia	0.42	-8	Vietnam	0.21	-2	Philippines	0.32	-6
35	India	0.41	2	Zambia	0.20	0	El Salvador	0.31	-10
36	Honduras	0.40	-2	Bangladesh	0.19	4	Peru	0.30	3
37	Jordan	0.38	-5	Pakistan	0.16	4	Mexico	0.29	-3
38	El Salvador	0.38	-14	Rwanda	0.16	-5	Nicaragua	0.28	-2
39	Philippines	0.36	-6	Zimbabwe	0.15	-3	Jordan	0.28	-8
40	Togo	0.35	9	Mauritania	0.15	-2	Tunisia	0.28	-13
41	Vietnam	0.35	-10	Cambodia	0.13	2	Bolivia	0.25	-1
42	Pakistan	0.34	2	Uganda	0.13	-3	India	0.25	2
43	Nicaragua	0.33	-2	Togo	0.12	2	Congo, Dem. Rep. of	0.24	-8
44	Cambodia	0.32	-2	Benin	0.11	4	Cameroon	0.24	3
45	Nigeria	0.25	-7	Senegal	0.10	1	Guatemala	0.23	-4
46	Cameroon	0.22	2	Congo, Republic of	0.09	-4	Honduras	0.22	-4
47	Mauritania	0.21	-4	Cameroon	0.09	2	Mauritania	0.18	-4
48	Congo, Dem. Rep. of	0.18	-3	Cote d'Ivoire	0.08	-4	Nigeria	0.15	-3
49	Congo, Republic of	0.15	-3	Myanmar	0.08	-2	Myanmar	0.15	2
50	Myanmar	0.15	0	Congo, Dem. Rep. of	0.03	0	Congo, Republic of	0.13	-4
51	Madagascar	0.09	0	Afghanistan	0.02	0	Madagascar	0.12	-1
52	Afghanistan	0.04	0	Madagascar	0.01	0	Afghanistan	0.04	0

Note: 'versus. 2014' refers to the respective country's change in ranking compared to 2014. Green shade suggests improvement in ranking from 2014 to 2017, whereas red shade indicates deterioration in country's ranking.