Measuring financial inclusion: a composite FI index for the developing countries

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Abstract

Purpose – The purpose of this paper is to focus on measuring financial inclusion (FI) level for the developing countries.

Design/methodology/approach – By using a two-stage principal component analysis method, we construct a composite FI index to measure the degree of FI. Data are collected through secondary sources including World Bank and IMF reports for the period 2012–2018.

Findings – We have built an overall FI index which is considered as a comprehensive measure of FI, a useful tool for policymaking and policy evaluation. Comparison with other studies shows that our FI index corroborates with them.

Practical implications – Building a good FI measurement method is important for developing countries. It helps to assess and compare the level of FI of each country and between countries together, made easily and accurately.

Originality/value – This study emphasizes the important role of FI in the economy. From there, an FI solution is integrated into the construction and calculation of its impact on other factors. This will help policymakers to take effective measures to increase FI levels to achieve sustainable economic growth.

Keywords Financial inclusion, Measuring financial inclusion, FI index

Paper type Research paper

1. Introduction

In recent years, financial inclusion (FI) has been seen as an important factor for sustainable development on a global scale. Because economic opportunities are linked to access to financial services and that access particularly affects the poor as it allows them to save, invest and benefit from credit (Subbarao, 2009). From the efforts to get the majority of people access to formal financial services, it has contributed to increasing the overall efficiency of the economy and the financial system. However, such benefits are limited to developed countries, since most developing countries lack access to financial services. Therefore, the promotion of FI level has posed policy challenges on scale with urgency for developing countries and emerging markets, where more than 90% of 1.7 billion people in the world do not have an account at a financial institution (Demirguc-Kunt *et al.*, 2018). Hence, FI is not only important but also the main goal of top priority in these countries.

On the other hand, as Sarma (2016) mentioned, measurement is the first step toward an awareness of FI. However, although the importance of FI has been well established, a formal consensus on how to measure it has not yet been achieved. And an important question in the emerging literature on FI relates to how it should be measured. Thus, measurement of FI is necessary to study the impact of various initiatives by stakeholders and to decide on the

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future course of action. And this is also the topic of concern among researchers, governments and policymakers.

In addition, in recent years, along with the explosion of mobile phone use globally, especially in developing countries, has increased the application of these mobile devices to services. And the penetration of mobile phones is considered as a proxy for mobile banking, gaining consensus to use it in FI measurement (Chauvet and Jacolin, 2017). Accordingly, mobile money accounts have become an important means of conducting financial transactions for many households in developing countries (Mehrotra and Nadhanael, 2016). However, it seems that due to the scarcity of available data, this factor is not yet considered in calculating FI index. Therefore, the construction of a new FI index that includes mobile money indicators is considered necessary to fill the research gap. On the other hand, in previous studies, the FI index was developed only taking into account banking-related financial services. Recent focus on FI has also included other financial services such as insurance, pension or services from microfinance, financial institutions and Fintech. We have considered these, in addition to banking services, and have developed a measurement of the degree of FI based on indicators of the three dimensions of FI, as suggested by Sarma (2016). Therefore, it can be concluded that developing a composite index to measure the degree of FI for developing countries is not only a very necessary issue but also particularly important for these countries.

The study attempts to construct the FI index – considered as a comprehensive measure of FI level for 41 developing economies and ranking is done. And to answer the main research questions, a two-stage PCA method is used to build the FI index. Through the indicators built from other studies, we also check the relevance of this index.

The remainder of this paper is structured as follows. The next section provides an overview of the theoretical basis and previous studies. Section 3 discusses the data and methodology. Subsequently, we report our results and discussion in Section 4. Finally, Section 5 provides conclusion and policy implications.

2. Literature review

2.1 Concept of financial inclusion

FI is a broad concept. Previous studies have provided different definitions of this. However, depending on the level of socio-economic development of each country, FI is defined in different aspects (Kempson and Whyley, 1999; Aduda and Kalunda, 2012; Akileng *et al.*, 2018). Although there is no consensus on a FI definition, it is generally understood that FI is the process of ensuring that people have easy access to and use of financial services from the formal financial institutions in a timely, adequate, affordable manner, especially for the financial disadvantaged group (Sarma, 2008; De Koker and Jentzsch, 2013; Joshi *et al.*, 2014). For the World Bank, FI means individuals and businesses have access to affordable financial products and services that meet their needs and are implemented in a way that is responsible and sustainable. In particular, the financial services mentioned in most of the studies here are savings, credit, insurance and payment (Hannig and Jansen, 2010; Ghosh and Ghosh, 2014; Camara, Tuesta, 2015; World Bank, 2018).

In many countries, FI is considered as a critical determinant for the economic development of a country. Hence, it has become the spotlight of economic-policymaking all over the world. And that is why more and more scholars and policymakers are interested in it.

2.2 Measurements of financial inclusion

As with the definition of FI, there is not yet a consistent method to measure or evaluate the FI level of a country or an economy. There are many methods to measure this factor. And one of the first attempts to measure the financial sector's access to nations was made by Beck *et al.* (2007).

Accordingly, the authors have designed new indicators of bank access for three types of services including *deposits, loans and payments* through two dimensions of access and use of financial services. Some other studies also seek to measure the level of FI by simply measuring the proportion of the adults or households of an economy that has access to formal financial services such as bank accounts (e.g. Honohan, 2008). Demirguc-Kunt and Klapper (2012); Demirguc-Kunt *et al.* (2015, 2018) have provided a set of indicators to measure the level of savings, borrowing, payments and risk management of adults in the world. This is a set of individual indicators that was developed through survey data from interviews with more than 150,000 nationally and randomly selected representatives aged 15 and over in 148 economies.

However, FI is a multidimensional concept that cannot be accurately captured by individual indicators such as bank account ratios, number of automatic teller machines (ATMs) (Camara and Tuesta, 2014). Since when used alone, these indicators can only provide partial and incomplete information about the comprehensiveness of the financial system. Even the use of individual indicators can lead to misunderstandings about the level of FI in an economy (Sarma, 2016). Many studies have been conducted when trying to identify an appropriate measurement to comprehensively assess the extent of coverage of a financial system. Such measurement is called the FI index. If Gupte *et al.* (2012) developed the FI index to measure level of FI in India by taking the average of four important dimensions such as: *outreach, usage, ease of transactions and cost of transactions*; then Sarma (2008, 2012, 2015, 2016) examined three basic dimensions of FI: *banking penetration*, *availability of banking services and usage*. And this index is calculated based on a multidimensional approach to similar dimensions of human development index (HDI) implemented by the United Nations Development Program (UNDP) [1]. She aggregated each index as the normalized inverse of Euclidean distance, where the distance is computed from a reference ideal point and then normalized by the number of dimensions included in the aggregate index. However, dimensional weights are set at arbitrary values (the weights for access, availability and usage are 1, 0.5 and 0.5). Similar to Sarma (2008), Park and Mercado (2015, 2018) calculated the FI index by combining five factors: *ATMs, bank branches, borrowers, depositors and domestics credit to GDP ratio*.

Although, the above studies have provided a better measurement of FI level than individual indicators; however, it assigns weights to all variables and dimensions based on the authors' experience and assumes that all parameters have the same effect on FI. And this has brought criticism in the academic community. Therefore, the contribution of Amidžić *et al.* (2014) in providing an index using Factor Analysis (FA) or Principal Component Analysis method (PCA) of Camara and Tuesta (2014) to determine the appropriate weights for calculating the FI index is an attempt to overcome the previous criticism, less arbitrary in proposing weights for variables and dimensions. If Amidžić *et al.* (2014) constructed a FI index as a composite of variables pertaining to multiple dimensions: *outreach, usage and quality*. Each measure is normalized, statistically identified for each dimension and then aggregated using statistical weights, the aggregation following a weighted geometric mean. However, one drawback of this approach is that it uses a factor analysis method to reduce a set of variables down to a smaller number of factors and, therefore, not fully utilizing all available data for each country. Although they defined proxies for a quality measure, they did not include it in their composite indicator due to a lack of reliable and available data. Meanwhile, Camara and Tuesta (2014) used two-stage PCA, wherein, in the first stage, they estimated three subindices (*usage, access and barriers*), which defined their FI measure. In the second stage, they estimated the dimension weights and the overall FI index by using the dimension subindices in the first stage as explanatory variables. In this study, the weights are drawn from available data, rather than relying on the researcher's discretion. Recently, from the perspective of policymakers, the degree of FI is measured from three main dimensions: *access, use and quality of financial services* (Mialou *et al.*, 2017; World Bank [2]). However, it is

difficult to compare metrics that measure the quality of financial services for a large number of countries. Thus, Amidžić *et al.* (2014); Mialou *et al.* (2017); Ahamed and Mallick (2019) ignored this dimension when developing a FI index.

In previous years, in developing countries, policymakers often used a variety of indicators of financial sector outreach to take stock of the state of FI. The most commonly used indicators are number of bank branches, number of ATMs, amount of bank credit and amount of bank deposits. However, since the global financial crisis in 2007, world leaders and policymakers have reconsidered and identified the need to focus on sustained FI development. Accordingly, with increasing interest from policymakers on the importance of FI, the measurement of FI has also been focused. Various measures are developed by researchers from time to time. However, there is currently no measure designed to rank. Despite this, most studies have used FI measurement in two approaches: PCA and Sarma (2008, 2016). In particular, it can be seen that many studies build index of FI based on the multidimensional approach proposed by Sarma (e.g. Huang and Zhang, 2020; Sethi and Sethy, 2019; Prastowo and Putriani, 2019; Goel and Sharma, 2017; Anwar *et al.*, 2017; Park and Mercado, 2015; Yorulmaz, 2013). The reason is easy to identify because this approach is similar to the calculation of the well-known development indicators of the UNDP such as the HDI, the Human Poverty Index (HPI), the Gender development index (GDI). In recent years, some other studies have built FI index based on PCA method to limit the criticism of imposing arbitrary weights proposed by Sarma (e.g. Ahamed and Mallick, 2019; Elsherif, 2019; Anarfo *et al.*, 2019; Ismail *et al.*, 2018; Park and Mercado, 2018; Lenka and Bairwa, 2016; Camara and Tuesta, 2014).

In general, the review of the literature discussed above shows that there has been some efforts to develop a composite index to measure FI level. However, this also opens the debate that these indices are necessary but not enough for an all inclusive idea called "FI". Each developmental approach to the FI index as discussed above has its own plus and minus points. Therefore, it can be seen that the measurement of the degree of FI has not yet reached a formal consensus (Park and Mercado, 2015; Mialou *et al.*, 2017). The measurements of FI through studies are not only different in approach, but the indicators selected to calculate the FI index are also different. In addition, as mentioned in the introduction, the absence of "mobile money" factor in measuring FI is also one of the key points that this study must fill. And the addition of other services besides banking-related services to the FI index when calculating this composite index is our special focus to ensure the most comprehensive of FI.

The summary of measurement variables and FI measurement methods from related studies is presented in Table A9 in the appendix.

3. Methodology

3.1 Data, research models and measurement variables

3.1.1 Data. This study uses annual data collected from the results of Financial Access Survey (FAS) of the IMF and Global Findex database of WB for period 2012–2018 in 40 developing countries (the list is attached in Appendix – Table A1). Our research sample does not cover all developing countries because countries data are incomplete over the years. We select research data in the period of 2012–2018 for the purpose of ensuring data collection of the most complete and consistent representative variables over time of countries. On the other hand, the starting year of the research period is 2012 because the introduction of mobile money this year is considered a bright spot in the expansion of financial services in developing world (Demirguc-Kunt and Klapper, 2012).

3.1.2 Research models and measurement variables. From literature review, we can see that there are two commonly used approaches to measuring FI through the development of a composite FI index: *non-parametric and parametric methods*. However, non-parametric

methods assign the importance of indicators by choosing the weighs exogenously, based on researchers' intuition. There is evidence that indices are sensitive to subjective weight assignment, since a slight change in weights can alter the results dramatically (Lockwood, 2004). Therefore, based on Camara and Tuesta (2014), we develop a FI index via PCA method to find the appropriate weights (parametric method) and postulate that the latent variable FII is linearly determined as follows:

$$\mathrm{FII}_i = w_1 Y_i^p + \ w_2 Y_i^a + w_3 Y_i^u + e_i \tag{1}$$

where FII_i is composite FI index of country i;

w_1, w_2, w_3: the relative weights of each dimension.

e_i is variation due to error.

(Y_i^p, Y_i^a, Y_i^u): the dimensions of the penetration, the availability and the usage respectively are computed as:

$$Y_i^p = \beta_1 \text{deposit accounts}_i + \beta_2 \text{mobile money accounts}_i + u_i \tag{2}$$

$$Y_i^a = \Theta_1 \text{branches}_i + \Theta_2 \text{ATMs}_i + \Theta_3 \text{mobile money agents}_i + \in_i \tag{3}$$

$$Y_i^u = \gamma_1 \text{deposits}_i + \gamma_2 \text{loans}_i + \gamma_3 \text{mobile money transactions}_i + v_i \tag{4}$$

The variables in the model (2), (3), (4) are as follows:

Based on Sarma (2015, 2016), we develop a multidimensional FI index on the basis of combining as many dimensions of FI information as possible. Accordingly, three dimensions of FI are chosen: *the access (penetration of financial services), the availability and the usage*.

(1) *The access (penetration of financial services):*

A comprehensive financial system needs to have as many users as possible, meaning that it must penetrate widely among those who use it. Therefore, on the basis of approaching this measure of Sarma (2012, 2015, 2016), we use the data of deposit accounts to measure this dimension. However, to ensure the comprehensiveness of FI, instead of just using the number of deposit accounts with commercial banks like Sarma, we include the data with both banks and other financial institutions. Accordingly, *the number of deposit accounts with commercial banks, credit unions and credit cooperatives per 1,000 adults* is one of the indicators used to measure for this dimension. Moreover, from the suggestion of Sarma (2016), we added the variable that previous studies have not included in the FI index: *the number of mobile money accounts (mobile money accounts)*. Because, in recent years, the growing development of the financial services industry has allowed previously excluded people access to financial services. And the main driver of this change is mainly due to new technologies (fintech), notably that the mobile phone application to exploit financial services has brought significant changes, especially in developing economies (Donovan, 2012).

(2) *The availability:*

Also according to Sarma (2016), in an overall financial system, bank transaction points: offices, branches, ATMs, etc. must be easily available to users. Therefore, for this dimension, we use data on *the number of branches and ATMs per 100,000 adults* to measure availability. And of course, the "branches" here include not only the number of commercial bank branches but also the data of credit union, credit cooperative and all microfinance institution branches.

At the same time, we add: *mobile money agent outlets per 100,000 adults (mobile money agents)* in this dimension serve as a proxy of mobile banking. This is to provide financial services to places where bank branches and ATM systems are not yet available.

(3) *The usage:*

To measure the usage dimension, Ahamed and Mallick (2019) used *the number of bank accounts per 1,000 people*. Meanwhile, Amidžić *et al.* (2014) propose an indicator of *deposit and loan accounts per 1,000 adults*. However, Sarma (2008, 2016) cited the opinion of Kempson *et al.* (2004) that in some countries, the proportion of people with bank accounts is high, but using very few services. Therefore, merely having an insufficient bank account for an overall financial system. Thus, for this dimension, based on the proposal of Beck *et al.* (2007); Gupte *et al.* (2014); Lenka and Bairwa (2016) and Sarma (2016), we consider the two basic services of the banking system are credit and deposits. Accordingly, *outstanding deposits (% of GDP) and outstanding loans (% of GDP) (deposits, loans)* have been used to measure this dimension. In addition, to ensure that financial services are fully utilized (such as credit, deposits, payments), the usage must be measured in many different forms of service. And as analyzed in two above dimensions, we add: *mobile money transactions value (% of GDP)* (*mobile money transactions*) to fill the research gap (see Table 1).

3.2 Methodology

(1) *Development of a FI index*

To address the first research objective, i.e. to develop the FI index for developing economies; based on the approach of Camara and Tuesta (2014), we compute FI index by employing a two-stage PCA:

- *The first stage of the PCA: estimate the dimensions (three sub-indices: Access, Availability and Usage).* That is three unobserved endogenous (Y_i^b, Y_i^a, Y_i^u) and the parameters (β, Θ and γ) in the system of Equations (2), (3) and (4). Three dimensions are also indices that we estimate by principal components as linear functions of the explanatory variables.

Dimension/ Variable	Description	Data sources
(1) Access (penetration)		FAS- IMF
– Deposit accounts (DPaccounts)	Number of deposit accounts with commercial banks, credit unions and credit cooperatives per 1,000 adults	
– Mobile money accounts (MBaccounts)	Number of registered mobile money accounts per 1,000 adults	
(2) Availability		FAS- IMF
– Branches	Number of commercial bank, credit union, credit cooperative and all microfinance institution branches per 100,000 adults	
– ATMs	Number of Automated Teller Machines (ATMs) per 100,000 adults	
– Mobile money agents (MBagents)	Number of registered mobile money agent outlets per 100,000 adults	
(3) Usage		FAS- IMF
– Deposits	Outstanding deposits with commercial banks, credit unions and credit cooperatives (% of GDP)	
– Loans	Outstanding loans from commercial banks, credit unions, credit cooperatives and all microfinance institutions (% of GDP)	
– Mobile money transactions (MBGDP)	Value of mobile money transactions (% of GDP)	

Source(s): The author

Table 1. Summary of variables and data sources are used in the model

- *The second stage of the PCA*: By applying the same procedure as described in the first stage, we estimate the weights of the three dimensions and the overall FI index by replacing Y_i^p, Y_i^a, Y_i^u (were estimated in the first stage) into Equation (1).

(2) *Verifying the strength of the FI index.*

In order to attain the second research goal, we conduct a test of the validity of the newly developed FI index.

- *First*, based on the ideas of Beck *et al.* (2007); Ahamed and Mallick (2019), we examine the correlation between household-based indicators of FI (*share of household account*) and our FI index. And one of the indicators commonly used in recent studies to measure FI (e.g. Demirguc-Kunt *et al.*, 2013; Allen *et al.*, 2014) is the percentage of adults who have an account at a bank or another type of financial institution. Therefore, in this section we use "*account (% age 15+)*" from Global Findex database (2017) [3] to check the correlation with our FI index. Accordingly, the linear relationship between variables (two indices) is indicated by the following equation:

$$\text{Account}_i = \alpha_0 + \alpha_1 \text{FII}_i + \varepsilon_i \quad (5)$$

where Account_i : financial institution account (% age 15+); FII_i : FI index that we built above.

- *Second*, we also check the power of our FI index through examining its correlation with the index built by the previous studies involved. Specifically, here we choose index of FI from Park and Mercado (2018). The reason for this selection is due to the time and country similarity of the sample. As in the first section, a linear equation is also expressed to describe the relationship between the two indices as follows.

$$\text{IFI}_i = \beta_0 + \beta_1 \text{FII}_i + t_i \quad (6)$$

where IFI_i : index of FI from Park and Mercado (2018); FII_i : our FI index.

4. Results and discussion

4.1 Estimated FI index (FII)

Table 2 above presents descriptive statistics about the indicators we use to measure FI. In particular, three dimensions (*penetration, availability and usage*) are three indices that we estimate by principal components as linear functions of the explanatory variables described in the order corresponding to each dimension.

Variable	Obs	Mean	Std. Dev.	Min	Max
Penetration dimension (Y_p)					
DBaccounts	287	741.7632	626.9181	57.4319	2490.8475
MBaccounts	287	406.2851	459.7925	0.0026	2249.5680
Availability dimension (Y_a)					
Branches	287	12.5835	9.0950	1.8625	45.6211
ATMs	287	21.6916	23.6989	0.0907	117.0364
MBagents	287	203.4901	308.2614	0.0005	2474.2820
Usage dimension (Y_u)					
Deposits	287	41.6305	28.4257	9.1608	182.1831
Loans	287	33.4363	23.0451	2.9582	116.2969
MBGDP	287	9.8601	17.8003	0.0002	118.0775

Source(s): Calculated by the author on Stata 14

Table 2.
Descriptive statistics

Before using PCA, indicators of each dimension are normalized to have values between zero and one to ensure that the scale in which they are measured is immaterial. Where zero indicates financial exclusion and one indicates FI.

4.1.1 First stage PCA results. Through the PCA method, we calculated eigenvalues of each sub-index and estimate the latent variables: penetration (Y_p), availability (Y_a) and usage (Y_u) (*described at* Table 1). The highest eigenvalue of the components retains more standardized variance among others, and an eigenvalue greater than 1 is considered for the analysis (Kaiser, 1960).

Table 3 shows the results of first-stage PCA. We can see the eigenvalues of the principal components (PCs) for all three dimensions in the corresponding order are: *1.05*; 0.95 (*Penetration*); *1.61*; 0.78; 0.61 (*Availability*) and *1.79*; 0.99; 0.22 (*Usage*). Except the first PC (comp1 of all three dimension), no other PCs have an eigenvalue greater than 1. Therefore, we only take the first component for analysis and estimate the dimensions by using the weights assigned to the first PC of each dimension. In detail, the results from Table A2 – Appendix indicates that the weights are obtained from the information in the PCs and the corresponding eigenvalues. Accordingly, regarding penetration dimension, the weights assigned to the first component are −0.7071 (DBaccounts); 0.7071 (MBaccounts). For the availability dimension, ATMs indicator has higher weight (0.6219) than branches (0.5770) and MBagents indicator (−0.5295). That's because ATMs is very high in more mature markets, the difference between countries is bigger. And finally, for the usage dimension (three indicators: deposits, loans and MB), the weights are at 0.7057, 0.7005 and −0.1063 respectively.

After performing the Kaiser–Meyer–Olkin (KMO) test (Table A3 – Appendix) to examine the suitability of the factors and by assigning the above extracted weights to Equation (2-4) we get: Y_i^p; Y_i^a and Y_i^u. And the average value results of FI indicators by dimension are shown in Table A4 in Appendix.

4.1.2 Second-stage PCA results. In the second stage, by applying the same procedure as described in the first stage, we apply PCA method on the three sub-indices to calculate their weights in the overall FI index. The following Table 4 shows the results of PCs estimates for our composite FI index.

The eigenvalues of the three PCs respectively are 2.39, 0.35 and 0.26. This shows that only the first component has eigenvalue greater than 1, so we just take it to find the weights assigned to the PCs. Figure 1 also illustrates this.

In terms of the PC structure, we observe that the first component, which accounts for 79.7% of the total variation of the data, is contributed by all three dimensions. This indicates that the three dimensions measuring the same latent structure are interpreted as the FI level.

Component	Eigenvalue	Difference	Proportion	Cumulative
(1) Penetration (DBaccounts; MBaccounts) – Estimate Y_p				
Comp1	*1.05056*	0.10111	0.5253	0.5253
Comp2	0.94944		0.4747	1.0000
(2) Availability (Branches; ATMs and MBagents) – Estimate Y_a				
Comp1	*1.60960*	0.82890	0.5365	0.5365
Comp2	0. 78070	0.17101	0.2602	0.7968
Comp3	0.60970		0.2032	1.0000
(3) Usage (Deposits; Loans and MBGDP) – Estimate Y_u				
Comp1	*1.78944*	0.79467	0.5965	0.5965
Comp2	0.99477	0.77898	0.3316	0.9281
Comp3	0.21579		0.0719	1.0000

Source(s): Calculated by the author using PCA on Stata 14

Table 3. Principal components estimates for sub-indices

Table A5- Appendix shows that the KMO measure value = 0.73 satisfies KMO > 0.5 (Hair *et al.*, 1998). Therefore, the analysis factor is consistent with the data. Similar to the method in the first phase, we also calculated weights for all three dimensions. Specifically, Table A6- Appendix also shows that the PCA assigns the highest weight to availability (0.5846), followed by penetration with a weight of −0.5838 and usage at 0.5634. And by doing so, we estimate the overall FI index for developing countries as shown in Tables 5 and 6.

Accordingly, Table 5 shows the FI index results of countries with relatively high FI levels (average value of FI index > 0.5), while Table 6 is the result of FI index of countries with low FI level (FI index ≤ 0.5). The results of the FI index rankings of the countries in these two tables also show that the economy with the highest FI level among the sample countries is Mauritius, while the lowest one is Tanzania.

And we can clearly see the change of the level of FI through the graph illustrated below (Figure 2).

4.2 Verifying the strength of the FI index

The following correlation matrices are designed to shed light on the relationship between our FI and other FI indexes.

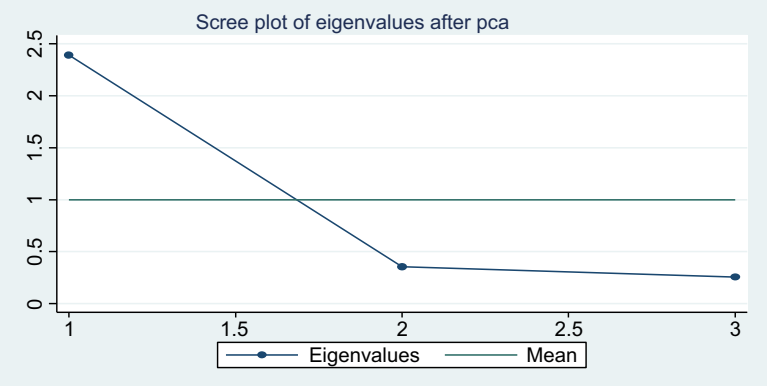
The results from Tables 7 and 8 present the correlation between our FI index generated by PCA technology and the household-based indicator (account) from Global Findex database, also as with index of FI from Park and Mercado (IFI) is very strong (the strength of association is 51% and 75% respectively). We can also see that our FI index has a positive and significant correlation at the 5% level for both indices.

From the analysis results of Tables A7 and Table A8 Appendix, we generate coefficients into Equation (7) and (8):

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	*2.39002*	2.03645	0.7967	0.7967
Comp2	0.35357	0.09716	0.1179	0.9145
Comp3	0.25641		0.0855	1.0000

Source(s): Calculated by the author using PCA on Stata 14

Table 4.
Principal components estimates for the overall FI index



Source(s): Drawed by the authors on Stata 14

Figure 1.
Scree plot of eigenvalues

Country	2012	2013	2014	2015	2016	2017	2018	*Mean*	Rank
Mauritius	0.9727	0.976	0.9879	1	0.9545	0.9519	0.8605	*0.9576*	1
Malaysia	0.941	0.9621	0.953	0.9383	0.9198	0.8986	0.9056	*0.9312*	2
Thailand	0.8335	0.8549	0.8722	0.8727	0.8613	0.847	0.8046	*0.8495*	3
India	0.7099	0.7295	0.7556	0.7704	0.767	0.7481	0.7307	*0.7444*	4
Albania	0.7171	0.7213	0.7242	0.7253	0.743	0.711	0.6815	*0.7176*	5
Samoa	0.6799	0.6803	0.6986	0.6914	0.749	0.7481	0.755	*0.7146*	6
South Africa	0.6981	0.7067	0.7207	0.7105	0.7176	0.7195	0.6919	*0.7093*	7
Namibia	0.6624	0.6757	0.6894	0.653	0.8579	0.7252	0.6674	*0.7044*	8
Armenia	0.6188	0.6443	0.6786	0.6903	0.7068	0.7112	0.7121	*0.6803*	9
Cambodia	0.555	0.559	0.6145	0.677	0.6827	0.6102	0.6325	*0.6187*	10
Tonga	0.5419	0.5873	0.5342	0.5938	0.6213	0.6655	0.6789	*0.6033*	11
Indonesia	0.5636	0.5863	0.6035	0.6125	0.6132	0.6281	0.5766	*0.5977*	12
Fiji	0.5861	0.6013	0.5726	0.5846	0.5853	0.5579	0.4841	*0.5674*	13
Dominican Republic	0.5037	0.5163	0.5171	0.531	0.5336	0.5345	0.534	*0.5243*	14
Guyana	0.53	0.5341	0.532	0.5274	0.5197	0.513	0.5125	*0.5241*	15
Togo	0.5337	0.545	0.563	0.5447	0.5393	0.4629	0.4564	*0.5207*	16
Philippines	0.465	0.4868	0.4917	0.5055	0.517	0.5295	0.5149	*0.5015*	17

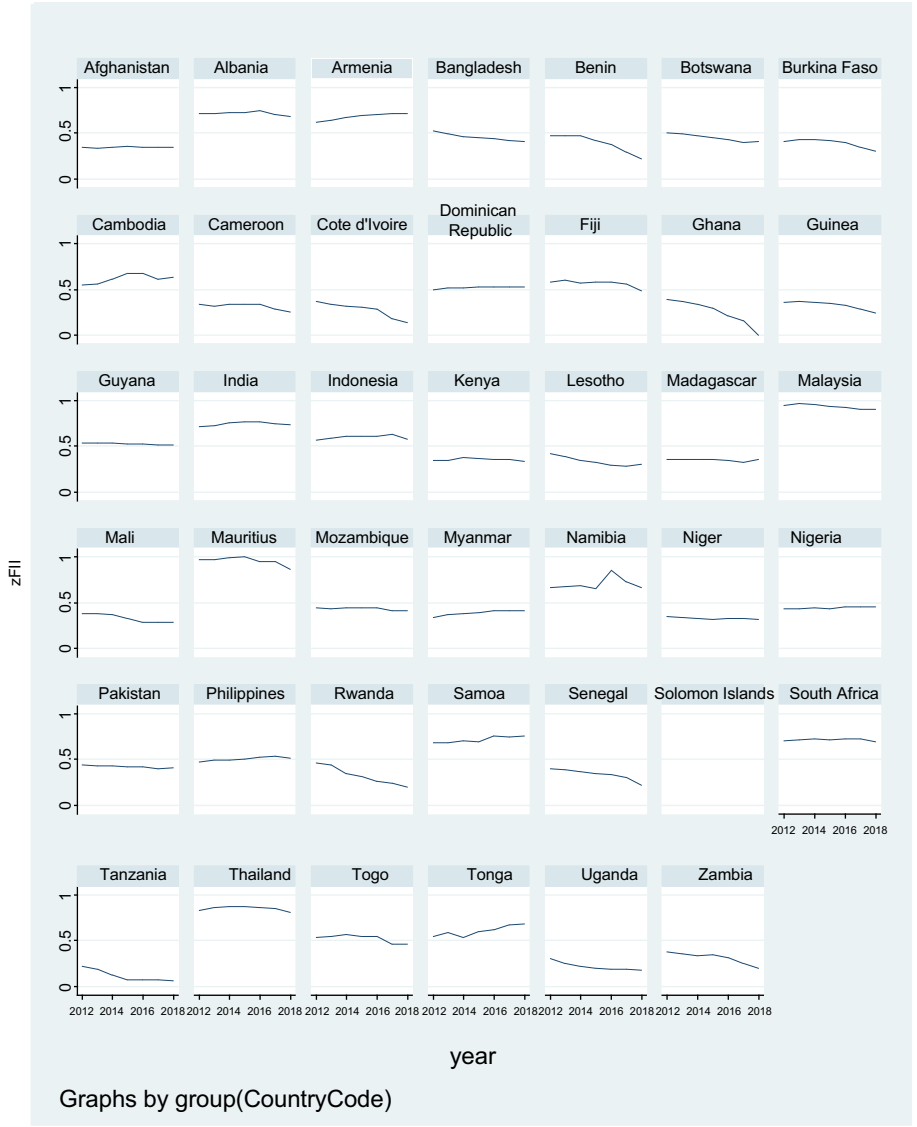
Table 5.
Estimation of FI Index of high FI level group in developing countries

Source(s): Calculated by the author using PCA method on Stata 14

Country	2012	2013	2014	2015	2016	2017	2018	*Mean*	Rank
Bangladesh	0.5248	0.496	0.4609	0.4551	0.4416	0.4243	0.4137	*0.4595*	18
Botswana	0.5097	0.495	0.4746	0.4478	0.4293	0.4042	0.4103	*0.453*	19
Nigeria	0.4306	0.4326	0.4398	0.4315	0.453	0.4569	0.4541	*0.4427*	20
Mozambique	0.4411	0.4321	0.4492	0.4494	0.4387	0.4149	0.4071	*0.4332*	21
Solomon Islands	0.4248	0.4243	0.4388	0.4417	0.4262	0.4327	0.4294	*0.4311*	22
Pakistan	0.4327	0.4287	0.4248	0.4138	0.4145	0.3987	0.4069	*0.4172*	23
Burkina Faso	0.4143	0.4278	0.4302	0.4177	0.403	0.3488	0.3038	*0.3922*	24
Benin	0.4731	0.4716	0.4719	0.4216	0.3744	0.2999	0.2156	*0.3897*	25
Myanmar	0.3435	0.3657	0.3818	0.3939	0.4075	0.4089	0.4179	*0.3884*	26
Kenya	0.3426	0.3406	0.3792	0.658	0.3555	0.3559	0.3377	*0.3539*	27
Afghanistan	0.3443	0.341	0.3451	0.3541	0.3523	0.3505	0.3492	*0.3481*	28
Madagascar	0.3568	0.3542	0.3511	0.3513	0.3398	0.3227	0.3608	*0.3481*	28
Lesotho	0.4217	0.3859	0.3493	0.3227	0.295	0.2807	0.2986	*0.3363*	30
Senegal	0.3953	0.3819	0.3609	0.3472	0.3349	0.2983	0.2153	*0.3335*	31
Mali	0.3843	0.3808	0.3684	0.3277	0.2872	0.2866	0.2843	*0.3313*	32
Guinea	0.3614	0.3764	0.366	0.3537	0.3277	0.291	0.2411	*0.331*	33
Niger	0.3493	0.3402	0.3237	0.3127	0.3275	0.3316	0.3209	*0.3294*	34
Rwanda	0.4629	0.4382	0.3461	0.3155	0.261	0.2391	0.1941	*0.3224*	35
Cameroon	0.3378	0.325	0.34	0.3403	0.3393	0.2837	0.2612	*0.3182*	36
Zambia	0.3709	0.3569	0.3357	0.3411	0.3141	0.2518	0.1974	*0.3097*	37
Cote d'Ivoire	0.3692	0.3414	0.3153	0.3077	0.2899	0.1867	0.1451	*0.2793*	38
Ghana	0.3912	0.3708	0.3425	0.2959	0.2188	0.165	0	*0.2549*	39
Uganda	0.3041	0.2513	0.2168	0.1956	0.1875	0.1816	0.1733	*0.2157*	40
Tanzania	0.2218	0.1814	0.1171	0.0699	0.0681	0.0656	0.0573	*0.1116*	41

Table 6.
Estimation of FI Index of low FI level group in developing countries

Source(s): Calculated by the author using PCA method on Stata 14



Source(s): Drawed by the author on Stata 14

Figure 2.
FI index in developing countries (2012–2018)

	zFII (our FI index)	Account (household-based indicator)
zFII	1.0000	
Account	0.5112*	1.0000

Note(s): *$p < 0.05$
Source(s): Calculated by the authors on Stata 14

Table 7.
Correlation between FII and household-based indicator

$$\text{Account}_i = 0.17 + 0.53\,\text{FII}_i + \varepsilon_i \quad (7)$$

$$\text{IFI}_i = -0.02 + 0.35\,\text{FII}_i + t_i \quad (8)$$

The regression results are presented in Table A7 Appendix give p-value = 0, showing that the relationship between our FI index and account is statistically significant at the 1% level. This suggests that greater FI is positively associated with many households with accounts at financial institutions. From there, we can also evaluate the strength of our FI index to see if our index is useful in predicting observable micro-level data (household-based indicator). Besides, our FI index has a strong correlation and is consistent with the index of FI from Park and Mercado's research (Equation 6).

To further illustrate these correlations, Figure 3 and Figure 4 compare our FI index with the household account indicator and with the index of FI from Park and Mercado (2018).

The graph (Figure 3) clearly shows that our FI index and the household-based indicator are closely related to each other and are positively correlated. Similarly, from the graph in Figure 4 we can also see that our FI index and index of FI from Park and Mercado (IFI) are strongly correlated. The fitted line of both graphs indicates that our FI index is relatively good at predicting the change of household-based indicator and IFI. Therefore, once again we have enough evidence to confirm that our FI index is valid and relatively strong when compared to other relevant FI indicators.

Comparing to the index of FI proposed by Sarmas (2008, 2016), it can be said that our FI index is superior in many ways. *First,* it is based on weights assigned by the author while our technique is independent of these weights. The PCA technique calculates the index by considering the variation in a given set of variables and developing the index in such a way that it can interpret the maximum variation in a given set of variables. Evidence from

Table 8.
Correlation between FII and index of FI from Park and Mercado

	zFII (our FI index)	ParkMercado (IFI)
zFII	1.0000	
ParkMercado	0.7513*	1.0000

Note(s): *$p < 0.05$
Source(s): Calculated by the authors on Stata 14

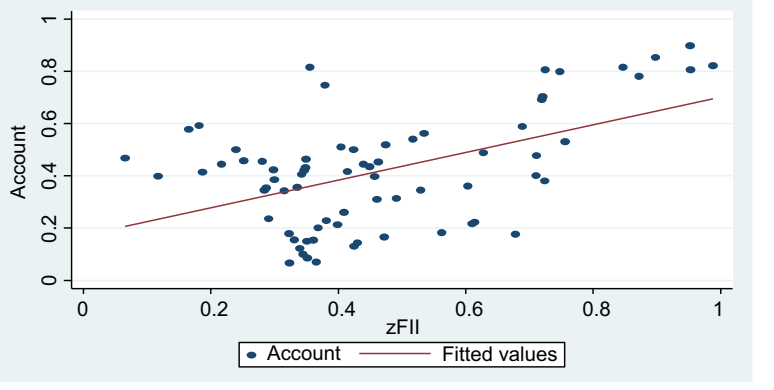
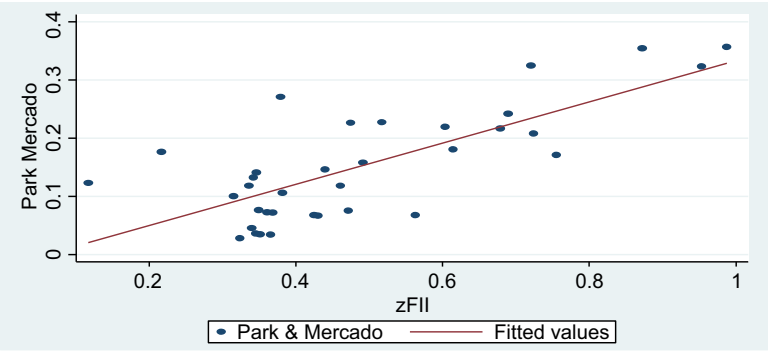


Figure 3.
FI index and household-based indicator (account)

Source(s): Drawed by the authors on Stata 14



Source(s): Drawed by the authors on Stata 14

Figure 4.
FI index and index of FI from Park and Mercado (2018)

previous studies shows that indicators respond quickly to subjective weight assignments, because a slight change in weight can affect the objectivity of the results (Camara and Tuesta, 2014; Lockwood, 2004). *Second*, our FI index overcomes the use of incomplete proxies for FI. Accordingly, in each dimension of FI, we have added many indicators related to mobile money services such as: number of mobile money accounts (penetration dimension), number of mobile money agents (availability dimension) and value of mobile money transactions (usage dimension). *Third*, Sarma's technique could be applied in cross-sectional data only (Sarma and Pais, 2008). If one has table data with t number of years, then one must apply the Sarma's technique t times separately, which is much laborious work. Therefore, large time-series panel data increases fatigue in in the case of Sarma's technique, while it increases the efficiency and degree of freedom in the case of PCA technique.

In summary, from the above, it is possible to conclude that the FI index that we propose to measure FI level for developing countries is appropriate and strong enough to yield more objective measurement results.

5. Conclusion and policy implications

FI is a matter of global concern because it brings many economic benefits to individuals, small businesses and sustainable growth in general. It is also seen as a way to prevent social exclusion. However, efforts to measure FI are scarce and inadequate. The current FI indices are questionable because they choose arbitrary weights. In addition, the factor "mobile money" has not been included in calculating them. Since in recent years the new technology applied by the financial industry has far exceeded traditional banking access as measured by the number of physical access points. Therefore, the absence of these factors in FI measurement will not accurately reflect its level. Moreover, in most studies, the FI index was developed taking into account only banking-related financial services. Meanwhile, many services provided by other financial institutions are not mentioned.

By using FAS's annual collected data (2012–2018) and through the use of weights extracted from a two-stage PCA method, we propose an overall FI index to measures FI level of 41 developing countries. This is considered a comprehensive measure of FI. This method is a good statistic for building a FI index because our FI index is a multidimensional index, it is determined by maximizing dimensions (*penetration, availability and usage*). In addition, our index is easy to explain and calculate. It can also be compared over time to a large number of countries around the globe. In particular, it has the advantage of not using any exogenous, subjective information. Moreover, when combined with other studies, it shows that our FI index not only corroborates with them but is also superior to Sarma's technique.

Overall, the contribution of this study is to help develop a composite FI index – a better measure of FI for developing countries. It makes it easy to analyze and assess the level of FI in these countries as well as to study the relationship between FI and other relevant macroeconomic variables. It can be a useful tool for policymaking and policy evaluation. In addition, the addition of mobile money-related indicators as well as consideration of financial services from other financial institutions (not just bank, such as micro-credit institutions, credit cooperatives, Insurance companies, Fintech companies ...) in calculating the FI index, is considered a significant effort of this research. This shows that Fintech and financialization have an important role to play in promoting FI and the comprehensive development. Because, innovations in mobile money services are expanding rapidly in developing countries, helping low-income people, people living in remote areas, where there are no branches of Commercial banks and financial institutions provide services, can access and use financial products/services.

In conclusion, this research helps policymakers and communities see the importance of FI in the economy. From here, there is a solution to combine FI into calculating its impact levels on other factors. Thereby, there are effective solutions to increase the level of FI to achieve the goal of sustainable economic growth.

For developing countries, from the report of McKinsey, the World Bank has shown that improving FI can increase the GDP of all of these economies by 6% (or 3.7 trillion dollars) by 2025. FI is recognized as important. 67% of bank regulators in 143 jurisdictions surveyed by the World Bank are tasked with promoting FI. More than 50 countries have set a target for FI.

However, in today's world when the financial market is growing rapidly in terms of asset value and revenue, nearly a quarter of the world's population is excluded from the financial system. And this part of the world's population comes mainly from developing regions of the world. So improving access to and building FI systems is an important goal for these countries to include the poorest populations in the financial flow.

In order to contribute to creating a clearer vision for FI development to a new level for developing countries, the focus that these governments should be:

First of all, switching to a cashless system like digitizing all government payments (wages, social transfers and payments to suppliers, etc.) is considered one of immediate action can accelerate FI.

Secondly, diversify and innovate forms of service provision, improve financial infrastructure in order to enhance opportunities to access and use financial services for people.

Third, formalize cash flow. Because in these countries, a large number of remittances still rely on cash. The challenge is to transfer money transfers via financial institutions, money transfer operators or mobile phone operators, to make this remittance transfer safer and lower cost.

Fourth, promote the role of digital financial services, including fintech and big data in increasing the FI level. Since, financial digitization and payment in developing countries can have a major impact on both FI and economic growth. In particular, mobile phones are a catalyst for FI. As across developing countries, mobile network coverage, registration and now smartphone ownership is high or rising rapidly. Therefore, consumers must have access to mobile phones and affordable data plans. A national payment infrastructure is required.

And finally, focus on financial education and consumer protection in increasing responsibility for financial services and building trust in them.

Notes

1. See from <http://www.undp.org (UNDP's Human Development)>.
2. See from <http://www.worldbank.org/en/topic/financialinclusion/brief/how-to-measure-financial-inclusion>.
3. See from <http://www.worldbank.org/globalfindex>.

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Appendix

Afghanistan, Rep	Dominican Republic	Malaysia	Rwanda
Albania	Fiji	Mali	Samoa
Armenia, Rep	Ghana	Mauritius	Senegal
Bangladesh	Guinea	Mozambique	Solomon Islands
Benin	Guyana	Myanmar	South Africa
Botswana	India	Namibia	Tanzania
Burkina Faso	Indonesia	Niger	Thailand
Cambodia	Kenya	Nigeria	Togo
Cameroon	Lesotho	Pakistan	Tonga
Cote d'Ivoire	Madagascar	Philippines	Uganda
			Zambia

Table A1.
List of countries

Variable	Comp1	Unexplained
Penetration dimension		
- zDBaccounts	−0.7071	0.4747
- zMBaccounts	0.7071	0.4747
Availability dimension		
- zBranches	0.5770	0.4642
- zATMs	0.6219	0.3775
- zMBagents	−0.5295	0.5487
Usage dimension		
- zdeposits	0.7057	0.1089
- zloans	0.7005	0.1219
- zMB	−0.1063	0.9798

Table A2.
Scoring coefficients for orthogonal varimax rotation (weights)

Variable	KMO
Penetration dimension	*(Overall) 0.5000*
- zDBaccounts	0.5000
- zMBaccounts	0.5000
Availability dimension	*Overall 0.6074*
- zBranches	0.6077
- zATMs	0.5814
- zMBagents	0.6539
Usage dimension	*Overall 0.4952*
- zdeposits	0.4959
- zloans	0.4958
- zMB	0.4878

Table A3.
KMO test (first stage)

Country	Mean of the indicators by Penetration	Availability	Usage	Country	Mean of the indicators by Penetration	Availability	Usage
Afghanistan	0.48	0.49	0.04	Mali	0.59	0.47	0.16
Albania	0.21	0.81	0.41	Mauritius	0.07	0.84	0.92
Armenia	0.26	0.89	0.27	Mozambique	0.52	0.57	0.25
Bangladesh	0.42	0.46	0.34	Myanmar	0.46	0.51	0.11
Benin	0.61	0.57	0.23	Namibia	0.43	0.92	0.50
Botswana	0.55	068	0.21	Niger	0.53	0.46	0.10
Burkina Faso	0.57	0.52	0.24	Nigeria	0.63	0.57	0.08
Cambodia	0.48	0.76	0.50	Pakistan	0.47	0.56	0.15
Cameroon	0.56	0.46	0.09	Philippines	0.43	0.63	0.26
Cote d'Ivoire	0.72	0.46	0.16	Rwanda	0.64	0.55	0.10
Dominican Republic	0.36	0.71	0.15	Samoa	0.67	0.91	0.36
Fiji	0.49	0.72	0.41	Senegal	0.58	0.42	0.22
Ghana	0.60	0.35	0.09	Solomon Islands	0.45	0.58	0.15
Guinea	0.54	0.52	0.04	South Africa	0.22	0.79	0.43
Guyana	0.31	0.61	0.22	Tanzania	0.90	0.32	0.06
India	0.28	0.85	0.48	Thailand	0.27	0.97	0.67
Indonesia	0.37	0.79	0.27	Togo	0.48	0.62	0.39
Kenya	0.56	0.44	0.23	Tonga	0.44	0.82	0.35
Lesotho	0.59	0.49	0.15	Uganda	0.70	0.40	0.03
Madagascar	0.54	0.52	0.07	Zambia	0.64	0.52	0.10
Malaysia	0.03	0.75	0.91				

Table A4. FI indicators of countries by dimension – results of first-stage PCA

Variable	KMO
zFIIp	0.7131
zFIIa	0.7107
zFIIu	0.7892
Overall	*0.7342*

Table A5. KMO test (second stage)

Variable	Comp1	Unexplained
zFIIp	−0.5838	0.1854
zFIIa	0.5846	0.1832
zFIIu	0.5634	0.2413

Table A6. Scoring coefficients (weights assigned to zFIIp, zFIIa, zFIIu)

Source	SS	df	MS	Number of obs	=	72
				$F(1, 70)$	=	24.77
Model	0.88679	1	0.88679	Prob > F	=	0.0000
Residual	2.50635	70	0.03580	R-squared	=	0.2613
				Adj R-squared	=	0.2508
Total	*3.39314*	*71*	*0.04779*	Root MSE	=	0.18922
Account	Coeff	Std. Err	t	$P > \|t\|$	[95% Conf.	Interval]
zFII	0.52965	0.10643	4.98	0.000	0.31739	0.74191
_cons	0.17171	0.05456	3.15	0.002	0.06289	0.28053

Table A7. Regression estimated results for FII and account

Table A8.
Regression estimated results for FII and IFI from Park and Mercado

Source	SS	df	MS	Number of obs	=	35
				$F(1, 33)$	=	42.78
Model	0.17592	1	0.17592	Prob > F	=	0.0000
Residual	0.13571	33	0.00411	R-squared	=	0.5645
				Adj R-squared	=	0.5513
Total	*0.31163*	*34*	*0.00916*	Root MSE	=	0.06413
ParkMercado	Coeff	Std. Err	t	$P > \|t\|$	[95% Conf.	Interval]
zFII	0.35445	0.05419	6.54	0.000	0.24419	0.46471
_cons	−0.02131	0.02863	−0.74	0.462	−0.07956	0.03693

Table A9. Summary of variables and methods of FI measurement from related studies

Author	Variable	Method
Sarma (2008, 2012)	(1) *Banking penetration (p)*: number of deposit bank accounts per 1,000 adults (2) *Availability (a)*: the number of bank branches and ATMs per 100,000 adults (using 2/3rd weight for bank branch index and 1/3rd for ATM index) (3) *Usage (u)*: the volume of credit and deposit to adult individuals as a proportion of GDP	*Designing a comprehensive indicator (IFI)* Using weights: 1 for the index of banking penetration, 0.5 for availability and 0.5 for of usage. In the three-dimensional Cartesian space, the point (0, 0, 0) indicate the worst and the point (1, 0.5, 0.5) indicate the best IFI for country k is measured by the normalized inverse Euclidean distance of the point (p_k, a_k, u_k) from the ideal point (1, 0.5, 0.5) $\text{IFI} = 1 - \frac{\sqrt{(1-p_k)^2+(0.5-a_k)^2+(0.5-u_k)^2}}{\sqrt{1.5}}$ where p_k, a_k, u_k are three dimensions (p, a, u)
Sarma (2015, 2016)	(1) *Banking penetration (p)*: number of deposit bank accounts per 1,000 adults (2) *Availability (a)*: the number of bank branches and ATMs per 100,000 adults. (using 2/3rd weight for bank branch index and 1/3rd for ATM index) (3) *Usage (u)*: the volume of credit and deposit to adult individuals as a proportion of GDP	*Similar to Sarma (2008), there is more improvement* than using the distance from the lowest point (0, 0, 0) to the ideal point (1, 0.5, 0.5). IFI for the country k is measured by the simple average of normalized Euclidean distance of the point (p_k, a_k, u_k) from the point (0, 0, 0), and its normalized inverse Euclidian distance the ideal point (1, 0.5, 0.5) $= \frac{1}{2}\left[\frac{\sqrt{p_k^2+a_k^2+u_k^2}}{\sqrt{1.5}} + \left(-\frac{\sqrt{(1-p_k)^2+(0.5-a_k)^2+(0.5-u_k)^2}}{\sqrt{1.5}}\right)\right]$ where p_k, a_k, u_k are three dimensions (p, a, u)
Park and Mercado (2015)	(1) ATMs per 100,000 adults (2) Commercial bank branches per 100,000 adults (3) Borrowers from commercial banks per 1,000 adults (4) Depositors with commercial banks per 1,000 adults (5) Domestics credit to GDP ratio	*Calculate the FI index as the method of Sarma (2008)* - *Calculate the dimension index*: ith dimension $d_i = A_i\text{-}m_i/M_i\text{–}m_i$ (A_i : actual value of dimension i, m_i : minimum value , M_i : maximum value). - *FII* is measured by the normalized inverse of Euclidean distance of point d_i from the ideal point (equal to 1) $\text{IFI} = 1 - \frac{\sqrt{(1-d1)^2 + (1-d2)^2 + \ldots + (1-dn)^2}}{\sqrt{n}}$ Used *period average values*, instead of focusing on a particular year, to avoid annual fluctuations and to include as many economies as possible
Park and Mercado (2018)	(1) *Access dimension*: the percentage share of the adults with an account (2) *Availability dimension*: number of bank branches and of ATMs per 100,000 adults	*Combine the approaches of Sarma (2016) and Camara and Tuesta (2014)* - Compute each indictor for each dimension: $X_{i.d} = \frac{x_i - m_i}{M_i - m_i}$ Where: * x_i : the actual value of indicator i * m_i : the minimum value of indicator i

(*continued*)

Author	Variable	Method
	(3) *Usage dimension*: the share of adults who borrowed and saved from a financial institution; the domestic credit-to-GDP ratio	* M_i: the maximum value of dimension i * $X_{i,d}$: the standardized value of indicator i of dimension d - Use PCA $IFI_i = w_1 D_{1,i} + w_2 D_{2,i} + w_3 D_{3,i}$ Where * IFI_i: the aggregate FI index for country i * w: the weights derived from PCA * D_i: the dimensions
Gupte *et al.* (2012)	(1) *Outreach*: the number of bank branches and ATMs per 1,000 km^2; the number of bank branches and ATMs per 100,000 people; the number of accounts per 1,000 adults (deposits and loans) (2) *Usage*: volume of deposits and loans as % of GDP (3) *Ease of transactions:* (3a) *Directly related variables*: the number of locations to open deposit or loan accounts (3b) *Inversely related variables*: the affordability of deposits or loans; minimum amount to open savings or checking accounts; minimum amounts of consumer or mortgage loans; the number of documents to open savings or checking accounts; the number of days to process loan applications (4) *Cost of transactions*: *annual fees charged to customers for ATM cards; accounts and the cost of international transfer of money*	*Computation of FI index* $FII = (D_1^{\frac{1}{1}}.D_2^{\frac{1}{2}}.\ D_{3a}^{\frac{1}{3}}.\ \ D_{3b}^{\frac{1}{3}}.\ D_4^{\frac{1}{4}})$ Where: $D_j = \sum \frac{d_i}{n}$, (n: number of variables for each dimension). d_i= (Actual value of X_i – minimum value of X_i)/ (Maximum value of X_i – minimum value of X_i)
Amidžić *et al.* (2014) Mialou *et al.* (2017)	(1) *Outreach of financial services*: number of ATMs and branches per 1,000 km^2 (2) *Use of financial services*: number of household borrowers and depositors per 1,000 adults	*Composite index uses factor analysis (FA) to derive a weighting methodology* The basic form of an FA m-factor model is as follows: $\overrightarrow{Y} = L\overrightarrow{F} + \overrightarrow{\epsilon}$ Where: $\overrightarrow{Y} = \overrightarrow{X} - \overrightarrow{\mu}$ ($\overrightarrow{X}$ be the vector of 4 observed random variables and $E(\overrightarrow{X}) = \overrightarrow{\mu}$ L: the matrix of factor loadings

(*continued*)

Author	Variable	Method
	(3) *Quality of financial services*: (financial literacy, disclosure requirements, dispute resolution, and the cost of usage) Because the data on the quality dimension are rather scarce, *this dimension is not considered*	$\overrightarrow{F}$: the vector of unobservable random variables called the common factors of $\overrightarrow{X}$ ($m < 4$) $\overrightarrow{\epsilon}$: the vector of specific factors of $\overrightarrow{X}$ Use the properties of FA model to derive the weighting scheme. And use it to calculate both the intermediate dimensional variables and the cross-dimension composite index
Camara and Tuesta (2014)	(1) *Usage*: account, savings and loan (2) *Barriers*: distance, affordability, documentation, lack of trust (3) *Access*: number of ATMs and bank branches per 1,000 km^2; the number of ATMs and bank branches per 100,000 people	*Compute FI index by employing a two-stage PCA method* _ *The first stage*: estimate the three sub-indices: usage, barriers and access $Y_i^u = \beta_1 account_i + \beta_2 saving_i + \beta_3 loan_i + u_i$ $Y_i^b = \Theta_1 adistance_i + \Theta_2 affordability_i + \Theta_3 documents_i + \Theta_4 trust_i + \epsilon_i$ $Y_i^a = \gamma_1 ATM_i + \gamma_2 branch_i + v_i$ _ *The second stage*: estimate the dimension weights and the overall FI index by using the dimensions as explanatory variables: $FI_i = w_1 Y_i^u + w_2 Y_i^b + w_3 Y_i^a + e_i$
Ahamed and Mallick (2019)	(1) *Financial outreach*: Demographic (*the number of bank branches and ATMs/100,000 people*), Geographic (*the number of bank branches and ATMs per 1,000 km^2*) (2) *Usage*: *number of bank accounts per 1,000 populations*	*Build a multidimensional index by using PCA method* - Capture common variation among 4 outreach variables by using the PCA and construct this financial outreach dimension - Use the PCA to extract the common PC of 2 dimensions. *construct a multidimensional index as follows:* *FI index* $= \sum \omega_{ij} X_i$ ω_i : the component's loadings or weights X_i : the original variables

Source(s): Synthesized by the author from review of related studies