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Yasmin Yasmin
Faculty of Economics and Business, Universitas Gadjah Mada, Yogyakarta, Indonesia,
yasmin@mail.ugm.ac.id

Sekar Utami Setiastuti
Faculty of Economics and Business, Universitas Gadjah Mada, Yogyakarta, Indonesia,
s.u.setiastuti@ugm.ac.id

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The Effect of Financial Inclusion on Food Security: Evidence from Developing and Developed Countries

Yasmin[a], & Sekar Utami Setiastuti[a,*]

[a] *Faculty of Economics and Business, Universitas Gadjah Mada, Yogyakarta, Indonesia*

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Abstract

This study investigates the global impact of financial inclusion on food security, with a focus on both developing and developed countries. The study constructs a financial inclusion index using the Sarma method and secondary data sourced from IMF and World Bank databases. System GMM is employed as the estimation method due to its effectiveness in addressing endogeneity issues and its efficient and consistent use of instruments. The analysis reveals that financial inclusion has a positive and statistically significant effect on food security across all research sub-samples. In addition, the study incorporates interaction variables between financial inclusion and the COVID-19 pandemic to explore how the crisis alters the relationship between financial inclusion and food security. The findings indicate that the COVID-19 crisis has globally diminished food security and moderates the impact of financial inclusion on food security. Overall, the study confirms that financial inclusion is a crucial factor in enhancing food security worldwide, with no substantial disparity between developed and developing countries. Nevertheless, the global COVID-19 pandemic has demonstrated a capacity to weaken the beneficial effects of financial inclusion on food security.

Keywords: financial inclusion, food security, COVID-19, System-GMM

JEL classifications: G21; G51; G53; Q01

1. Introduction

Food security, a critical topic in international forums and empirical studies, is essential for fostering quality human resources. However, impoverished individuals often lack access to adequate, nutritious food (McMichael 2009; Widada, Masyhuri & Mulyo 2017). Prolonged food insecurity can lead to starvation and death (Arshad 2022).

The Food and Agriculture Organization (FAO) and the United States Department of Agriculture (USDA) define food security as a condition in which all individuals have sufficient physical, social, and economic access to meet their daily food needs. This includes the availability of safe and nutritious food as well as the ability to obtain it in socially acceptable ways (Bawadi et al. 2017; Bazga 2012). Food security is central to the second Sustainable Development Goal (SDG), which aims to end hunger by 2030. In 2022, global hunger affected an estimated 691–783 million people worldwide, with the prevalence of malnutrition increasing by 1.3% since 2019 (FAO et al. 2023).

Financial inclusion plays a crucial role in reducing poverty and increasing food security, particularly in low-income countries (Lee, Chen & Chu 2023). The World Bank defines it as access to beneficial and affordable financial products and services for individuals and businesses. It is integral to seven of the 17 SDGs and considered vital for reducing extreme poverty and improving shared prosperity (World Bank 2022).

Significant progress has been made in promoting financial inclusion, with 1.2 billion adults gaining access to accounts between 2011 and 2017. Dig-

*Corresponding Address: Jalan Sosio Humaniora No. 1, Bulaksumur, Caturtunggal, Depok, Sleman Regency, Special Region of Yogyakarta 55281. Email: yasmin@mail.ugm.ac.id.

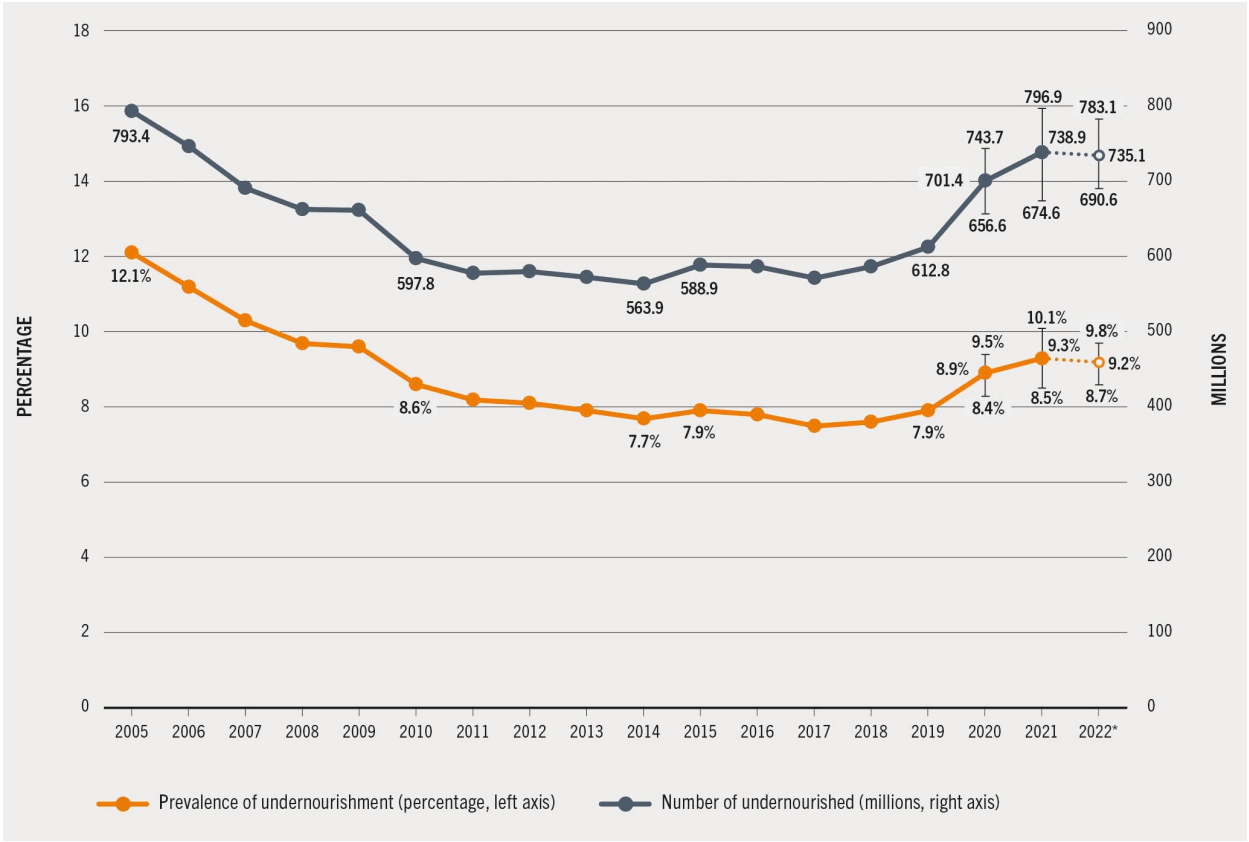

Figure 1. Global Hunger Rate
(Global Hunger Rate as Measured by Malnutrition Prevalence 2005–2022)
Source: FAO et al. (2023)

ital financial services have been implemented in over 80 countries, enabling millions of previously underserved customers to access formal financial services. However, as of 2017, nearly a third of the 1.7 billion adults worldwide still lacked access to a bank account (World Bank 2022).

Financial inclusion, which facilitates access to affordable formal financial services, contributes to broader policy goals such as improved financial health, economic growth, and food security (Lewis, Villasenor & West 2017). Arshad (2022) validates a substantial relationship between financial inclusion and food security utilizing a financial inclusion index with multiple proxies.

Salima et al. (2023) confirm that financial inclusion, measured through formal credit access, increases household food security by enabling investment in productive activities or small businesses. This can increase household income and the ability to purchase nutritious food. Cull, Ehrbeck & Holle (2014) discover that financial inclusion at the household level helps reduce the impact of shocks on food security status.

However, Baborska et al. (2020) and Nepal & Neupane (2022) report different results, that access to credit is not always effective in addressing food insecurity due to high interest rates and short repayment periods of informal loans. Furthermore, a lack of financial literacy can lead to poor spending decisions and difficulties in purchasing food (Carman & Zamarro 2016).

The existing literature lacks comprehensive research explaining the relationship between financial inclusion and food security, with most studies

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utilizing limited proxies and yielding mixed results. This study employed multiple proxies representing each dimension of financial inclusion as introduced by Sarma (2012): the number of deposit accounts and depositors per 1,000 adults (penetration dimension), the number of financial institution branches and ATMs per 100,000 adults (availability dimension), and the number of loan accounts and borrowers per 1,000 adults (usage dimension).

The novelty of this study lies in its attempt to understand the differing impacts of financial inclusion on food security between developed and developing countries, while considering the COVID-19 pandemic as a moderating factor. The inclusion of a COVID-19 dummy variable as a moderator aims to capture potential dynamic changes due to the global health crisis, allowing the authors to identify whether the relationship between financial inclusion and food security shifted significantly during the pandemic period. By incorporating the COVID-19 dummy variable into the model, this study not only captures variations in the impact of financial inclusion on food security but also explicitly considers the context of the pandemic crisis. This approach enables a more comprehensive analysis of how financial systems interact with food security in diverse economic settings during times of global upheaval. Thus, this study contributes to the literature by providing a deeper perspective on the role of financial inclusion in responding to global crisis challenges and its implications for food security across various economic contexts. The findings may offer valuable insights for policymakers and researchers alike.

The remainder of this paper is organized as follows: The second section presents the literature review, examining existing research on financial inclusion and food security. The third section describes the data and research methods employed in this study. The fourth section outlines discussions and recommendations based on data analysis, highlighting key findings and their potential implications. The final section provides conclusions, emphasizing the application of the findings and suggesting areas for future research.

2. Literature Review

The concept of food security has evolved since Malthus (1798), focusing on the imbalance between population growth and food production, stresses population control. In 1985, Sen expanded this concept by incorporating access to food, not just its availability. The definition introduced by the 1996 World Food Summit includes four dimensions: availability, access, utilization, and stability, emphasizing that food security is achieved when everyone has physical, social, and economic access to sufficient, safe, and nutritious food.

Financial inclusion is crucial for bolstering food security. Financial development theory suggests that a growing financial sector supports economic growth and poverty reduction by efficiently allocating resources and increasing access to capital. This helps marginalized individuals access financial services, manage finances, and secure venture capital (Durusu-Ciftci, Ispir & Yetkiner 2017; Ozili 2018; World Bank 2020). It underscores the importance of financial inclusion programs for vulnerable groups, with strategies such as direct government cash transfers (G2P) encouraging engagement with the formal financial sector.

Progress in financial inclusion, by providing access to affordable formal financial services, contributes to broader policy goals such as financial health, economic growth, financial stability, sustainable development, and food security (Lewis, Villasenor & West 2017). Observed from a supply-side perspective, financial inclusion through digital finance and traditional credit access is vital in enhancing food security and agricultural productivity in both developed and developing countries. In China, digital financial inclusion promotes urbanization, market development, food production and distribution efficiency, and regional equalities, thus contributing to multidimensional food security (Tan et al. 2024). Even with limited digitalization, the widespread adoption

and extensive utilization of digital financial services generate positive impacts.

In developing countries such as Mali, access to credit positively affects agricultural outputs by improving access to inputs and optimizing the production calendar (Diamoutene & Jatoe 2021). Similar findings in Ghana reveal a positive correlation between financial literacy, credit access, and food security (Twumasi et al. 2023). Digital financial inclusion in China also enhances the efficiency of land use and encourages the transfer of land management to more productive farmers or organizations (Zhou et al. 2023).

Economically, better access to credit reduces post-harvest losses, increases farmer incomes, and supports sustainable development goals related to food security and nutrition (Akpa et al. 2023). Savings in financial institutions facilitate investments in new equipment and technology, boosting agricultural productivity (Fowowe 2023). Farmers with access to credit are more likely to adopt modern agricultural technologies, leading to increased crop yields and enhanced food security (Raza et al. 2023). These benefits extend beyond production, optimizing resource use and bolstering general well-being for farmers and communities.

Observed from the demand side, financial inclusion is also crucial for boosting food security in various countries. In the United States (USA), households without access to formal financial services are more prone to food insecurity (Fitzpatrick 2017). In Ghana, financial inclusion reduces food insecurity, particularly in rural and male-headed households, often through entrepreneurship which increases income (Koomson, Asongu & Acheampong 2023). In Rwanda, access to formal financial services boosts consumption spending and nutritious dietary patterns, especially in female-headed households (Bali Swain & Nsabimana 2024). The utilization of digital money improves financial management and access to credit and savings, positively impacting food security (Atta-Aidoo et al. 2024).

Further research reveals that access to formal credit can enhance household food security. In many developing countries, formal credit helps households cope with shocks to their food security status (Cull, Ehrbeck & Holle 2014; Salima et al. 2023). A comprehensive financial inclusion index demonstrates that increasing financial inclusion helps the poor manage difficult situations and bolsters food security (Arshad 2022). In Indonesia, Astuti & Hartono (2023) also discover a significant positive relationship between financial inclusion and household food security, consistent across different poverty statuses and locations. Thus, financial inclusion is an essential mechanism to ensure that households have access to adequate and nutritious food, thereby strengthening food security in diverse settings.

Baborska et al. (2020) examine the effect of financial services at the household level in low- and lower-middle-income countries and discover results that contradict previous studies. They note that access to credit, a key focus of financial inclusion, is not always effective in dealing with food insecurity. This ineffectiveness is often caused by high interest rates and short repayment periods for informal credits, which can lead to debt and financial stress (Nepal & Neupane 2022). Moreover, Carman & Zamarro (2016) disclose that in developed countries such as the USA, individuals with low financial literacy may struggle with money management, leading to poor spending decisions and difficulties in purchasing food.

3. Method

3.1. Model Specifications

This study employed the System GMM estimation method due to its ability to identify country-specific effects, control for unobserved effects using first differences, and address potential endogeneity among explanatory variables. The Generalized Method of Moments (GMM) is a widely applied estimation technique because it selects parameter values that align sample moments with popu-

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lation moments, also known as the orthogonality condition (Arellano & Bond 1991). GMM is advantageous because it provides asymptotic properties that are relatively easy to analyze, especially when the data-generating process is unknown or imprecise (Hansen 2010).

There are two types of GMM estimation methods: First Difference GMM (FD-GMM) and System GMM (Sys-GMM). However, FD-GMM has limitations, as lagged levels may not serve as effective instruments for variables transformed into first differences, particularly if those variables exhibit a random walk (Arellano & Bover 1995; Blundell & Bond 1998). To resolve this issue, the Sys-GMM method estimates equations using both levels and first differences, offering more efficient parameter estimates, particularly when the time dimension (T) is small and initial conditions are necessary (Blundell & Bond 1998).

Despite its several advantages, Sys-GMM also has limitations. One key drawback is its sensitivity to instrument selection, as using too many instruments can result in biased estimates (instrument proliferation). To mitigate this, the study followed the recommendation by Rodman (2009) to limit the number of lags used as instruments. The validity of Sys-GMM also relies on the assumption that instruments are exogenous. To verify this, the study implemented the Sargan/Hansen test for over-identifying restrictions, as suggested by Arellano & Bond (1991).

Another limitation is the potential persistence in dependent variables, which can render lagged instruments weak predictors. This study tested for persistence and reported first- and second-order autocorrelation (AR(1) and AR(2)) to ensure model validity, as recommended by Blundell & Bond (1998). While Sys-GMM addresses time-invariant unobserved heterogeneity, it may not fully account for time-varying heterogeneity. To resolve this, the study included various control variables and performed subsample analyses to examine robustness against potential heterogeneity.

Rodman (2009) outlines that the GMM estimation method is suitable in situations where: i) panel data has more cross-sectional components than time series; ii) a linear relationship is observed; iii) a dynamic dependent variable is present; iv) several independent variables are not strictly exogenous; v) fixed individual effects are present; and vi) heteroscedasticity and autocorrelation exist within individuals but not across them. The equation for the Sys-GMM method is as follows:

$$\begin{aligned} FS_{it} &= \alpha_0 + \alpha_1 FS_{it-1} + \alpha_2 FII_{it} \\ &\quad + \alpha_3 FII * Covid\text{-}19_{it} + \alpha_4 Z_{it} \\ &\quad + \alpha_5 Covid\text{-}19_{it} + \mu_{it} \\ &\quad i = 1, \ldots, N; \;\; t = 2, \ldots, N \end{aligned} \tag{1}$$

Where FS represents Food Security as a dependent variable, FS_{t-1} is food security in the previous year, FII indicates the Financial Inclusion Index as an independent variable, $FII * Covid$-19 is an interaction variable between the Financial Inclusion Index and the COVID-19 dummy, Z signifies a vector control variable, covid-19 is a Covid-19 dummy, α_0 is the intercept, $\alpha_2, \alpha_3, \alpha_4, \alpha_5$ is the parameter of each variable, μ symbolizes an unobserved idiosyncratic error, i denotes the unit cross section in this state, and t indicates the unit time series.

In this study, the second lag of the food security variable was implemented as an instrument variable. This choice addresses potential endogeneity issues in a dynamic panel analysis by ensuring the instrument is sufficiently removed from the current period to avoid correlation with the error term, while still being relevant for the endogenous variable (Arellano & Bover 1995; Rodman 2009). The second lag strikes a balance between relevance and exogeneity, as the first lag may still be endogenous, and longer lags may lose predictive power (Blundell & Bond 1998).

3.2. Measurement and Data Sources

This study adopted a quantitative approach to test hypotheses derived from theoretical and empirical literature. Using balanced panel data, it examined 61 countries across six regions: 8 from East Asia

and the Pacific, 13 from Europe and Central Asia, 14 from Latin America and the Caribbean, 7 from the Middle East and North Africa, 3 from South Asia, and 16 from Sub-Saharan Africa (Appendix A3). The dependent variable, food security, is proxied by Dietary Energy Supply. The main independent variable is financial inclusion, with additional control variables including per capita income, education level, urbanization rate, GDP deflator, and food growth index. Data for these variables were sourced from the World Development Index (WDI) and the International Monetary Fund (IMF) for the period 2011–2021.

3.3. Construction of the Financial Inclusion Index (FII)

The initial and primary task of this study was to construct a Financial Inclusion Index (FII) to evaluate and compare the level of financial inclusion across various countries, particularly in developing economies. This comprehensive measure helps monitor progress towards achieving national financial inclusion targets and facilitates cross-country comparisons. The FII incorporates three key dimensions: penetration, availability, and usage. Data for these dimensions were sourced from the Financial Access Survey (FAS) and The Global Financial Database (Findex) of the World Bank and the International Monetary Fund (IMF), spanning the period from 2011 to 2021.

The penetration dimension measures the inclusion of individuals in the formal financial system. It applies two main indicators: the number of deposit accounts per 1,000 adults and the number of depositors per 1,000 adults (Arshad 2022; Omar & Inaba 2020; Sarma 2012). The weighted average for these indices is 0.70 for deposit accounts and 0.30 for depositors, reflecting the importance of deposit accounts in assessing the banking population. The index for depositors receives a lower weight because not all depositors maintain active accounts. The overall weight for this dimension is set at 1 for the calculation of FII (Omar & Inaba 2020).

The availability dimension evaluates the reach of financial services, considering both geographic and demographic penetration through financial institution outlets such as offices, branches, and ATMs. This dimension is measured using two indicators: the number of financial institution branches and ATMs per 100,000 adults (Omar & Inaba 2020; Sarma 2012). These indices are weighted 0.70 for branches and 0.30 for ATMs. While electronic financial services are becoming more common, inconsistent data prevent their inclusion in this dimension. Consequently, the availability dimension is assigned an overall weight of 0.60 in the calculation of FII (Omar & Inaba 2020).

The usage dimension estimates how frequently and effectively customers utilize various financial services, such as saving, borrowing, and making payments. It assesses the efficiency of the financial system, acknowledging that access alone is insufficient for financial inclusion. Due to inconsistent data on payments, remittances, and cross-country transfers, this dimension implements two main indicators: the number of loan accounts per 1,000 adults and the number of borrowers per 1,000 adults (Arshad 2022; Omar & Inaba 2020; Sarma 2015). Both indices are equally weighted at 0.50. The number of loan accounts reflects a higher level of financial inclusion, as individuals with loan accounts typically also have other financial services, including bank accounts. The number of borrowers is equally weighted at 0.50 as those with active loan accounts are also engaged with the financial system. The overall weight for this dimension in FII is also set at 0.50, considering the limitations of available data for other relevant indicators (Omar & Inaba 2020).

The weights from the index by Sarma (2012) may be outdated due to factors such as technological changes (Ozili 2018), shifts in financial policies (Demirguc-Kunt & Klapper 2012), changes in consumer behavior (Gabor & Brooks 2017), and varying contexts. However, the authors encountered challenges in updating these weights due to limited data for recalibration. Nevertheless, an analysis using the PCA index (Table 7), which applies newer

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weights and reflects current conditions, yields results consistent with those from the index by Sarma. This demonstrates that while weights from Sarma (2012) may not perfectly align with current circumstances, they still offer reasonably accurate estimates of financial inclusion within the scope of this study.

A multidimensional approach is effective in constructing a financial inclusion index as it can accommodate various relevant aspects. This method is similar to that applied by UNDP to create various indices such as the Human Development Index and the Gender Discrimination Index. In this study, we adopted the Sarma method to construct the financial inclusion index using the following formula:

$$FII_i = 1 - \sqrt{\frac{(1-d_1)^2 + (1-d_1)^2 + \cdots + (1-d_n)^2}{\sqrt{n}}} \quad (2)$$

In the formula above, the numerator represents the Euclidean distance from the ideal point I, which is normalized by $\sqrt{n}$. Subtracting the equation by 1 will produce an inversely normalized distance. The weights for each indicator in this study follow those specified by Omar & Inaba (2020) as presented in Table 1.

This study also employed the Principal Component Analysis (PCA) method to construct the financial inclusion index, following Cámara & Tuesta (2014). PCA helps determine the appropriate weights for each variable by assuming that FII is a linear combination of several variables. Each variable is assigned a specific weight, and the index value is calculated from these weighted combinations. The equation for FII using PCA is as follows:

$$FII_i = w_1 Y_i^p + w_2 Y_i^a + w_3 Y_i^u + e_i \quad (3)$$

Where FII_i is a composite FII for country i; w_1,w_2,w_3 are the relative weights for each dimension; e_i is the error term; and Y_i^p,Y_i^a, and Y_i^u constitute the dimensions of penetration, availability, and usage, each of which is calculated as follows:

$$Y_i^p = \beta_1 depositaccounts_i + \beta_2 depositors_i + u_i \quad (4)$$

$$Y_i^a = \theta_1 branches_i + \theta_2 ATMs_i + \epsilon_i \quad (5)$$

$$Y_i^a = \gamma_1 borrowers_i + \gamma_2 loans_i + v_i \quad (6)$$

4. Results and Analysis

4.1. Summary Statistics

This study examines the impact of financial inclusion on food security using balanced panel data from 61 countries (46 developing and 15 developed) over the period 2011–2021, totaling 671 observations. Food security is proxied by dietary energy supply—an indicator that measures the average availability of daily food energy per individual, expressed in kilocalories. The average value of the dietary energy supply in this study is 1,821 kilocalories per day per individual, slightly above the minimum standard of 1,800 kilocalories determined by FAO, indicating relatively good food security. The financial inclusion index, calculated using the Sarma method, has an average value of 0.382, reflecting low financial inclusion across the sample. Control variables include per capita income, food production index, consumer price index, education level, and urbanization rate to reduce bias.

4.2. Pearson Correlation Test

The Pearson Correlation Test helps identify potential multicollinearity in regression models. A correlation coefficient above 0.8 suggests a multicollinearity issue between the variables (Lind, Marchal & Wathen 2005).

Table 3 shows that no correlation coefficient exceeds 0.8, indicating that the variables in this study do not exhibit multicollinearity issues.

Table 1. The Weight of Each Indicator of Financial Inclusion Index

Dimension of Financial Inclusion	Indicator	The weight of each indicator
Penetration (overall dimensional weight to calculate FII = 1)	Number of deposit accounts in financial institutions per 1,000 adults	0.70
	Number of depositors engaged with financial institutions per 1,000 adults	0.30
Availability (overall dimensional weight to calculate FII = 0.60)	Number of branches of financial institutions per 100,000 adults	0.70
	Number of automated teller machines (ATMs) per 100,000 adults	0.30
Usage (overall dimensional weights to calculate FII = 0.50)	Number of loan accounts in financial institutions per 1,000 adults	0.50
	Number of borrowers from financial institutions per 1,000 adults	0.50

Table 2. Summary Statistics

Variable	N	Average	Deviation Standards	Minimum Values	Maximum Value
Food Security (kcal/capita/day)	671	1821	89.497	1,665	2,074
Financial Inclusion Index	671	0.382	0.075	0.025	0.529
GDP Deflator (USD)	671	129.599	91.492	8.490	1,503.614
Food Production Index	671	102.091	11.699	62.4	162.02
Income per Capita (USD)	671	9,787.643	13,373.78	357.826	7,493.27
Urbanization (%)	671	2.045	1.740	-4.170	10.150
Education (Mean Years School)	671	8.251	2.566	1.916	13.25

Source: World Bank, IMF, FAO (data processed)

Table 3. Pearson Correlation Test

Variable	FS	FII	GDP	FPI	IP	Urban	Educ
Food Security	1.000						
Financial Inclusion Index	-0.086	1.000					
GDP Deflator	-0.270	0.194	1.000				
Food Production Index	-0.043	0.103	0.318	1.000			
Income per Capita	0.726	-0.149	-0.341	-0.045	1.000		
Urbanization	-0.508	0.011	0.161	0.009	-0.433	1.000	
Education	0.704	-0.075	-0.150	-0.052	0.691	-0.594	1.000

Source: Processed by authors

4.3. Arellano-Bond Test

The Arellano-Bond test evaluates serial correlation in the error terms within panel regression models using the GMM method. The results of AR (1) and AR (2) tests display no serial correlation in any of the models, with p-values above the 5% significance level, indicating no temporal bias in the dynamic panel estimates. The AR (2) test is particularly noted for its efficiency in short sample periods (Rodman 2009).

4.4. Instrument Validity Test (The Sargan-Hansen Test)

The Sargan-Hansen test checks the validity of instruments in GMM estimation. Table 5 shows that all p-values from both the Sargan and Hansen tests exceed 10%, indicating that the instruments applied are valid and not correlated with the error term. According to Rodman (2009), a Hansen p-value below 10% may signal issues with the instruments; however, in this study, all p-values demonstrate that the instruments are appropriate, ensuring consistent and efficient estimation results.

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Table 4. Arellano-Bond Test

Arellano-Bond Test	Food security, all countries	Food security, developing countries	Food security, developed countries
AR (1)	-1.190	-1.180	-0.020
AR (1) p-value	0.234	0.237	0.981
AR (2)	1.010	-0.390	-0.080
AR (2) p-value	0.312	0.699	0.935

Source: Processed by authors

Table 5. The Sargan-Hansen Test

Instrument Validity Test	Sample of All Countries	Sample of Developing Countries	Sample of Developed Countries
Sargan Test	2.900	3.800	0.480
(*p-value*)	0.716	0.578	0.993
Hansen Test	3.140	6.060	11.460
(*p-value*)	0.678	0.301	0.177

Source: Processed by authors

4.5. Coefficient Bias Test

This test evaluates whether the coefficient of the lagged dependent variable in the GMM estimation model falls between the coefficients from the fixed effects model (FEM) and the pooled least squares (PLS) model. If the lag coefficient lies between these two, it demonstrates that the model effectively incorporates autoregressive effects while retaining the characteristics of both fixed effects and pooling. This approach leverages historical data of the dependent variables and individual-specific effects, leading to more efficient and consistent estimates by addressing potential autocorrelation or relationships between observations over time (Baltagi 2021; Wooldridge 2010).

The results illustrate that all lag coefficients in the GMM model are significant and fall between the FEM and PLS coefficients (Appendix A1). Therefore, GMM offers more efficient and consistent estimates compared to FEM, which may produce downward-biased results, and PLS, which may yield upward-biased estimates.

4.6. Estimation Results using the Sarma Index (Baseline Method)

Financial inclusion has been shown to boost food security in both developed and developing countries. These results are consistent with research conducted by Arshad (2022), Fowowe (2023), and Koomson, Asongu & Acheampong (2023). Examined from a supply-side perspective, financial inclusion substantially enhances food security and agricultural productivity. Access to credit positively impacts agricultural production by increasing input accessibility and boosting production efficiency (Diamoutene & Jatoe 2021). Financial literacy and access to credit have been linked to better food security, with credit enabling better management and productivity in agriculture (Twumasi et al. 2023).

Economically, improved credit access reduces postharvest losses, boosts farmer incomes, and supports sustainable development goals related to food security and nutrition (Akpa et al. 2023). Savings in financial institutions enhance agricultural productivity by facilitating investments in modern equipment and technology (Fowowe 2023). Access to credit often leads to the adoption of advanced agricultural practices, resulting in higher crop yields and improved food security (Raza et al. 2023). Farmers can have access to capital and credit that allows them to increase production and productivity by purchasing quality seeds, fertilizers, and pesticides, or investing in more advanced agricultural technology. In general, financial inclusion positively affects agricultural productivity by optimizing resource use and increasing production.

On the demand side, access to formal financial services, such as savings, loans, and other transactional products, plays an important role in reducing

Table 6. System GMM Estimation Results with the Sarma Index

Variable	All Countries	Developing Countries	Developed Countries
Food Security	0.004**	0.003**	0.006*
	(0.002)	(0.001)	(0.003)
Food Security *COVID-19	-0.015**	-0.012**	-0.013*
	(0.007)	(0.006)	(0.007)
Ln GDP Deflator	0.000	0.000	0.000
	(0.000)	(0.001)	(0.042)
Ln Food Production Index	-0.002	-0.001	-0.001
	(0.002)	(0.002)	(0.078)
Ln Income per Capita	0.002*	0.002	0.000
	(0.001)	(0.003)	(0.047)
Urbanization	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.002)
Ln Education	0.001	0.002	0.002
	(0.002)	(0.004)	(0.121)
COVID-19	-0.006**	-0.005*	-0.004*
	(0.003)	(0.003)	(0.002)
Constant	0.363	0.409	0.190
	(0.226)	(0.511)	(4.443)
Observation	610	460	150
Number of Countries	61	46	15
Number of Instruments	15	15	15
AR (2)	0.312	0.237	0.935
Prob Hansen	0.678	0.301	0.177

Source: Processed by authors

Note: Standard errors in parentheses and ***, **, *, indicate significance levels of 1%, 5%, and 10%, respectively

food insecurity. Households without bank accounts or access to formal financial services often struggle to manage their finances properly, rendering them more vulnerable to economic shocks and income instability. This can negatively impact their ability to purchase sufficient and nutritious food (Fitzpatrick 2017). Several other studies have also proven that financial inclusion has a stronger positive effect on male-led and rural-led households. Entrepreneurship is identified as one of the channels through which financial inclusion boosts food security, as it allows households to increase their spending and access more nutritious food. Female-led households also demonstrate improvements in nutritious diets when having access to formal financial services (Bali Swain & Nsabimana 2024; Koomson, Asongu & Acheampong 2023).

Financial inclusion through savings facilities also has an important role in providing a financial safety net. With reserve funds, households are better prepared to face sudden financial crises, such as job losses or natural disasters, which may threaten their food security. Furthermore, savings offer additional benefits, such as higher yields, which can increase household wealth and income. All these factors contribute to boosting food security by reducing food insecurity and providing a foundation for household financial stability (Baborska et al. 2020).

An analysis of country-group classifications reveals that financial inclusion significantly enhances food security in both developed and developing countries, with a notably greater impact in developing nations. This indicates that access to financial services is crucial for bolstering food security, though its effectiveness varies depending on the level of economic development of a country. In developing countries, where the agricultural sector often forms the backbone of the economy, access to credit and other financial services directly influences the capacity of farmers to boost food production and distribution (Allen et al. 2016). Consequently, financial inclusion exerts a more substantial impact on food security in these nations. In addition, the relatively low penetration of financial services in developing countries means that financial inclusion programs can introduce previously inaccessible essential ser-

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vices (Demirguc-Kunt & Klapper 2012), thereby enhancing food security more effectively.

Conversely, in developed countries, where the economic structure is more diversified with predominant service and industrial sectors, the positive effect of financial inclusion on food security is less pronounced. This is attributable to the higher stability of food security and the extensive availability of financial services in these countries, which most of the population already accesses. Moreover, government policies in developed countries are often centered on macroeconomic stabilization and financial risk management, whereas in developing nations, policies tend to focus more on expanding financial services to farmers and low-income households. These policy differences contribute to the variation in the impact of financial inclusion on food security across these country groups (Allen et al. 2016; Cull, Ehrbeck & Holle 2014; Demirguc-Kunt & Klapper 2012).

Based on Table 4, the interaction variable between financial inclusion and COVID-19 shows a negative and significant effect, with a coefficient of -0.015 for all countries, -0.012 for developing countries, and -0.013 for developed countries. This indicates that the COVID-19 crisis has diminished the impact of financial inclusion on food security by 1.5 percent globally, 1.2 percent in developing countries, and 1.3 percent in developed countries, significant at the 5% and 10% levels. This is contrary to findings from previous studies.

The COVID-19 crisis has caused dramatic shocks to income, employment, and production, which is expected to lead to a widespread increase in global food insecurity. The poorest households, which spend most of their income on food and have limited access to financial markets, are particularly vulnerable to income shocks. In addition, movement restrictions and lockdowns during the pandemic may hinder physical access to financial institutions, such as banks or credit cooperatives, particularly in rural areas. This can hinder farmers and agribusiness actors from accessing financial services, negatively impacting their ability to manage risk and increase production. The pandemic has also affected agriculture and food security in two important ways: food supply and demand. Disruptions to food supply chains and transportation have made it difficult for people to access food, and the loss of income has further complicated the ability of people to purchase food. Therefore, while financial inclusion remains an important means of achieving food security, the COVID-19 crisis has made this goal more challenging to achieve.

In addition, the COVID-19 dummy variable reveals a negative and significant impact on food security, with a coefficient of 0.006 for all countries, -0.005 for developing countries, and -0.004 for developed countries. This suggests that the COVID-19 crisis has decreased food security by 0.6 percent globally, 0.5 percent in developing countries, and 0.4 percent in developed countries, with significance at the 5% and 10% levels. These results differ from the findings of several prior studies.

Movement restrictions and lockdowns have caused major disruptions to the food supply chain. Transportation has been hampered, distribution disrupted, and access to markets blocked. This has led to stockpiling in one place and shortages in another, which in turn can increase prices and result in food scarcity. Supply chain disruptions and rising demand for certain products can pose a serious problem for consumers already facing economic pressures, reducing their purchasing power for food and causing food inflation. Movement restrictions, labor supply uncertainty, and logistical issues may hinder agricultural production. Farmers may experience difficulties in accessing seeds, fertilizers, and other agricultural inputs. The closure of processing plants and quarantine policies may impede the processing and distribution of crops. Furthermore, the economic crisis caused by the COVID 19 pandemic has also caused the loss of jobs and income for many people. People who have lost their source of income may struggle to purchase food and meet basic food needs, which can ultimately increase levels of hunger and food insecurity. In terms of policy, the government has also shifted their priorities

to the health sector and economic recovery. This may reduce support and attention to the agricultural sector and food security.

4.7. Estimation Results using the PCA Index (Robustness Check)

As presented in Table 7, the estimation results using the PCA index to measure financial inclusion demonstrate outcomes that are relatively similar to those obtained using the Sarma method, albeit with a smaller coefficient. This consistency highlights the reliability and robustness of the research findings, suggesting that the relationship between financial inclusion and food security is not dependent on any single method. These results indicate confidence that the observed link is stable across different approaches.

Moreover, the similarity of results from both methods confirms the consistency of the relationship between financial inclusion and food security, indicating that this relationship is significant and not merely a feature of one specific method. The implementation of both methods enriches the analysis by offering diverse perspectives, thereby reinforcing the findings and providing a more comprehensive and contextualized understanding of how financial inclusion impacts food security.

5. Conclusion

The estimation results reveal that financial inclusion positively impacts food security across all research sub-samples. However, the COVID-19 pandemic has moderated this positive effect, with the crisis reducing food security across the board. The robustness of these findings is further validated by employing an alternative estimation method, using the PCA Method to construct the financial inclusion index, yielding consistent results. This study significantly enhances the understanding of the interplay between financial inclusion and food security within a global context in the face of the pandemic. The findings underscore the critical need for policies and strategies aimed at bolstering food security amidst such crisis.

The study presents several important policy implications. In developing countries, particularly in rural and remote areas, access to financial services is often limited. Enhancing financial services, such as bank accounts, credit, and insurance, is crucial. This includes expanding banking networks and improving financial infrastructure in underserved regions. Banks should offer loans to individuals to support business ventures and mitigate food insecurity. In addition, agricultural insurance schemes should be developed to provide credit and support to smallholders, helping them handle uncertainties and food insecurity. Microinsurance should also be facilitated to safeguard farmers and low-income households against risks such as accidents, illness, or death. Enhancing financial literacy through education on financial management and the use of financial products is essential, and collaboration between the government, educational institutions, and the private sector can facilitate this. Addressing gender and location disparities through targeted financial training and support for micro-enterprises in marginalized areas is also necessary. Moreover, governments should implement policies to shield communities from external shocks, including national food reserves, economic diversification, and agricultural insurance. Effective implementation of these recommendations will require concerted efforts among the government, the private sector, and Non-Governmental Organizations (NGOs) to drive financial innovations, improve infrastructure, and deliver better services.

This study acknowledges several limitations, including the use of dietary energy supply as a sole proxy for food security, which does not fully encompass the complexity of the concept. Moreover, while the financial inclusion index considers various dimensions, it does not capture all critical indicators, such as mobile money account ownership, debit or credit card ownership, and insurance ownership.

Future research could benefit from a comparative analysis across different continents or regions us-

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Table 7. System GMM Estimation Results with the PCA Index

Variable	All Countries	Developing Countries	Developed Countries
Food Security	0.003**	0.0001*	0.001*
	(0.000)	(0.000)	(0.000)
Food Security *COVID-19	-0.001*	-0.002**	-0.003**
	(0.001)	(0.000)	(0.001)
Ln GDP Deflator	0.000	0.000	0.0009
	(0.000)	(0.000)	(0.002)
Ln Food Production Index	0.000	0.000	0.001
	(0.002)	(0.003)	(0.001)
Ln Income per Capita	0.001	0.000	0.0009
	(0.001)	(0.002)	(0.000)
Urbanization	-0.000	-0.000	0.000
	(0.000)	(0.000)	(0.002)
Ln Education	0.001	0.002	-0.000
	(0.001)	(0.005)	(0.000)
COVID-19	-0.001**	-0.002**	-0.0001**
	(0.000)	(0.000)	(0.000)
Constant	0.180	0.217	0.107
	(0.134)	(0.428)	(0.146)
Observation	610	460	150
Number of countries	61	46	15
Number of Instruments	15	15	15
AR (2)	0.949	0.851	0.387
Prob Hansen	0.146	0.166	0.833

Source: Processed by authors

Note: The error standards in parentheses and the ***, **, * marks indicate a significance level of 1%, 5%, and 10%, respectively

ing financial inclusion and food security indices. Expanding studies to include additional variables, such as child mortality rates, carbon emissions, and foreign investment, could generate further insights. Moreover, utilizing alternative proxies for food security and developing indices to assess their impact on various factors could offer valuable contributions to the field.

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Appendices

A1. Estimation Result Pool Least Square (PLS), Fixed Effect Model (FEM), Two Step Generalized Method of Moment (GMM) (Sarma Index)

Variabel	Semua Negara				Negara Berkembang				Negara Maju			
	FD GMM	PLS	FEM	System GMM	FD GMM	PLS	FEM	System GMM	FD GMM	PLS	FEM	System GMM
L1.lfs	0.933***	0.978***	0.868***	0.885***	0.940***	0.976***	0.855***	0.871***	0.880***	0.980***	0.870***	0.924**
	(0.002)	(0.004)	(0.024)	(0.071)	(0.056)	(0.006)	(0.026)	(0.161)	(0.117)	(0.003)	(0.031)	(0.355)
Fii	0.004**	0.005	0.001**	0.004**	0.003**	-0.0009	0.001	0.003**	0.000	0.001*	0.002	0.006*
	(0.002)	(0.000)	(0.000)	(0.002)	(0.001)	(0.000)	(0.000)	(0.001)	(0.003)	(0.000)	(0.001)	(0.003)
Fii*Covid-19	-0.001	0.004	-0.001	-0.015**	-0.009**	0.0004	-0.0009	-0.012**	-0.006	-0.005	-0.001	-0.013*
	(0.006)	(0.000)	(0.000)	(0.007)	(0.004)	(0.001)	(0.000)	(0.006)	(0.014)	(0.001)	(0.001)	(0.007)
Ln GDP def	0.006*	0.004***	0.001***	0.000	0.0004**	0.0003***	0.001***	0.000	0.000	-0.000	-0.000	0.000
	(0.003)	(0.000)	(0.000)	(0.000)	(0.0002)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.042)
Ln Fpi	-0.000	-0.000	-0.001	-0.002	0.000	-0.000	-0.001	-0.001	-0.002	0.001	-0.002**	-0.001
	(0.001)	(0.000)	(0.001)	(0.002)	(0.001)	(0.000)	(0.002)	(0.002)	(0.002)	(0.000)	(0.000)	(0.078)
Ln Ip	-0.001	0.004***	-0.001**	0.002*	-0.000	0.005***	-0.001	0.002	-0.004	-0.000	-0.004***	0.000
	(0.001)	(0.000)	(0.000)	(0.001)	(0.001)	(0.000)	(0.001)	(0.003)	(0.002)	(0.000)	(0.001)	(0.047)
Urb	-0.000	0.000	-0.000	-0.000	-0.001**	-0.000	0.0001***	-0.000	0.000	0.001***	0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.002)
Ln Educ	-0.002	-0.0007*	0.004*	0.001	-0.004	-0.0008*	0.004	0.002	0.007	-0.002***	0.006	0.002
	(0.004)	(0.000)	(0.002)	(0.002)	(0.003)	(0.000)	(0.002)	(0.004)	(0.004)	(0.000)	(0.003)	(0.121)
Covid-19	-0.004	-0.0001	-0.004	-0.006**	-0.003*	-0.000	-0.000	-0.005*	-0.002	0.000	-0.000	-0.004*
	(0.002)	(0.000)	(0.003)	(0.003)	(0.003)	(0.000)	(0.000)	(0.003)	(0.004)	(0.000)	(0.000)	(0.002)
Constant		0.069***	0.366***	0.363		0.075***	0.469***	0.409		0.065***	0.313**	0.190
		(0.013)	(0.081)	(0.226)		(0.022)	(0.087)	(0.511)		(0.011)	(0.107)	(4.443)
Observasi	549	610	610	610	414	460	460	460	135	150	135	150
Jumlah negara	61	61	61	61	46	46	46	46	15	15	15	15
Jumlah Instru	13			15	13			15	13			15
AR (2)	0.594			0.312	0.228			0.237	0.924			0.935
Prob Hansen	0.496			0.678	0.413			0.301	0.591			0.177
R-Squared		0.998	0.999			0.997	0.998			0.999	0.821	

Catatan: Standar Error dalam tanda kurung, dan tanda ***, **, *, masing-masing menunjukkan tingkat signifikansi 1%, 5%, dan 10%

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A2. Estimation Result Pool Least Square (PLS), Fixed Effect Model (FEM), Two Step Generalized Method of Moment (GMM), and Bias Coefficient Test (PCA Index)

Variabel	Semua Negara				Negara Berkembang				Negara Maju			
	FD GMM	PLS	FEM	System GMM	FD GMM	PLS	FEM	System GMM	FD GMM	PLS	FEM	System GMM
L1.lfs	0.918***	0.978***	0.861***	0.942***	0.980***	0.986***	0.835***	0.931***	0.973***	0.983***	0.912***	0.967**
	(0.092)	(0.003)	(0.025)	(0.042)	(0.077)	(0.006)	(0.025)	(0.135)	(0.142)	(0.003)	(0.037)	(0.045)
Fii	0.000	-0.000	0.000	0.003**	0.0003	-0.000	0.000	0.0001*	0.0002**	-0.001**	-0.000	0.001*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.0001)	(0.000)
Fii*Covid-19	-0.001	0.000	-0.0001	-0.001*	-0.001	0.0001	-0.0002	-0.002**	-0.006	0.0003**	-0.0002	-0.003**
	(0.001)	(0.000)	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.0001)	(0.001)
Ln GDP def	0.001***	0.003***	0.001***	0.000	0.008***	0.0003***	0.001***	0.000	-0.000	-0.000	-0.0002	0.0009
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.002)
Ln Fpi	-0.000	-0.0006	-0.001	0.000	0.000	-0.000	-0.001	0.000	-0.002*	0.000	-0.002**	0.001
	(0.001)	(0.000)	(0.001)	(0.002)	(0.001)	(0.000)	(0.002)	(0.003)	(0.001)	(0.000)	(0.000)	(0.001)
Ln Ip	-0.001	0.004***	-0.001	0.001	-0.001	0.005***	-0.0006	0.000	-0.004	-0.0002	-0.004***	0.0009
	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)	(0.000)	(0.001)	(0.002)	(0.003)	(0.000)	(0.001)	(0.000)
Urb	-0.000	0.000	-0.000	-0.000	-0.001**	-0.000	-0.001***	-0.000	0.000	-0.0001**	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.004)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.002)
Ln Educ	0.002	-0.0007*	0.005**	0.001	-0.001	-0.0008*	0.005**	0.002	0.006	-0.002***	0.006*	-0.000
	(0.004)	(0.000)	(0.002)	(0.001)	(0.004)	(0.000)	(0.002)	(0.005)	(0.005)	(0.000)	(0.003)	(0.000)
Covid-19	-0.000	0.000	-0.000	-0.001**	-0.000	0.000	-0.000	-0.002**	-0.000	0.000	-0.000	-0.0001**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Constant		0.069***	0.421***	0.180		0.075***	0.469***	0.217		0.056***	0.303**	0.107
		(0.013)	(0.083)	(0.134)		(0.022)	(0.084)	(0.428)		(0.010)	(0.122)	(0.146)
Observasi	549	610	610	610	414	460	460	460	135	150	135	150
Jumlah negara	61	61	61	61	46	46	46	46	15	15	15	15
Jumlah Instru	13			15	13			15	13			15
AR (2)	0.807			0.949	0.992			0.851	0.328			0.387
Prob Hansen	0.284			0.146	0.221			0.166	0.895			0.833
R-Squared		0.998	0.999			0.997	0.998			0.999	0.821	

Catatan: Standar Error dalam tanda kurung, dan tanda ***, **, *, masing-masing menunjukkan tingkat signifikansi 1%, 5%, dan 10%

A3. List Countries

Regions	Countries		
East Asia & Pacific	Brunei Darussalam	Singapore	Indonesia
	Philippines	Samoa	Timor-Leste
	Malaysia	Thailand	
Europe & Central Asia	Belgium	Croatia, Rep. of	Hungary
	Italy	Latvia	Poland, Rep. of
	Portugal	Kyrgyz Rep. of	Ukraine
	Bosnia and Herzegovina	Georgia	North Macedonia
	Türkiye, Rep of		
Latin America & Caribbean	Chile	Uruguay	Bolivia
	Honduras	Nicaragua	Belize
	Brazil	Colombia	Costa Rica
	Dominican Rep.	Ecuador	Guatemala
	Paraguay	Peru	
Middle East & North Africa	Kuwait	Qatar	Saudi Arabia
	United Arab Emirates	Algeria	Egypt, Arab Rep. of
	Lebanon		
South Asia	Bangladesh	Pakistan	Maldives
Sub-Sahara Africa	Chad	Madagascar, Rep. of	Malawi
	Mozambique, Rep. of	Rwanda	Uganda
	Cabo Verde	Congo, Rep. of	Eswatini, Kingdom
	Ghana	Kenya	Lesotho, Kingdom
	Mauritania, Islamic Rep.	Nigeria	Zimbabwe
	Botswana		

A4. Scoring Coefficients for Orthogonal Varimax Rotation (Weights)

Variable	Comp1	Unexplained
Number of deposit accounts in financial institutions per 1,000 adults	0.5473	0.1992
Number of depositors engaged with financial institutions per 1,000 adults	0.5228	0.3649
Number of branches of financial institutions per 100,000 adults	0.3335	0.6617
Number of automated teller machines (ATMs) per 100,000 adults	0.5783	0.7680
Number of loan accounts in financial institutions per 1,000 adults	0.5558	0.3580
Number of borrowers from financial institutions per 1,000 adults	0.2379	0.76830

A5. Scoring Coefficients (Weights Assigned to Penetration, Availability, and Usage Dimensions)

Variable	Comp1	Unexplained
Penetration	0.5841	0.2574
Availability	0.5634	0.2865
Usage	0.5573	0.1936

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