Enhancing food security through agricultural financing and loans within Indonesia's dual banking system: empirical study approaches

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Food security is a crucial issue due to its role in community welfare, and one approach to achieving this is through agricultural financing and loans provided by the banking industry. Indonesia's dual banking system combines interest-based conventional banking and Islamic banking, which offers interest-free financing and profit-sharing. This study empirically analyses the impact of agricultural financing and loans from Islamic and conventional banks on food security in Indonesia. Using panel data from provinces in Indonesia (2018–2024), this study applies selected static panel data techniques, namely the fixed effects model (FEM) and robust least squares (RLS) with method of moments estimation. Based on the FEM results, the main findings of this study show that increasing agricultural financing from Islamic and conventional banks improve food security in Indonesia. However, some explanatory variables were confirmed to be insignificant in this model. To validate these results, a robustness test using RLS was conducted, which reaffirmed that agricultural financing from both bank types significantly impacts food security. This strengthens the consistency of the findings and highlights the critical role of agricultural financing in improving food security. The novelty of this study lies in its comprehensive analysis of the role of agricultural sector financing and loans in enhancing food security across all provinces in Indonesia, providing unique insights into the relationship between banking support and food security at a national level.

Introduction

Food security, a target of sustainable development goals (SDGs) number 2, focuses on ending hunger, achieving food security, and improving nutrition by 2030 (Abduh 2019). These goals are interconnected with sustainable agriculture, as achieving them relies on sustainable agricultural practices. The agricultural and plantation sectors are vital for ensuring food availability, serving as key suppliers of raw materials. However, in recent decades, a concerning trend has emerged: extensive agricultural land is being converted into residential areas, buildings, or for other purposes (Rondhi et al. 2019). This is because the agricultural sector is no longer seen as a promising source of economic growth.

Rural depopulation and agricultural land conversion are major challenges to food security in Indonesia. Migration to urban areas for better job opportunities leaves the agricultural sector understaffed (Abduh 2019, Osabohien et al. 2020b). The conversion of agricultural land for settlements, industries, and infrastructure disrupts food production, harming soil fertility, water quality, and biodiversity (Adam et al. 2018, Rondhi et al. 2019, Ustaoglu–Collier 2018). Additionally, the younger generation's disinterest in farming, driven by perceptions of low prestige and uncertain income, exacerbates the issue (Dalmiyatun et al. 2024, Mardiyanti et al. 2023, Ma'rufah et al. 2022).

Economic uncertainties, including conflicts, the Covid-19 pandemic, and emerging threats such as monkeypox, destabilize food security by causing price fluctuations and disrupting supply chains (Kotur et al. 2024, Sharif–Irani 2017). Limited access to land, technical knowledge, and capital makes agriculture less attractive to the youth (Leavy–Hossain 2014). Food security, a national priority, is crucial for sustaining human life and requires availability, access, and effective utilization of food (Abduh 2019, Osabohien et al. 2020b).

To address these various issues, intervention from various policymakers is crucial, including through financial institutions such as banking, Islamic, and conventional. The banking industry plays a crucial role as a catalyst in increasing agricultural productivity, which will ultimately enhance food availability, accessibility, and benefits) (Osabohien et al. 2020a, 2018). Financing or credit provided by banking institutions will motivate farmers, especially young farmers, to regain enthusiasm for increasing agricultural productivity (Adetiloye 2012). One of the issues for many farmers is their lack of interest in the agricultural sector due to limited access to capital (Leavy–Hossain 2014). In fact, financing or credit provided by banks can help address the issues and impacts of volatility, uncertainty, complexity, and ambiguity on the agricultural and economic sectors, directly and indirectly.

Based on the background and previous research, there has been limited study on the effect of agriculture financing and loans from Islamic or conventional banking on food security in countries with a dual banking system such as Indonesia. Indonesia's dual banking system includes conventional banking, which operates on interest-based

transactions, and Islamic banking, which adheres to Islamic principles by prohibiting *riba* (interest) and utilizing profit-sharing models (Abduh 2019). Islamic banking supports smallholder farmers through interest-free financing, improving accessibility, productivity, and sustainable social welfare (Al-Roubaie–Sarea 2019). This system provides flexibility, allowing individuals to choose financial services according to their beliefs and needs (Osabohien et al. 2020a). While considerable research on this topic has been conducted in other countries, such as Nigeria, focusing on the effects of commercial credit and agricultural credit schemes on food security and agricultural productivity (Adetiloye 2012, Egwu 2016, Osabohien et al. 2020a, 2018), little has been done in Indonesia.

Therefore, this study aimed to empirically analyse the effects of agricultural financing and loans from Islamic and conventional banking on food security across Indonesia's provinces from 2018 to 2024. Thus, the following main research question can be raised: what is the impact of agricultural financing and loans under the dual banking framework on food security for the sample of 31 provinces in Indonesia during the period 2018–2024? To address this question, the study employs the fixed effects model (FEM) as the baseline analytical framework, complemented by robust least squares (RLS) with method of moments (MM) estimation as a robustness check to ensure the reliability of the findings. The structure of the study is as follows: it begins with a literature review, followed by the methodology, then the results and discussion are presented, and it concludes with the final remarks.

Literature review

Brief overview of food security

Numerous definitions of food security are currently in use. In broad terms, the Food and Agriculture Organization (FAO) of the United Nations describes food security as a situation where individuals consistently have access to adequate, safe, nutritious, and culturally appropriate food (FAO 2006). Thus, food security is a dynamic concept that ensures all people have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and preferences for an active and healthy life (FAO 2006). Food security is built upon four primary dimensions – availability, accessibility, utilization, and stability – while sustainability has emerged as a critical fifth dimension to address long-term challenges (Ericksen 2008, FAO 2006, Peng–Berry 2019). These dimensions are interdependent and collectively ensure that food systems are resilient and inclusive. Measurement approaches to food security vary, ranging from dietary diversity and nutrient intake to coping strategies and food environments, reflecting the complexity of the issue at individual, household, and national levels (Maxwell 1996, Pérez-Escamilla 2017).

Food security is shaped by social, economic, and environmental factors, with gender inequality being a key barrier. Women, vital to food production and household

welfare, often face resource access limitations (Burchi–De Muro 2016). Sustainable and equitable approaches are essential for creating regenerative and socially just food systems that address challenges such as poverty, inequality, and environmental degradation (Ericksen et al. 2009). Several factors influence food security, including limited agricultural land due to urbanization and industrialization, inadequate agricultural infrastructure, and farmers' technological knowledge and skills. Other contributing factors include energy access – direct and indirect sources – financial support through credit and investment, the physical environment influenced by climate change, sector collaboration, and the availability of essential inputs for agriculture. Addressing these interconnected challenges is vital for ensuring a sustainable and secure food future.

Measuring food security index in Indonesia

There are various methods for measuring food security, each using different indicators. However, this study follows the approach established by Indonesia's authorized authority, the National Food Agency (2023, 2024). To assess the level of food security in a region and its supporting factors, the NFA has developed a food security index system, which is based on the definition of food security and the subsystems that constitute the food security framework.

Table 1

Food security indicators based on the national food agency

No.	Indicator	Weight value
Food availability aspects		
1	Ratio of normative consumption to net production of rice, corn, sweet potatoes, cassava, and sago, as well as regional government rice stocks	0.30
Food affordability aspects		
2	Percentage of population below the poverty line	0.15
3	Percentage of households with a proportion of expenditure on food of >65% of total expenditure	0.075
4	Percentage of households without access to electricity	0.075
Food utilization aspects		
5	Average length of schooling for girls aged over 15 years	0.05
6	Percentage of households without access to clean water	0.15
7	Ratio of the number of residents per health worker to the population density level	0.05
8	Percentage of stunted toddlers	0.05
9	Life expectancy at birth	0.10

Source: NFA (2023).

The food security index is constructed using nine indicators derived from three main aspects of food security: availability, affordability, and food utilization (see Table 1).

The selection of these indicators is based on a review of the global food security index, their sensitivity in measuring food and nutrition security, their representation of the three pillars of food security, and the availability of consistent annual data covering all districts, cities, and provinces (NFA 2023). These criteria ensure that the indicators comprehensively reflect various dimensions of food security.

The food security index is calculated using a weighting method, with indicator values standardized using the z-score and scaled on a range from 0 to 100, as outlined by the NFA (2023). The final score is obtained by multiplying the standardized values of each indicator by its respective weight and summing them. This method provides a comprehensive and systematic measure of food security at various levels. The result is obtained by multiplying the standardized indicator values by their respective weights and summing them, using the following formula:

$$Y(j) = \sum_{t=1}^{9} ai\, X_{ij}$$

where i represents the indicators 1 through 9 in Table 1, j represents the districts/cities/provinces, Y_j represents the food security index, ai represents the weight of indicator i, and X_{ij} represents the standardized value of indicator i for district/city/province. Figure 1 shows the average value of the food security index calculation from 2018 to 2024 across provinces in Indonesia (NFA 2024).

Brief overview of agricultural financing and loans

Agricultural financing has the potential to revolutionize the sector by overcoming major challenges that impede productivity and sustainability. Unlike green financing, which generally addresses environmental issues, agricultural financing focuses specifically on advancing food production and improving supply chains. By investing in modern agricultural techniques, enhanced storage facilities, and efficient transportation systems, agricultural financing can greatly improve the overall efficiency of food systems (Basyariah 2022).

One key benefit of agricultural financing is its capacity to empower smallholder farmers, who are the backbone of food production in many developing nations, including Indonesia. With access to affordable and timely financing, these farmers can overcome financial constraints, invest in essential agricultural inputs, and adopt innovative practices that enhance productivity while minimizing environmental impact. This approach ensures better livelihoods for farmers and promotes more sustainable food production systems (Osabohien et al. 2020b).

In the Indonesian context, expanding agricultural financing through Islamic and conventional banking systems has been identified as a crucial strategy for strengthening food security. Research indicates that channeling financial resources directly to the agricultural sector can stabilize food availability and affordability, especially in regions with high poverty rates and food insecurity. This targeted

financing not only addresses pressing food supply issues but also builds resilience against future economic and environmental shocks (Abduh 2019).

To maximize the effectiveness of agricultural financing, policymakers and financial institutions must design financial products that address the unique challenges farmers face. Initiatives such as microfinance programs, agricultural insurance schemes, and partnerships with farming cooperatives can enhance farmers' access to resources and encourage innovation. By prioritizing these tailored solutions, agricultural financing can play a pivotal role in achieving national food security and advancing SDGs.

Link between agricultural financing, loans and food security in previous studies

Several studies have explored the impact of agricultural banking credit, loans, and financing on the agricultural sector, with a focus on food security and productivity, yielding diverse results and methodologies. Key studies include those by Osabohien et al. (2020a, 2020b, 2018), Egwu (2016), and Adetiloye (2012). In addition, other relevant research, such as those by Basyariah (2022), Abduh (2019), Srinita (2018), Njogu et al. (2018), and Abdelhady (2013), contributes to the foundation of this study. The following sections will discuss these studies in greater detail.

Osabohien et al. (2020a) analysed the impact of agricultural sector financing on agricultural productivity in Nigeria. Using the Johansen and Canonical Cointegration approach with an observation period from 1981 to 2018, the results of this study revealed that agricultural sector financing significantly influences the increase in agricultural productivity in Nigeria. A 1% increase in agricultural sector financing leads to an increase in agricultural productivity ranging from 0.002% to 0.006%, depending on the model specification used.

Osabohien et al. (2020b) investigated the relationship between farmers' household access to financing and agricultural productivity in Nigeria. After analysing 4,210 households using data from the Living Standard Measurement Study – Integrated Survey on Agriculture and applying the propensity score matching method, it was concluded that households with access to agricultural financing achieved three times higher crop yields than those without financing. Households without access to financing often had to sell assets and adjust their consumption due to unhealthy financial conditions.

Osabohien et al. (2018) researched the potential of commercial bank credit and the Agricultural Credit Guarantee Scheme Fund (ACGSF) in the agricultural sector to improve agricultural production in Nigeria. After analysing the data using the autoregressive distribution lag method, it was concluded that commercial bank credit in the agricultural sector can increase agricultural production by 8.12%, while ACGSF contributes a 0.002% increase in agricultural output. This study analysed how population growth can decrease food security by 0.001%.

Egwu (2016) examined the impact of banking sector financing and the ACGSF on agricultural production, economic growth, and poverty reduction. The results of the study indicated that banking sector financing and ACGSF had a significantly positive impact on increasing agricultural output, promoting economic growth, and reducing poverty in Nigeria.

Adetiloye (2012) investigated the provision of credit to the agricultural sector and the performance of the ACGSF while evaluating the status of food security in Nigeria from 1978 to 2006. The results of the study demonstrated that the performance of ACGSF was not very effective in Nigeria due to delays in the claims process. Additionally, Nigeria was found to have poor food security, with national food needs generally being supplied from abroad.

Basyariah (2022) conducted a qualitative study with a descriptive–exploratory approach on the potential for enhancing Islamic finance and food security through financing in the agricultural sector. The findings of this study indicate that Islamic finance and food security have significant potential for improvement through financing in the agricultural sector, particularly for food and herbal crops. Additionally, cross-sectoral government cooperation should be established to facilitate financing in the agricultural sector.

Abduh (2019) explored the role of Islamic social finance, including zakat, infak, shadaqah, and waqf, as well as *ihya al-mawat* and *al-iqta,'* in achieving SDG number 2, which aims to end hunger, achieve food security, improve nutrition, and promote sustainable agriculture by 2030. The study concluded that *zakat* (alm), *infaq* (charity), and *waqf* (endowment) are excellent alternatives for providing $2.5 trillion annually to address the investment gap for SDG number 2. These funds could be used to end hunger, combat malnutrition, and develop research laboratories. Moreover, the concepts of *ihya al-mawat* and *al-iqta'* could be applied to create sustainable agricultural practices.

Njogu et al. (2018) researched the impact of farmers' production capacity on access to capital from commercial banks in Murang'a County, Kenya. After analysing 21,576 farmers using the double urdle approach for inferential analysis, it was concluded that production capacity has a positive and significant effect on access to banking credit.

Abdelhady (2013) proposed the concept of waqf in Islamic social finance as an alternative for achieving food security in the Middle East. This concept is referred to as "food security waqf". Food security waqf would serve as a tool for allocating and managing capital and other resources for investment in the agricultural sector. The concept includes financing various relevant activities such as research, technological innovation, knowledge transfer, enhancing agricultural production capacity, and creating job opportunities. This food security waqf is expected to facilitate access to much needed financing, either directly or indirectly, especially for

small farmers, small- and medium-sized enterprises, and other stakeholders along the food supply chain.

All studies show that agricultural financing significantly improves productivity and food security. Access to financing increases crop yields, improves agricultural output, and drives economic growth. However, there is limited research examining agricultural financing from both banking models, namely, Islamic and conventional banking, in relation to food security, especially in Indonesia as an agricultural country that adopts a dual banking system. Therefore, this study fills the gap by presenting a comprehensive analysis of the role of agricultural sector financing and loans within the dual banking framework on food security across provinces in Indonesia.

Research methodology

Variables and data sources

Based on data availability, the research period was set from 2018 to 2024. Samples were selected from all provinces in Indonesia, except for North Kalimantan Province, due to incomplete data. Most of the data were obtained in aggregate from publications by relevant government agencies. The food security index was measured using calculations and statistical data published by the NFA (2024). Moreover, data on agricultural financing from Islamic banks and agricultural loans from conventional banks were obtained from periodic statistical reports published by Sharia Banking Statistics and Indonesia Banking Statistics from the FSA (2024) at the provincial level for the agricultural sector. The variables and their measurements follow previous studies. All variables have been summarized in Table 2.

Research methods

In this empirical study, we analyse the relationship between conventional and Islamic bank agricultural financing factors and food security across Indonesian provinces using panel data econometric techniques. These include a static approach – pooled ordinary least squares (POLS), the random effects model (REM), and the FEM (Gujarati–Porter 2009, Pindyck–Rubinfield 1998, Wooldridge 2001) – and RLS regression with the MM estimation method to address outliers and heteroscedasticity (Massart et al. 1986, Späth 1992). The model assessing the impact of agricultural financing or loans on food security was developed based on the factors outlined in Table 2 and insights from previous research as follows:

$$FS_{it} = f(AF_{it}, AL_{it}, FER_{it}, IF_{it}, ND_{it}, HDI_{it}, TP_{it}$$

Based on the equation above, the three-model equation for this study is as follows: equation (1) for agricultural financing in Islamic banks and food security

$$FS_{it} = \beta_0 + \beta_1 AF_{it} + \beta_2 FER_{it} + \beta_3 IF_{it} + \beta_4 ND_{it} + \beta_5 HDI_{it} + \beta_6 TPF_{it} + \varepsilon_{it}$$

Equation (2) for agricultural loans in conventional banks and food security

$$FS_{it} = \beta_0 + \beta_1 AL_{it} + \beta_2 FER_{it} + \beta_3 IF_{it} + \beta_4 ND_{it} + \beta_5 HDI_{it} + \beta_6 TPF_{it} + \varepsilon_{it}$$

Equation (3) for agricultural financing and loans and food security

$$FS_{it} = \beta_0 + \beta_1 AF_{it} + \beta_2 AL_{it} + \beta_3 FER_{it} + \beta_4 IF_{it} + \beta_5 ND_{it} + \beta_6 HDI_{it} + \beta_7 TPF_{it} + \varepsilon_{it}$$

where FS_{it} denotes the value of the food security index (see equation (1)) for cross-sectional unit i at time t; AF_{it}, AL_{it}, FER_{it}, IF_{it}, ND_{it}, HDI_{it}, and TP_{it} denote the values of the main independent and explanatory variables for cross-sectional unit i at time t, with i representing the 31 provinces in Indonesia and t representing the time periods 2018, 2019,…, 2024. Moreover, β_0 and βn represent the coefficients, and ε_{it} represents the error term.

Table 2

Variables and data sources

Variables		Definition	Symbol	Exp. sign	Sources
Dependent variable	Food security	The food security index is prepared using indicators of food availability, food affordability, and food utilization.	FS	n/a	National Food Agency of Indonesia
Main independent variables	Agricultural financing	Number of agricultural financings in Islamic banks (in billion Rupiah)	AF	(+)	Financial Services Authority of Indonesia
	Agricultural loan	Number of agricultural loans in conventional banks (in billion Rupiah)	AL	(+)	
Explanatory variables	Farmer exchange rate	Farmer exchange rate by province in Indonesia	FER	(+)	Indonesian Central Bureau of Statistics
	Informal farmer	Percentage of informal workforce in the agricultural sector	IF	(+)	
	Natural disasters	Number of natural disasters by province in Indonesia	ND	(−)	
	Human development index	The human development index is calculated using indicators of health, education, and standard of living.	HDI	(+)	
	Total population	Total population by province in Indonesia (in thousand people)	TP	(−)	

Note: all data were transformed into natural logarithms except for data with percentage units.
Source: FSA (2024) and NFA (2024).

Research estimation strategy

In the context of static panel data analysis, equations (1), (2), and (3) are estimated using POLS, REM, and FEM (Gujarati–Porter 2009, Pindyck–Rubinfield 1998, Wooldridge 2001). To select the most suitable model, several diagnostic tests are

employed. The redundant fixed effects (RFE) test is used to decide between POLS and FEM, the Breusch–Pagan Lagrangian multiplier (BPLM) test is applied to differentiate between POLS and REM, and the Hausman test determines the better option between REM and FEM (Gujarati–Porter 2009). This study evaluates the correlation matrix to ensure the absence of multicollinearity, a condition where predictor variables are excessively interrelated. Multicollinearity can lead to nonoptimal model solutions and hinder result interpretation due to overlapping effects between variables (Nisbet et al. 2018).

To analyse the integration order and stationarity of the dataset, this study employs various panel unit root tests, including the Levin, Lin, and Chu (LLC) test, Breitung's t-test for general unit root processes, and the Im, Pesaran, and Shin (IPS) test. Additionally, the augmented Dickey–Fuller (ADF–Fisher χ^2) and Phillips–Perron (PP–Fisher χ^2) tests are used for individual unit root validation (Lakhdari 2024, Mroua–Trabelsi 2020). Panel unit root tests are preferred for their reliability and ability to handle small time-series samples by combining cross-sectional and time-series dimensions, ensuring robust analysis of variable stationarity for accurate panel data estimations.

The study sample includes Indonesian provinces with varying food security levels and sizes, which may result in heteroscedasticity, while agricultural and geographical variables introduce the potential for outliers. To address these issues, the final model uses RLS regression with the MM estimation scheme, which is effective in mitigating the effects of outliers and non-normally distributed residuals (Massart et al. 1986, Späth 1992). This method employs weighting functions to reduce the impact of extreme data, ensuring more reliable and accurate estimates. The use of RLS regression enhances the robustness and precision of the findings by accounting for heteroscedasticity and outliers, improving the overall reliability of the analysis.

Results and discussion

Descriptive statistics results

Table 3 provides the descriptive statistics for the sample data on the determinants of food security in Indonesia. The food security index, as the dependent variable, shows regional averages of 71 for Sumatra, 79 for Java, 74 for Kalimantan, and 68 for eastern Indonesia (see Figure 1). The table includes descriptive statistics for independent variables such as agricultural financing (AF), agricultural loans (AL), farmer exchange rate (FER), informal farmer (IF), human development index (HDI), and total population (TP). All variables are based on 217 observations, with details on the mean, maximum, minimum, and standard deviation.

Table 3

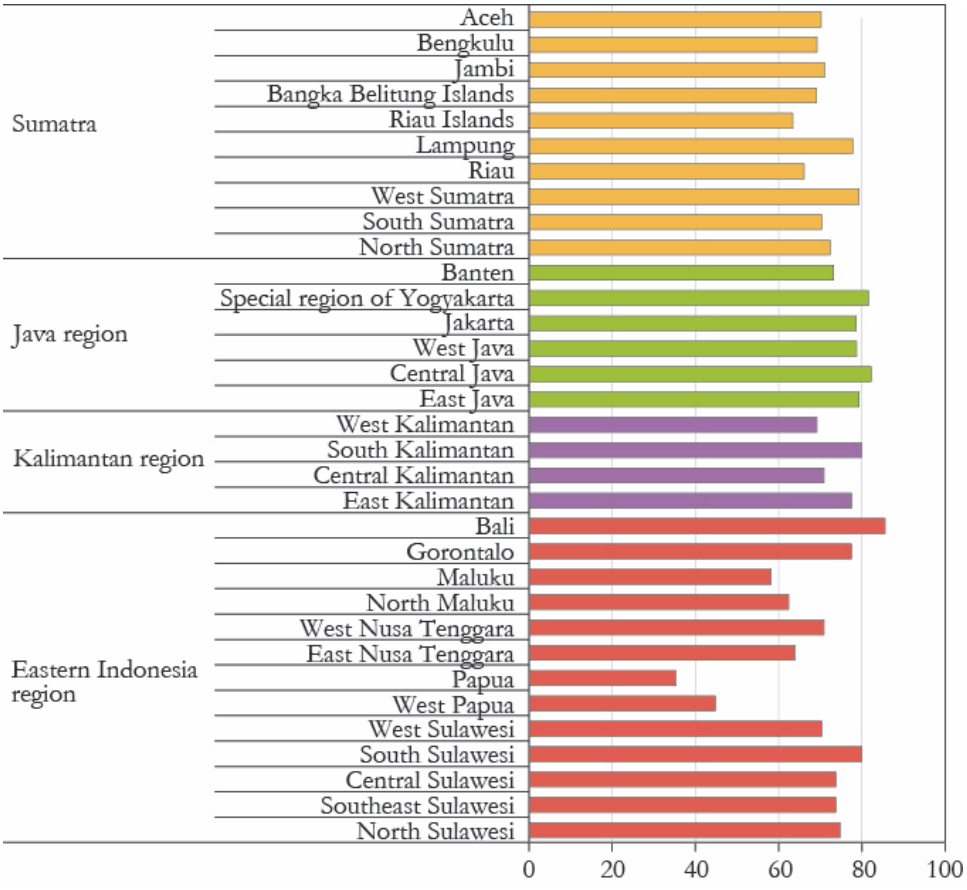
Descriptive statistics

Variables	Observations	Mean	Maximum	Minimum	Standard deviation
FS	217	71.739	88.200	25.100	10.728
AF	217	644.37	11,187.20	0.00	1,620.39
AL	217	13,764.33	178,237.00	57.00	31,074.98
FER	217	108.377	181.900	92.800	13.201
IF	217	86.626	99.400	38.900	10.444
ND	217	127.76	1,358.00	0.00	186.49
HDI	217	71.858	83.100	60.100	4.070
TP	217	8,551.64	50,345.20	701.80	11,625.00

Note: for abbreviations, see Table 2.

Figure 1

Mean food security index of four regions in Indonesia, 2018–2024



Source: NFA (2024).

Correlation matrix results

Table 4 presents the correlation coefficients among the independent variables utilized in the panel data regression model. Correlation matrix results reveal that there is no evidence of multicollinearity in this model, as indicated by the low correlation coefficients between the independent variables (Nisbet et al. 2018). Consequently, the findings are deemed efficient. According to Gujarati (2003) and Gujarati–Porter (2009), multicollinearity is a concern when the pairwise correlation coefficient between two variables exceeds 0.8. Since all the independent variables exhibit correlation coefficients below this threshold, it can be concluded that the empirical model is free from multicollinearity issues.

Table 4

Correlation matrix results

Variables	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
[1] FS	1							
[2] AF	0.427***	1						
[3] AL	0.425***	0.774***	1					
[4] FER	0.146**	0.369***	0.296***	1				
[5] IF	−0.177***	−0.611***	−0.488***	−0.280***	1			
[6] ND	0.476***	0.418***	0.407***	0.073	0.056	1		
[7] HDI	0.609***	0.474***	0.359***	0.098	−0.447***	0.244***	1	
[8] TP	0.303***	0.441***	0.409***	−0.017	−0.175***	0.443***	0.389***	1

Notes: for abbreviations, see Table 2. *p < 10%, **p < 5%, ***p < 1%.

Static panel estimation results for baseline model

The baseline model in this study employs a static panel data approach. Tables 7–9 present the results of static panel regressions using REM and FEM. The generalized least squares (GLS) approach is used to evaluate REM, while the ordinary least squares (OLS) method is used to estimate FEM.

This study begins by conducting individual unit root tests before proceeding with static panel data estimation. To assess the common unit root process, the LLC test, along with Breitung's t-test, is utilized. Additionally, the IPS test, as well as the ADF–Fisher χ^2 and PP–Fisher χ^2 tests, are applied to verify the individual unit root process, following the approach outlined by (Mroua–Trabelsi 2020).

The results of the panel unit root test for all model variables at the I(0) and I(1) levels are summarized in Table 5. As shown in Table 5, at a 5% significance level, all variables except TP are stationary at level I(0), based on the common unit root test results through the LLC test. Individually, results demonstrate varying outcomes from the IPS, ADF–Fisher χ^2, and PP–Fisher χ^2 tests. Furthermore, all variables are stationary at first difference, suggesting that all variables are integrated of order one I(1), particularly based on the results of the LLC and PP–Fisher χ^2 tests.

Table 5

Results of panel unit root tests for all variables

Variables	Levin, Lin, and Chu t*	Breitung's t-stat	Im, Pesaran, and Shin W-stat	ADF–Fisher χ^2	PP–Fisher χ^2
Results of panel unit root tests for model variables at level I(0)					
FS	−20.456 [0.000]	−3.139 [0.000]	−1.261 [0.103]	90.504 [0.001]	144.304 [0.000]
AF	−10.577 [0.000]	1.005 [0.569]	0.176 [0.719]	55.137 [0.719]	82.110 [0.044]
AL	−2.609 [0.004]	5.193 [1.000]	2.051 [0.979]	23.538 [1.000]	31.599 [0.999]
FER	−7.471 [0.000]	2.934 [0.998]	0.688 [0.754]]	40.604 [0.826]	72.422 [0.021]
IF	−14.789 [0.000]	−4.953 [0.000]	−0.383 [0.351]	76.352 [0.104]	136.241 [0.000]
ND	−18.957 [0.000]	−4.052 [0.000]	−1.668 [0.048]	112.650 [0.000]	189.927 [0.000]
HDI	−2.763 [0.003]	2.212 [0.987]	0.495 [0.689]	5.857 [0.923]	7.554 [0.819]
TP	1.762 [0.961]	7.159 [1.000]	3.002 [0.998]	4.822 [1.000]	1.427 [1.000]
Results of panel unit root tests for model variables at the 1st difference I(1)					
D(FS)	−43.167 [0.000]	−3.431 [0.000]	−4.361 [0.000]	145.492 [0.000]	239.778 [0.000]
D(AF)	−21.044 [0.000]	−0.017 [0.493]	−1.268 [0.103]	78.653 [0.075]	129.597 [0.000]
D(AL)	−19.169 [0.000]	0.279 [0.609]	−0.402 [0.344]	75.772 [0.082]	138.841 [0.000]
D(FER)	−13.595 [0.000]	−3.141 [0.000]	−0.229 [0.409]	56.454 [0.247]	109.039 [0.000]
D(IF)	−30.972 [0.000]	−4.883 [0.000]	−2.245 [0.012]	118.624 [0.000]	220.458 [0.000]
D(ND)	−28.053 [0.000]	4.154 [0.000]	−2.224 [0.013]	119.928 [0.000]	220.898 [0.000]
D(HDI)	−6.545 [0.000]	−1.921 [0.027]	−0.056 [0.478]	12.278 [0.424]	23.845 [0.021]
D(TP)	−29.664 [0.000]	−0.596 [0.276]	−2.536 [0.006]	119.023 [0.000]	258.892 [0.000]

*A panel unit root test which checks whether panel data are stationary, with the null of non-stationarity and the alternative of stationarity.

Notes: for abbreviations, see Table 2. [ ] indicates the level of probability at 5%.

Before analysing the panel data estimation results, this study conducted the best model selection test among POLS, REM, and FEM. Table 6 shows the results of the model selection test from the RFE test, the BPLM test, and the Hausman test to select the optimal model estimation. The RFE, BPLM, and Hausman tests yield *p*-values below the 5% significance threshold. These results indicate that all models – equations (1), (2), and (3) – consistently identify FEM as the most suitable model for this study. Statistically, FEM outperforms the other models across all three research models. Moreover, FEM can capture the effects of time-invariant provincial level variables on FS, enabling the generation of reliable and consistent estimates.

Table 6

Optimal model selection for static panel data

Model	Type of test			Summary
	RFE test	BPLM test	Hausman test	
Equation (1)	18.657*** [0.000]	203.763*** [0.000]	28.811*** [0.000]	FEM
Equation (2)	17.278*** [0.000]	187.156*** [0.000]	30.618*** [0.000]	FEM
Equation (3)	18.440*** [0.000]	187.471*** [0.000]	33.925*** [0.000]	FEM

Notes: RFE=redundant fixed effects; BPLM=Breusch–Pagan Lagrangian multiplier, FEM=fixed effects model. ***$p < 1\%$; [ ] indicates the level of probability at 5%.

Based on the evaluation of the optimal models, this study determined that the FEM is the best model as follows:

Equation (1): $FS_{it} = 2.3576 + 0.0257AF_{1it} + 0.1349FER_{2it} + 0.0033IF_{3it} + 0.0097ND_{4it} + 0.2116HDI_{5it} - 0.0079TP6_{it}$

Equation (2): $FS_{it} = 2.0815 + 0.0410AL_{1it} + 0.1395FER_{2it} + 0.0023IF_{3it} + 0.0072ND_{4it} + 0.2252HDI_{5it} - 0.0014TP6_{it}$

Equation (3): $FS_{it} = 2.6757 + 0.0022AF_{1it} + 0.0317AL_{2it} + 0.0821FER_{3it} + 0.0026IF_{4it} + 0.0073ND_{5it} + 0.1465HDI_{6it} - 0.0053TP_{7it}$

In addition, when the probability value or *p*-value (prob (F = statistic)) is equal to 0, the coefficient of determination for equations (1), (2), and (3) is 0.8789, 0.8765, and 0.8828, respectively. This indicates that the level of FS in the provinces in Indonesia in the sample is explained by 87.89%, 87.65%, and 88.28% by the proposed independent variables, while the remaining 12.11%, 12.35%, and 11.72% are influenced by other variables not included in the model. In addition, FEM results on the three research models confirm that there is no autocorrelation problem, as indicated by the Durbin–Watson statistical values above 2, suggesting negative autocorrelation with values of 2.205, 2.243, and 2.261, respectively (see Tables 7, 8, 9).

Table 7

Estimation results of static panel data for equation (1): agricultural financing in Islamic banks and food security

Independent variables	Equation (1) – Islamic banks	
	dependent variable – food security (FS)	
	(1.1) REM	(1.2) FEM
AF	0.0243***	0.0257***
p-values	[0.000]	[0.000]
FER	0.0976*	0.1349**
p-values	[0.098]	[0.033]
IF	0.0025	0.0033
p-values	[0.123]	[0.175]
ND	0.0159**	0.0097
p-values	[0.043]	[0.246]
HDI	0.5582***	0.2116
p-values	[0.001]	[0.277]
TP	−0.0027	−0.0079
p-values	[0.766]	[0.429]
Constant	1.0535	2.3576***
p-values	[0.1825]	[0.006]
R^2	0.2324	0.8794
Adjusted R^2	0.2104	0.8552
F-statistic/χ^2	10.595***	10.775***
Durbin–Watson statistic	1.8	2.205
Number of observations	217	217
Number of group	31	31
Estimation method	GLS	OLS

Notes: REM=random effects model; FEM=fixed effects model. *p*-values are based on two-tailed tests; *$p < 1\%$, **$p < 5\%$, ***$p < 1\%$; [ ] indicates that value of probabilities or *p*-value.

According to Table 7, the results of FEM in equation (1) reveal that the AF in Islamic banks show an extremely strong positive and significant influence on FS in Indonesia at a significance level of 1%. These results indicate results that are in line with expectations. This means that every 1% increase in financing in the agricultural sector in Islamic banking will increase FS by 0.0257%. Additionally, the FER variable contributes 0.1349% to FS in various provinces in Indonesia when there was a 5% increase. Moreover, other variables are not significant in this model.

Table 8

Estimation results of static panel data for equation (2): agricultural loans in conventional banks and food security

Independent variables	Equation (2) – conventional banks	
	dependent variable – food security (FS)	
	(2.1) REM	(2.2) FEM
AL	0.0372***	0.0410***
p-values	[0.000]	[0.003]
FER	0.1048*	0.1395**
p-values	[0.078]	[0.033]
IF	0.0016	0.0023
p-values	[0.296]	[0.345]
ND	0.0146*	0.0072
p-values	[0.070]	[0.403]
HDI	0.6088***	0.2252
p-values	[0.000]	[0.254]
TP	0.0028	−0.0014
p-values	[0.754]	[0.890]
Constant	0.6273	2.0815**
p-values	[0.421]	[0.016]
R^2	0.2261	0.8765
Adjusted R^2	0.204	0.8518
F-statistic/χ^2	10.2269***	35.4753***
Durbin–Watson statistic	1.8	2.243
Number of observations	217	217
Number of group	31	31
Estimation method	GLS	OLS

Notes: REM=random effects model; FEM=fixed effects model. *p*-values are based on two-tailed tests; *$p < 1\%$, **$p < 5\%$, ***$p < 1\%$; [ ] indicates that value of probabilities or *p*-value.

The results in equation (2) are shown in Table 8. Based on the FEM estimation results, the AL in conventional banks show an extremely strong positive and significant influence on FS in Indonesia at a significance level of 1%. Results indicate that every 1% increase in financing in the agricultural sector in conventional banking can contribute to increasing FS by 0.0410%. Additionally, the FER contributed 0.1395% to FS in various provinces in Indonesia when there was a 1% increase. Moreover, the remaining variables did not show a significant effect on these estimation models.

Table 9

Estimation results of static panel data for equation (3): agricultural financing/loans in Islamic and conventional banks and food security

Independent variables	Equation (3) – Islamic + conventional banks	
	dependent variable – food security (FS)	
	(3.1) REM	(3.2) FEM
AF	0.0182***	0.0022***
p-values	[0.004]	[0.002]
AL	0.0245**	0.0317**
p-values	[0.021]	[0.022]
FER	0.07	0.0821
p-values	[0.237]	[0.216]
IF	0.0028*	0.0026
p-values	[0.076]	[0.268]
ND	0.0130***	0.0073
p-values	[0.099]	[0.383]
HDI	0.5279***	0.1465
p-values	[0.002]	[0.451]
TP	−0.0021	−0.0053
p-values	[0.817]	[0.588]
Constant	1.1126	2.6757***
p-values	[0.154]	[0.002]
R^2	0.2519	0.8828
Adjusted R^2	0.2269	0.8586
F-statistic/χ^2	10.057***	36.452***
Durbin–Watson statistic	1.755	2.261
Number of observations	217	217
Number of group	31	31
Estimation method	GLS	OLS

Notes: REM=random effects model; FEM=fixed effects model. *p*-values are based on two-tailed tests; *$p < 1\%$, **$p < 5\%$, ***$p < 1\%$; [ ] indicates that value of probabilities or *p*-value.

Furthermore, FEM test results confirmed that equation (3) had the same results as the FEM test on equations (1) and (2). The main variable of AF and AL in the agricultural sector showed a contribution to increasing FS in all provinces in Indonesia at a significance of 1%. FEM results indicated that AF and AL contributed 0.0022% and 0.0317% when there was a 1% increase in agricultural financing for Islamic banks and conventional banks. Moreover, the remaining variables did not show a significant effect on these estimation models.

Based on the results of the FEM test presented in Tables 7, 8, and 9, we conclude that AF from Islamic banks and conventional banks shows a strong influence on FS, as evidenced by equations (1), (2), and (3). This is followed by the farmer's exchange rate, which contributes to the level of FS in all provinces in Indonesia, while other independent variable parameters are considered insignificant.

RLS regression results for robustness check

To validate FEM results, we conducted a robustness test because FEM is sensitive to outliers, which can bias the estimation. Using RLS with MM estimation reduces the impact of outliers without eliminating data, resulting in more accurate and stable estimation. The integration of FEM and RLS with MM estimation improves the reliability of the analysis, especially when dealing with data characterized by high variation or heteroscedasticity.

Table 10

RLS regression results for robustness check

Independent variables	Robustness test [robust least squares–MM estimation]		
	equation (1) Islamic banks	equation (2) conventional banks	equation (3) Islamic + conventional banks
AF	0.0109***	n/a	−0.0011
p-values	[0.003]	n/a	[0.775]
AL	n/a	0.0297***	0.0305****
p-values	n/a	[0.000]	[0.000]
FER	−0.0095	−0.0297	−0.0264
p-values	[0.867]	[0.548]	[0.605]
IF	0.0035***	0.0039***	0.0004***
p-values	[0.000]	[0.000]	[0.000]
ND	0.0155***	0.0084	0.0088
p-values	[0.021]	[0.151]	[0.147]
HDI	0.7714***	0.7339***	0.7369***
p-values	[0.000]	[0.000]	[0.000]
TP	0.0029	0.0006	0.0008
p-values	[0.702]	[0.931]	[0.900]
Constant	0.6008	0.666	0.6408
p-values	[0.327]	[0.217]	[0.246]
R^2	0.2033	0.2678	0.2678
Adjusted R^2	0.1805	0.2469	0.2433
Number of observations	217	217	217
Number of group	31	31	31

Notes: FEM=fixed effects model. *p*-values are based on two-tailed tests; ***$p < 1\%$; [ ] indicates that value of probabilities or *p*-value.

The results of the RLS with MM estimation test are presented in Table 10. Based on our findings, it is confirmed that the sign and magnitude of the coefficients are the same as those reported in the FEM for equations (1), (2), and (3). This study observed that the key variables of AF/AL from Islamic and conventional banks have the greatest impact on FS in Indonesia at a significance level of 1% with a contribution of 0.0109% and 0.0297%, respectively. The robustness test found a significant contribution from the informal farmer (IF) and HDI variables to FS at a significance

of 1% with a contribution of 0.004%–0.039% and 0.7339%–0.7714%, respectively. Moreover, other variables were not significant.

The robustness test confirms that the initial FEM results are reliable, showing that AF significantly affects FS in Indonesia at the same significance level. In other words, the findings from RLS with MM estimation reinforce the consistency of the initial FEM results, demonstrating that the overall outcomes of this study are robust.

Discussion of main findings

This study empirically examines three research models (equations (1), (2), and (3)) to assess the effect of agricultural loans and financing from Islamic and conventional banks on FS in Indonesia. The analysis utilizes FEM and RLS with MM estimation methods. The research covers all Indonesian provinces, excluding North Kalimantan, Gorontalo, and Maluku. The findings, which are consistent across all models, suggest that increased AF from Islamic and conventional banks play a significant role in improving FS in Indonesia, as evidenced by the econometric results.

The first main finding of this study is that AF in Islamic banking has proven to be significantly positive in supporting FS in Indonesia. AF offered by Islamic banking can help farmers and agricultural entrepreneurs to adopt more efficient, sustainable practices. The findings show the relevance of Islamic banking AF to SDGs, especially in the agriculture and food sectors. This significance illustrates that Islamic banks have financing characteristics that focus on the agricultural sector, which supports national food sovereignty in Indonesia. Islamic banking AF, which in principle promotes responsible financing and is based on sharia values, can provide significant benefits to provinces in Indonesia, which are highly dependent on the agricultural sector and natural resource management.

Furthermore, these findings emphasize the importance of Islamic banking policies and initiatives to expand the AF portfolio, as well as encourage the development of financial products that support sustainable agriculture. In line with (Al-Roubaie–Sarea 2019), Islamic banking offers Sharia-compliant, interest-free financing, making it more accessible to smallholder farmers and rural communities. This model supports productivity, aligns with ethical principles, and ensures financing contributes to social welfare.

The second crucial finding is conventional banking AF as measured by the amount of conventional bank financing disbursed in the agricultural sector per province in Indonesia. It reflects the support of the conventional banking sector in supporting economic development through the agricultural sector and its management, especially in maintaining food availability through the agricultural sector. Empirically, there is a significant relationship between conventional banking AF and FS in Indonesia. This finding opens the door to increasing farmers' income and welfare while still paying attention to the sustainability of their agriculture. This means that agricultural banking

financing has brought significant positive changes to the FS agenda in Indonesia. This investment contributes not only to economic growth but also to community protection and the achievement of better national FS.

Therefore, Islamic and conventional banking AF must continue to be supported and improved as part of efforts to realize national resilience in Indonesia, especially amidst global economic uncertainty, and the development of sustainable and competitive agriculture. Furthermore, the main findings of this study align with previous research by Basyariah (2022), Osabohien et al. (2020a, 2020b, 2018), Abduh (2019), Srinita (2018), Njogu et al. (2018), Egwu (2016), Abdelhady (2013), and Adetiloye (2012). These studies demonstrate a significant relationship between financing, credit, or loans, and increased agricultural productivity, FS, and poverty reduction through various financing mechanisms and innovations.

The other findings of this study reveal that several factors play a crucial role in enhancing FS across all provinces in Indonesia. First, an increase in the FER reflects an improvement in farmers' welfare. When the FER rises, farmers' income from harvests exceeds production costs, encouraging them to boost productivity. Second, the growing number of informal agricultural workers indicates an increase in labour directly involved in the agricultural sector, contributing to the sustainability of food production. Third, human development, such as improvements in education, health, and living standards, enhances labour efficiency in agriculture. These combined factors create a multiplier effect that boosts agricultural production, thereby strengthening FS in Indonesia.

Conclusions

This study examines the significant role of conventional and Islamic banking agricultural financing and lending in enhancing FS in a sample of 31 provinces in Indonesia during the period 2018–2024 using FEM and RLS with MM estimation. This study utilizes three models to evaluate the impact of AF on FS in Indonesia. The first model examines the AF of Islamic banking, the second focuses on the AL of conventional banking, and the third combines both systems. Each model incorporates explanatory variables to analyse their collective contribution to enhancing FS across all provinces in Indonesia.

According to the baseline model, FEM results demonstrate a significant positive impact of AF by Islamic and conventional banks on FS in Indonesia. Equation (1) shows that a 1% increase in Islamic bank financing improves FS by 0.0257%, while Equation (2) indicates conventional bank financing contributes 0.0410%. The FER positively influences FS in both models. Equation (3) confirms these findings, with combined AF contributing 0.0022% and the FER adding 0.0317% to FS. Other variables showed no significant effects across all models. The robustness of the initial results was analysed using RLS regression, addressing outliers and heteroscedasticity.

Key variables – agricultural financing and loans from Islamic and conventional banks – showed the strongest impact on FS in Indonesia, with contributions of 0.0109% and 0.0297% at a 1% significance level. These findings confirm the robustness of the FEM results. Therefore, this study finds the potential for agricultural financing and loans of Islamic and conventional banking as a vital determinant in achieving FS in Indonesia.

According to empirical findings, this study provides several useful recommendations for encouraging increased FS in Indonesia. First, the banking industry needs to increase access and availability of agricultural funding, which is one of the crucial factors in encouraging national FS. The fragility of FS in Indonesia is partly due to limited funding. Therefore, the distribution of agricultural financing and loans in the agricultural sector needs to be increased to support the realization of national and regional FS. Second, the government can create education and skills training programs for rural youth who focus on being farmers or who are motivated to become entrepreneurs in the agricultural sector. This is because increasing the number of qualified and educated farming workers has the potential to increase the productivity of the agricultural sector in Indonesia and has positive implications for national FS. In other words, the level of knowledge of farmers, along with other factors such as the availability of funds, is a vital component that ensures the success and smoothness of agricultural modernization.

However, this study has certain limitations, namely, sample size and data availability, particularly regarding FS in each province of Indonesia. Therefore, further research is recommended to independently calculate the FS index and to include additional research sample periods. Additionally, future studies should incorporate other relevant variables, such as climate change risk, global economic uncertainty risk, and other factors that may influence food vulnerability risks in Indonesia.

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