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ARTICLE

Analysis of Food Sovereignty in Indonesia: Macroeconomic Data

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ABSTRACT

Indonesia, an archipelagic nation, faces significant challenges in achieving food sovereignty due to low agricultural productivity and high dependence on food imports. This study analyzes the impact of the number of farmers (NFARM), rice productivity, food imports, government food reserves, and food price stability (STAB) on food sovereignty. Using panel data analysis with provincial data as a cross-section and food sovereignty index data from 2018 to 2023, the results showed that based on Common Effect Model and Random Effect Model estimates, NFARM significantly and positively influenced food sovereignty. Non-oil and gas food imports had large and negative effects. Fixed Effect Model estimation showed that variations among the 34 provinces had a significant effect. Meanwhile, the independent variables—NFARM, rice productivity, non-oil and gas food imports and STAB—had no effect. The best model, according to the Chow and Hausman tests, was Fixed Effect Model, demonstrating that Indonesian entities or modifications of the food sovereignty index contributed substantially to food sovereignty. Only 11 provinces had a food sovereignty index above the national average. To enhance food sovereignty, Indonesia must prioritize technological innovations to boost domestic productivity. These findings offer policy insights into strengthening local resource-based agricultural production to reduce dependence on food imports. Additionally, the government needs to maintain STAB, particularly for rice, while making technological innovation a top priority in agricultural development. This study adds global insight into sustainable agriculture policy by offering in-depth information on the variables that affect Indonesia's food sovereignty.

Keywords: Sustainable Food System; Productivity; Food Imports; Government Food Reserves; Price Stability

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1. Introduction

Food sovereignty is defined as the state authority to set food policies in line with regional requirements, customs, and knowledge. It refers to the community's right to access healthy food that reflects local culture and is produced in a manner that prioritizes environmental sustainability [1,2]. The concept is built on the idea that a country's food system should be a local right, ensuring that people have control over the sources [3]. Food sovereignty also establishes sustainable systems, policies, and strategies for producing, distributing, and consuming nutritious and accessible food, while respecting local cultures [4,5]. It refers to the right of the community to access sufficient, nutritious, and healthy food by local culture, which is produced by protecting the environment and is sustainable. Moreover, food sovereignty gives producers the right to determine food and agricultural systems [6, 7]. Other studies also defined food sovereignty as the ability of the state to meet food needs independently, without relying on imports from other countries [3,8].

The concept of food sovereignty challenges existing power structures by prioritizing the interests of local producers and consumers, to engage citizens in transforming the food system [9]. It is a political paradigm that arose from the farmer movement and has become a discussion in academic studies on the relationship between food and the environment. Food sovereignty is essential for social justice [10], as well as in making economically independent, and sustainable policies [11], without relying on the global market. Food sovereignty guarantees access for the people, supports sustainable production, and facilitates the localization of food systems with fair trade [9]. This concept also ensures a controlled food system from producers to distributors, and consumers, as well as developing knowledge, culture, and equality between communities. However, to realize food sovereignty, policies that support increasing local food production and protecting farmers are needed [12,13].

The Indonesian government plays an important role in implementing policies to increase domestic food production, protect local farmers, and reduce import dependence [14]. In this context, food governance must start from the aspects of land tenure (agrarian reform), production models (agroecology), processing and storage (food reserves), distribution (commercial system), and consumption [15]. Miyasto stated that food sovereignty is the main pillar of achieving national food security [16]. Furthermore, local governments have a strategic role, because national food sovereignty is greatly influenced by regional conditions reflected in the extent to which local governments determine food system policies based on local resources [17]. Food implementation in Indonesia is interrelated, starting with government policies to ensure the availability of food from within the country. These policies also focus on fulfilling needs at the household level, where food security is closely related to aspects of availability, adequacy, and sustainability. Therefore, food security has a key role in realizing food sovereignty [18].

Indonesia faces major challenges in food sovereignty, particularly due to the fertile soil. The average productivity of rice remains low at around 5 per hectare [19]. Consequently, the fulfillment of rice needs still depends on imports, which amounted to 3.062.857.6 tones in 2023 [20]. Indonesia's dependence on the global food market poses a high risk, both in terms of price fluctuations and supply availability. Rice as a strategic commodity experienced an approximately 15 % price increase, from $400 to $464 per tonne [21]. Food consumption containing rice per capita in 2022 decreased by 0.46 % with an average population growth rate of 1.11 % [22,23]. The availability of rice per capita experienced an average growth of 1.72 % in 2022, but the prevalence of food insecurity (prevalence of undernourishment (PoU)) in Indonesia reached 8.53 % in 2023, showing that the majority of the population regularly consumes food lacking in energy to live a healthy and active life [24]. On the other hand, to meet domestic food needs, the government through Government Rice Reserve (GRR) stock reached 6,304,996 tons in 2023, which was sourced from imports [25].

Factors associated with access to productive land, agricultural technology, and food price stability (STAB) greatly affect the achievement of food sovereignty [26–28]. Food sovereignty in Indonesia can be achieved by focusing on policies to increase local agricultural productivity, optimizing reserves sourced from government production, and reducing import dependence through increasing local production and price stability to ensure fair and sustainable food availability [1,3,29]. This study was conducted by constructing variables divided based on aspects of the food sovereignty pillar. Variables from the production aspect consist of productive land area and local agricultural productivity [6]. Variables from the economic aspect, including the stability of domestic food prices, will contribute to supporting the welfare of farmers. Meanwhile, variables from the social aspect include local food availability and per capita consumption. This study also considered the context of government policies through regulatory variables regarding food reserves and reducing import dependence [10]. Increasing productivity in the local agricultural sector is essential to promote food sovereignty and sustainable economic growth [30,31].

Many nations continue to import food, which weakens domestic control over their food systems and leaves them open to changes in the world market. Dependence on the liberalization of world food trade is a threat to domestic food security. Unstable global markets increase vulnerabilities in local food production, distribution, and consumption [32]. Particularly in the Global South, excessive reliance on food imports can destabilize domestic food supplies, exposing nations to global market volatility and the hazards of crop failures in both importing and exporting nations [33]. Food productivity (PROD) in Indonesia is still low compared to several countries in Asia. The skill and creativity of local farmers [34], high production costs, limited access, and cooperation are obstacles to the application of sustainable agricultural technology, hindering the increase in production and food security in developing countries [35].

The national food reserve is a staple food supply managed by the government and the community to ensure the availability of food to face emergencies and maintain price stability sourced from domestic production [36]. Indonesia's food reserves are partly derived from food imports which can pose a risk to domestic food price instability. Trade bottlenecks can result in price increases and shortages of supplies [37]. Excessive price volatility in the food supply chain can arise from inadequate food storage and distribution systems. This leads to source uncertainty and food security risks, especially affecting consumers who spend most of their income on food [38].

The stability of a nation's food supply can be affected by policies that do not encourage local agriculture and reliance on food imports, which is why an examination of food sovereignty is crucial. The analysis of associated variables, such as the number of farmers (NFARM), PROD, and management of food reserves, can help determine which policies require strengthening to increase domestic food security. Achieving food sovereignty is often difficult when a nation continually relies on imports to meet the food needs of the people [3,39]. Without supportive policies for farmers and local production, achieving food sovereignty will remain a major challenge [40 – 42]. Furthermore, limited access to productive land, agricultural technology, and STAB are obstacles to achieving food sovereignty [2,6,43]. The low productivity of the local agricultural sector is the main obstacle to supporting food sovereignty and sustainable economic growth [44,45].

The analysis model integrating macroeconomic data is a new insight to investigate fluctuations in the NFARM and the stasis of rice productivity, which remains at five to six tons per hectare. In addition, the analysis highlights the importance of non-oil factors that are necessary to meet food demand. The report also emphasizes the increase in non-oil imports needed to meet food demand. In addition, analysis underscored that government food (GFOOD) reserves have not reached a safe level, and per capita rice consumption ranges between 93 and 98 kg per year. The results also show that food price fluctuations have a significant impact on food sovereignty, affecting supply stability and national food security. There is a need to provide a comprehensive perspective in designing food sovereignty policies that can sustainably address national food security challenges. Therefore, the purpose of this study was to examine how Indonesian food sovereignty is influenced by the NFARM, rice production, non-oil and gas food imports (IMP), GFOOD reserves, and STAB.

2. Literature Review

The theoretical framework for the analysis of food sovereignty is based on several important concepts that explain the relationship between food sovereignty and the factors that influence it. Food sovereignty is the right of the state and the community to determine food policies according to local conditions and needs, which focus on sustainable food production, fair distribution, and healthy consumption in accordance with local culture.

2.1. Number of Farmers to Food Sovereignty

Sen discusses the theory of the relationship between food security and access to resources, which underlies the importance of the NFARM in increasing domestic food production capacity [46]. According to Sen, access to resources, including access to land and technology, greatly affects the food production capacity of a society. In this case, the NFARM involved in the agricultural sector is one important indicator to see the extent to which the agricultural sector can contribute to food security and sovereignty.

The La Via Campesina organization initially presented the Food Sovereignty Theory in 1996 during the FAO-sponsored Food Health Conference. Food sovereignty, according to La Via Campesina, is the right of every individual to choose their food system. The movement places a strong emphasis on the value of smallholders in the food system, sustainable resource management, and local food production, and reduces dependence on imported food [47]. This theory supports the contribution of local farmers and smallholders to food sovereignty. The more farmers are involved in food production, the greater the control that the state or

society has over the food system. A study using different methods shows that the NFARM contributes significantly to food sovereignty in Nigeria [48].

H1 *The more farmers involved in the agricultural sector (NFARM), the higher the level of food sovereignty in an area.*

2.2. Food productivity and sovereignty

Malthus in his theory of population growth and food security argued that increasing agricultural productivity is one of the solutions to ensure food sufficiency for a rapidly growing population. Increasing PROD can reduce dependence on food imports and increase food sovereignty [49].

Increasing productivity, especially for key commodities such as rice, is essential to ensure that a nation does not depend on imports but rather achieves food sovereignty. Technological innovation, the development of a more efficient agricultural system, and the existence of a supportive market mechanism are crucial factors for increasing domestic production capacity in the Asia-Pacific region [50]. An empirical study by Prayuginingsih et al. emphasized that increasing productivity is an important strategy for achieving rice self-sufficiency and food sovereignty in Indonesia [51].

H2. *Increasing rice productivity (PROD) will increase the level of food sovereignty in an area.*

2.3. Food Imports and Sovereignty

Hirschman in the theory of economic development proposed that dependence on food imports can reduce a country's economic sovereignty [52]. The author also explained that countries that depend on food imports are vulnerable to global market fluctuations, which can threaten a country's food sovereignty. According to Patel, reducing dependence on food imports and increasing domestic capacity is the core of food sovereignty. Countries that continue to import food will lose control of their domestic food systems, reducing their ability to set food policies that are tailored to local needs [47].

La Via Campesina also promotes self-sufficient local food production and reduces dependence on imported food. The higher the food imports, the lower the level of food insecurity. This theory supports reducing dependence on food imports as a step toward strengthening food sovereignty. Countries that are too dependent on food imports cannot control their food supply and prices. This aligns with the findings of the study by Bini [1]. This highlights that liberalization policies have the potential to dominate, to the detriment of local farmers. Latin America and the Caribbean have the potential to save up to $2.7 billion annually by increasing trade between countries in the region, which in turn could strengthen food sovereignty and reduce dependence on foreign food supplies, which currently reduce local control over food systems [39].

H3. *An increase in non-oil and gas food imports (IMP) will reduce the level of food sovereignty in a region.*

2.4. Government Food Reserves

Brazil's Fome Zero program illustrates how food reserves can be integrated with public procurement initiatives to support local agriculture and improve food sovereignty [53]. Rice reserves managed by the government affect food sovereignty in Indonesia by strengthening state control over food security, supporting the goal of national self-sufficiency. However, this can indirectly negatively affect vulnerable groups, as political actors prioritize personal gains rather than ensuring equitable access to food for the entire community [54]. Government-managed rice reserves play an important role in food sovereignty in Indonesia through rice supply and price stability policies, overcoming fluctuations caused by high demand, and providing support to smallholders through the highest retail price (HET) policy and food programs for the community [36].

H4. *Increasing government food reserves (GFOOD) will increase the level of food sovereignty in a region.*

2.5. Food Price Stability

According to Keynesian Economics, sharp fluctuations in food prices can affect people's purchasing power, especially low-income groups [55]. Keynes argued that price stability is key to maintaining economic balance and reducing uncertainty in the food market. Piketty explained that economic instability, including fluctuations in food prices, has an impact on social inequality and reduces access to adequate food. In this context, STAB plays an important role in ensuring equitable access to food for all levels of society [56].

H5. *The higher the STAB, the higher the level of food sovereignty in a region.*

Previous research used aggregate data that did not consider differences in characteristics between provinces in Indonesia. Significant conflicts do not integrate certain local variables, such as differences in production capacity between regions, geographical factors, or local government policies that can deeply affect food sovereignty. Most studies also did not use panel data models or focused more on simple regression, which was not able to capture heterogeneity between

entities such as provinces effectively. This study uses a panel data method that combines time series data and cross-sectional data, allowing for a more in-depth analysis of differences between provinces and how local factors affect food sovereignty.

2.6. Research Framework

Economic development theories based on food security suggest that every country must have policies that support domestic food security, increase production capacity through technological innovation, and reduce dependence on global markets. Good government policies, effective management of food reserves, and support for local farmers are part of efforts to realize food sovereignty. The Research Framework is shown in **Figure 1**.

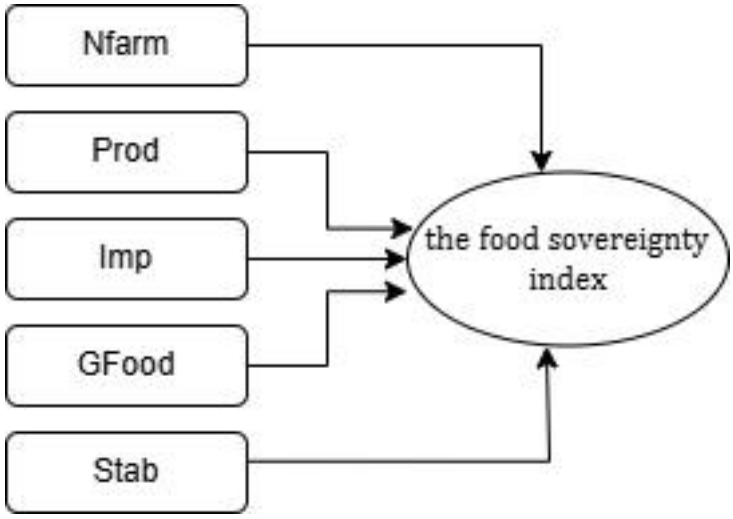

Figure 1. Research Framework.

3. Materials and Methods

The method used was an inferential quantitative approach in which data were generalized in quantitative form to infer population characteristics or relationships [57]. Secondary data were used in the form of time series data for 34 provinces in Indonesia from 2018-2022 sourced from the Central Statistics Agency and Food Security Agency collected through literature studies and documentation. Each province in Indonesia has unique local capacities and characteristics, such as the diversity of agricultural ecosystems, access to agricultural technology, and the level of investment in the agricultural sector. Selecting provinces with these regional characteristics in mind allows for a more in-depth analysis of how each province manages its food security and sovereignty. The food sovereignty index is calculated by

$$\text{Food Sovereignty index} = (\text{Domestic food production}/\text{Domestic food needs}) \times 100 \quad (1)$$

where Domestic Production is the total rice production produced by the province, while Domestic Consumption is the total rice consumption in the region. This index shows whether a country or region can produce enough food to meet the needs of its population [53].

Multiple linear regression was the data analysis technique employed in the Eviews 9 program. The general model for multiple linear regression can be expressed as [58]:

$$Yi = \beta_0 + \beta_i X_{it} + \alpha_i + \mu_{it} \quad (2)$$

where Y is a bound variable, X is an independent variable, i is cross-section data, t is time series data, α is the value of the difference between cross-sections, and μ is a disturbance error.

The equation was applied through eight predictors, namely:

$$Y_{it} = \beta_0 + \beta_1 Nfarm_{it} + \beta_2 Prod_{it} + \beta_3 Imp_{it} + \beta_4 Gfood_{it} + \beta_5 Stab_{it} + \mu_{it} \quad (3)$$

where Y is the food sovereignty index, Nfarm is the number of farmers, Prod is rice productivity, Imp is non-oil and gas food imports, Gfood is government food reserves, Stab is food price stability, β_1-β_5 is the partial regression coefficient, and μ is the disruptive variable.

In the Data Panel Model, three modalities are produced: the random effect model (REM), the fixed effect model (FEM), and the common effect model

(CEM). The CEM assumes that cross-sectional data behaves differently at different times. Therefore, this model used the Panel Ordinary Least Square (POLS) approach with the general form:

$$Y_{it} = \beta_0 + \beta X_{it} + \mu_{it} \quad (4)$$

where Y_{it} is a variable bound to the first observation unit and the time, X_{it} is a free variable in the first observation unit and the time, β is the variable coefficient, β_0 is the intercept, and μ_{it} is the error component in the first observation unit and the time

The FEM assumed that differences between individuals can be correlated with free variables. Therefore, the estimate used was Least Square Dummy Variable (LSDV) with

$$Y_{it} = \beta_0 + \alpha_1 + \Sigma\, \alpha_k D_{ki} + \beta X_{it} + \mu_{it} \quad (5)$$

The REM assumed that the assessment of differences between individuals should not correlate with free variables. Generalized Least Square (GLS) was the estimate technique employed, along with

$$Y_{it} = \alpha_i + \beta X_{it} + \mu_{it} + \varepsilon_{it} \quad (6)$$

The best among the three-panel data regression models was selected using testing procedures, including:

To determine which model, out of CEM and FEM, would be best for interpreting the results, the Chow test was conducted. This test was based on the F-test with the following stages:

H0 = an = 0; the overall effect of the cross-section unit is not significant.

H1 ≠ an ≠ 0; at least one cross-section unit has a significant regional effect.

To determine whether FEM and REM should be used, the Hausman test was applied. The hypotheses for this test were as follows:

H0: There is no difference between FEM and REM.

H1: There is a difference between the two models.

The operational definition of variables is given in **Table 1**.

Table 1. Variables and Operational Definitions of Research Variables.

Variable	Definition	Unit
	Dependent Variables	
Food Sovereignty (Y) Indicator	Food sufficiency includes quality, diversity, and sustainability in local food production and consumption	Index
Food Availability	The overall quantity of food produced over a specific time by a nation or region	Ton
Food Consumption Needs	The amount of food needed by the population to meet the per capita food consumption needs is calculated based on food sufficiency standards.	Ton
	Independent Variables	
NFARM (X1)	Total population of labor in the agricultural sector	Person
Rice Productivity (X2)	The amount of rice harvested per hectare of land during a certain period	Tonn/Ha
Non-Oil and Gas Food Imports (X3)	The value of non-oil and gas food imports in one year	Million USD
Government Rice Reserve (X4)	Total national food reserves, including government-managed rice stocks	Ton
Food Price Stability (X5)	Variability of the price of the main food (rice) at the market level in one year	Rp

The use of multiple linear regression models and panel data (CEM, FEM, REM) in this study is very relevant because it facilitates the analysis of the relationship between food sovereignty and various influencing factors such as the NFARM, rice productivity, imports, GFOOD reserves, and price stability, both in the context of inter-province (cross-sectional) and in time series changes. With this model, the analysis can provide a more accurate picture regarding the influence of each variable on food sovereignty and consider the variations between provinces and yearly changes.

The secondary data used were obtained from various official sources such as the Central Statistics Agency and the Food Security Agency. This is because the possibility of general method bias may occur when the data collected originate from a single source. Considering that this study used verified secondary data and incorporated various government institutions, the risk of bias of general methods was minimized. Therefore, an examination of general method bias was not considered necessary. Common method bias refers to the potential distortion of results that occurs when all data are collected using the same method or instrument, such as a survey or questionnaire. This can lead to invalid correlations between the variables being measured, rather than due to an actual causal relationship. The bias is often a problem when the data collected comes from a single source or a uniform

instrument, which can affect the results of the analysis and the validity of the conclusions [59].

Other methods are generally used to analyze only time series data, including Ordinary Least Square (OLS) and Maximum Likelihood (ML) with different variants. In multiple regression, data that contains non-constant variance uses the Autoregressive Conditional Heteroscedasticity (ARCH), General-ARCH (GARCH) method. Minimal data can use the Autoregressive Moving Average (ARMA) or Autoregressive Integrated Moving Average (ARIMA). In general, there has been no method
that can analyze time series and cross-section data at the same time. This study used the Panel Data Method which has the potential to analyze combined time series data, namely the 2018-2022 period and cross sections covering 34 provinces in Indonesia.

4. Results

4.1. Indonesia's Food Sovereignty Index

The distribution of the food sovereignty index in Indonesia showed that there was a significant inequality between provinces. Based on the food sovereignty index data presented, diverse patterns in various provinces in Indonesia are shown in **Figure 2**.

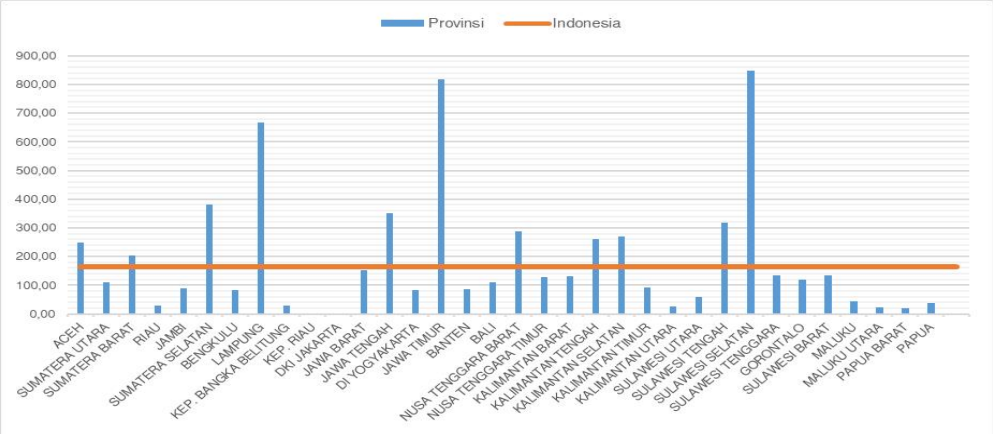

Figure 2. Average Food Sovereignty Index 2018–2023 per province in Indonesia.

Source: BPS Indonesia, 2019–2023.

Certain provinces had a food sovereignty index well above the national average (163.19), while others had index values below. South Sulawesi (848.93), East Java (818.75), Lampung (665.79), and South Sumatra (380.76) provinces had the highest food sovereignty index. In addition to the four provinces, the provinces of Aceh, West Sumatra, Central Java, West Kalimantan, Central Kalimantan, Selatan Kalimantan, and Central Sulawesi have an above-average food sovereignty index. In other words, these regions have strong food security and a good distribution system. These four regions can act as food buffers for other regions with a low index in Indonesia. Western Indonesia including the Riau Islands (0.20), DKI Jakarta (0.27), as well as eastern Indonesia, namely West Papua (18.98), Papua (38.36), and North Maluku (22.06), tended to have a very low food sovereignty index. This is due to geographical factors, limited access to transportation, and low agricultural productivity in the region

4.2. Panel Data Regression Estimation Results

The results of the analysis are presented based on a multiple linear regression model and panel data, which includes estimates using the Common Effect Model (CEM), Fixed Effect Model (FEM), and Random Effect Model (REM). Each model shows the influence of independent variables on food sovereignty in Indonesia, focusing on differences between provinces and changes over time. The panel data regression estimation results from the Common Effect, Fixed Effect, and REM phases obtained using Eviews 9 are shown in **Table 2**.

Table 2. CEM Estimation Results.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
NFARM?	1.105392	0.076467	14.45577	0.0000
PROD?	0.617086	0.399798	1.543.494	0.1243
IMP?	–0.195658	0.028713	–6.814.330	0.0000
GFOOD?	0.049904	0.061997	0.804946	0.4218
STAB?	-1.263904	0.146585	-8.622315	0.0000
R-squared	0.614054	Mean dependent var		4.302292
Adjusted R-squared	0.606296	S.D. dependent var		1.839152
S.E. of regression	1.153991	Akaike info criterion		3.148534
Sum squared resid	265.0072	Schwarz criterion		3.229860
Log-likelihood	–316.1504	Hannan-Quinn criteria		3.181432
Durbin-Watson stat	0.272029			

Source: Eviews 9 Data Processing Results.

The CEM in panel data analysis does not consider heterogeneity between entities in the model. The CEM estimate in **Table 2** shows that the NFARM variable has a significant and negative effect on food sovereignty, with a coefficient of 1.105 and a probability value of 0.00000. The Non-Oil and Gas Food Import (IMP) variable has a coefficient of –0.195658 and a probability of 0.0000, meaning that it has a negative and significant effect on food sovereignty, indicating that an increase in imports can reduce food sovereignty in Indonesia. Meanwhile, the productivity variable (PROD) and GFOOD reserves did not have a significant influence with probabilities of 0.1234 and 0.4218, respectively.

To assess the impact of independent factors that vary over time on dependent variables, FEM was then assessed by considering the heterogeneity among the entities in the model. **Table 3** displays the FEM estimation findings.

Table 3. FEM Estimation Results.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	21.33528	8.778590	2.430377	0.0162
NFARM	-0.915437	0.499887	-1.831289	0.0689
PROD	0.831555	0.717245	1.159373	0.2480
IMP	-0.087071	0.052510	-1.658177	0.0992
GFOOD	-0.067961	0.070526	-0.963631	0.3366
STAB	-0.769924	0.645913	-1.191992	0.2350
Fixed Effects (Cross)				
AC--C	1.255839			
SU--C	1.790389			
SB--C	1.483020			
R--C	0.027889			
J--C	0.274155			
SS--C	2.476605			
B--C	-0.917831			
L--C	3.027931			
KBB--C	-1.971993			
KR--C	-7.192066			
DKJ--C	-8.205682			
JB--C	2.403265			
JTE--C	3.333453			
DY--C	-0.958467			
JTU--C	4.023815			
BTN--C	0.285245			
BL--C	-0.170004			
NTB--C	1.255900			

Table 3. *Cont.*

Variable	Coefficient	Std. Error	t-Statistic	Prob.
NTT--C	1.173235			
KB--C	1.603302			
KT--C	0.953096			
KS--C	1.609250			
KTIM--C	-0.054821			
KUT--C	-2.538165			
SUTA--C	-1.027246			
SUTE--C	1.571852			
SUSE--C	2.998310			
SUTEN--C	0.436577			
GOR--C	-1.384624			
SUBAR--C	-1.114802			
ML--C	-1.349847			
MAUT--C	-1.842449			
PABA--C	-2.757073			
P—C	-0.498056			
Effects Specification				
Cross-section fixed (dummy variables)				
R-squared	0.912539	Mean dependent var		4.302292
Adjusted R-squared	0.892396	S.D. dependent var		1.839152
S.E. of regression	0.603298	Akaike info criterion		1.997368
Sum squared resid	60.05483	Schwarz criterion		2.631715
Log-likelihood	-164.7315	Hannan-Quinn criteria		2.253973
F-statistic	45.30381	Durbin-Watson stat		1.046069
Prob(F-statistic)	0.000000			

Source: Eviews 9 Data Processing Results.

The results of the Fixed effect test show that the dependent variable can be explained by the variance in the independent variable, according to the value of R-squared 0.912539 and modified R-squared 0.892396. This shows that the variable of food sovereignty in Indonesia is greatly influenced by the differences between entities between provinces. The results of the calculation of the food sovereignty index in **Figure 2** show that 11 provinces have a Sovereignty Index above the national average value, while 23 other provinces have a value below. Additionally, **Table 3** FEM calculation showed that, with a probability value of 0.01262, the constant coefficient was significant at the 5% level. Independent variables, including the NFARM, productivity (PROD), IMP, GFOOD actors, and STAB, generally had no significant effect at the 5% level even though the variables of the NFARM and IMP were close to the significance at the 10% level, with a probability of 0,0689 and 0,0992, respectively. This implies that a more thorough investigation and improved model adjustment are necessary to enhance the relevance of independent factors on food sovereignty. Subsequently, the REM was estimated, and the results are shown in **Table 4**.

Table 4. Random Effect Model Estimation Results.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.348896	6.419086	0.054353	0.9567
NFARM	0.913612	0.156879	5.823654	0.0000
PROD	0.927092	0.584655	1.585709	0.1144
IMP	-0.127962	0.041143	-3.110168	0.0021
GFOOD	-0.041576	0.064036	-0.649262	0.5169
STAB	-1.152186	0.603543	-1.909037	0.0577
Random Effects (Cross)				
AC--C	0.344790			
SU--C	-0.661685			

Table 4. *Cont.*

Random Effects (Cross)			
SB--C	0.676298		
R--C	-1.070367		
J--C	-0.343945		
SS--C	0.380791		
B--C	-0.712448		
L--C	0.954032		
KBB--C	-0.027200		
KR--C	-3.160407		
DKJ--C	-2.006126		
JB--C	-0.727569		
JTE--C	-0.254019		
DY--C	-0.464301		
JTU--C	-0.289959		
BTN--C	0.196843		
BL--C	0.067797		
NTB--C	0.470386		
NTT--C	-0.450871		
KB--C	0.376315		
KT--C	1.220728		
KS--C	1.386385		
KTIM--C	0.975562		
KUT--C	0.623509		
SUTA--C	0.166848		
SUTE--C	1.460808		
SUSE--C	1.158543		
SUTEN--C	0.994220		
GOR--C	0.704995		
SUBAR--C	-0.323682		
ML--C	0.115036		
MAUT--C	0.323651		
PABA--C	-0.356572		
P--C	-1.748387		
Effects Specification			
		S.D.	Rho
Cross-section random		1.039630	0.7481
Idiosyncratic random		0.603298	0.2519
Weighted Statistics			
R-squared	0.212888	Mean dependent var	0.991791
Adjusted R-squared	0.193012	S.D. dependent var	0.692989
S.E. of regression	0.622530	Sum squared resid	76.73358
F-statistic	10.71051	Durbin-Watson stat	0.872284
Prob(F-statistic)	0.000000		
Unweighted Statistics			
R-squared	0.588261	Mean dependent var	4.302292
Sum squared resid	282.7180	Durbin-Watson stat	0.236750

Source: Eviews 9 Data Processing Results.

Table 4 shows the Results of Random Effect Estimation that there are variables positively and significantly influencing food sovereignty. The NFARM variable has a positive and significant effect, with a probability value of 0000 and a coefficient of 0.9136. This shows that an increase in NFARM by one unit will increase the food sovereignty index by 0.9136 units. The variable of IMP showed a significant negative influence with a coefficient of -0.1279 and a probability of 0.002, indicating that an increase in IMP by one unit could reduce the food sovereignty index by 0.127962. The PROD, GFOOD reserve, and STAB variables did not have a significant effect on food sovereignty, although the direction of the relationship for each variable was in accordance with the theory. The variability of food sovereignty can be explained by the model shown by the R-squared value of 0.2128, while the rest is influenced by factors that are not included in the model. A significant statistical probability of F (0.000) supports the overall validity of the model.

4.3 Selection of the Best Models

The Chow and Hausman Tests were used to determine which of the three models was the best, and the results are provided in **Table 5**.

Table 5. Chow Test Results.

Effects Test	Statistic	d.f.	Prob.
Cross-section F	16.939210	(33,165)	0.0000
Cross-section Chi-square	301.682859	33	0.0000

Source: Eviews 9 Data Processing Results.

Based on the cross-section F statistic of 16,939 with a probability of 0,000,000 and the Chi-square cross -section statistic of 301,682 with a probability of 0,000,000, the Chow test in **Table 5** showed that Fixed Effect was the superior model compared to Random Effect. Therefore, the null hypothesis was rejected because the p-value of these two tests was below the significance level of 0.05. The specific differences between the cross-sections in the data used justify the use of the FEM as the more appropriate approach. The results obtained from the Hausman Test are presented in **Table 6**.

Table 6. Hausman Test Results.

Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Cross-section random	17.824674	5	0.0032

Source: Eviews 9 Data Processing Results.

The null hypothesis was rejected since the Chi-square value of 17,824 with a degree of freedom of 5 and a p-value of 0,0032 was less than the significance level of 0.05. FEM was selected to accommodate specific differences between cross-sections in the data used.

5. Discussion

The Chow and Hausman tests showed that FEM was better than CEM and REM due to the significant differences between the observation units. Therefore, the unique characteristics of the entities in the data panel play an important role and should be considered in the analysis. The statistical model for Indonesia's food sovereignty study based on the findings of FEM estimates is established as:

$$Yit = 2{,}133528 - 0{,}91543NFARM_{it} + 0{,}831555PROD_{it} - 0{,}08707IMP_{it} - 0{,}067961GFOOD_{it} - 0{,}769924STAB_{it} + \alpha_i + \varepsilon\_it$$

The results of FEM estimation showed that only the variables of the NFARM and IMP had a significant effect on the 90 % confidence level. A significance level of 0,0162 and a food sovereignty constant value of 2,133528 indicated that, at a 95% confidence level, food sovereignty was at 2,133528 when all independent variables were at zero. The coefficient for the NFARM variable at -0,915437 shows a negative relationship with food sovereignty. This implies that every increase in the NFARM by one unit will reduce food sovereignty by 0,915437, suggesting that the increase in the NFARM in Indonesia is correlated with a decrease in food sovereignty, which is contrary to the hypothesis that considers the NFARM as a supporting factor in increasing food sovereignty. Theoretically, the NFARM is often considered an indicator in favor of food sovereignty because more farmers are expected to increase domestic food production. However, these findings reject the hypothesis. Several factors relevant to these results include the large NFARM in Indonesia, which is dominated by small farmers who have limited access to modern agricultural technology, capital, and fair markets. With a large NFARM, agricultural land in Indonesia may be fragmented and inefficient, which in turn can reduce food production capacity, and despite the high NFARM, inadequate access to resources (such

as land, water, and agricultural technology) and weaknesses in agricultural infrastructure can hamper efforts to improve food sovereignty.

The PROD variable had a coefficient of 0,831555, suggesting that an increase in PROD by one unit has a positive influence on food sovereignty although not statistically significant. Heightened productivity increases production levels through policy simulations involving the expansion of irrigation areas, leading to increased rice self-sufficiency in Indonesia [51]. In the Indonesian context, variability in PROD between regions (e.g., differences in natural conditions, levels of agricultural technology use, and regional policies) can be very high. This can lead to large deviations in the data and reduce the likelihood of statistically significant outcomes, although a positive relationship between PROD and food sovereignty was found. In addition, policy simulations that include the expansion of irrigation areas and increased productivity may not fully reflect the more complex factors in agricultural policy.

The IMP coefficient of − 0,087071 shows that an increase by one unit has a negative and significant impact on food sovereignty at a confidence level of 90 %. Rivera et al. emphasized the importance of autonomy and strengthening local food production [9]; heavy dependence on foreign food supplies threatens food sovereignty by reducing control over the food system, demonstrating the need for measures that support domestic food production and consumption. Strong interstate trade in the region, Latin America, and the Caribbean could save up to $2.7 billion annually, which would strengthen food sovereignty and reduce dependence on foreign food supplies, which currently reduces local control over the food system [39].

GFOOD reserves had a coefficient of − 0,067961, showing that an increase in food reserves by one unit has a negative effect but is not significant. Government rice reserves play an important role in food sovereignty in Indonesia by strengthening state control over food security, in line with the goal of national self-sufficiency. However, this could inadvertently hurt vulnerable groups, as political actors prioritize self-interest over ensuring equitable food access for all [54]. The price stability variable (STAB) had a coefficient of −0,769924, showing that STAB in Indonesia hurts food sovereignty, although the influence was not significant with a probability of 0,2350. Rice is the main source of inflation in Indonesia. This significant fluctuation in rice prices shows the instability of food prices [60].

The results of the effect estimation in **Table 3** show that the regional coefficients in Indonesia's food sovereignty model have significant differences. This means that each province in Indonesia has different regional characteristics, and specific environmental carrying capacity has contributed to food sovereignty. The positive fixed effect (αi) suggests that each province has additional variables beyond the variables studied in the model that improve food sovereignty. Some provinces on the island of Sumatra that have regional coefficients with positive effects include Aceh, North Sumatra, West Sumatra, Riau, Jambi, South Sumatra, and Lampung. On the island of Java, positive effects were found in West Java, Central Java, East Java, and Banten. In addition, there are beneficial side effects in the provinces of East Nusa Tenggara (NTT) and West Nusa Tenggara (NTB). On the island of Kalimantan, almost all provinces showed positive effects. Meanwhile, several provinces on the island of Sulawesi, including Central Sulawesi, South Sulawesi, and Southeast Sulawesi, have positive coefficients. However, some provinces have a negative fixed effect, which shows that the province has a high dependence on limited food and agricultural land imports.

This study shows that factors such as the NFARM, rice productivity (PROD), food imports (IMP), GFOOD reserves, and STAB affect food sovereignty in Indonesia. The results of the estimation using the FEM and REM models show that the NFARM and IMP have a significant influence on food sovereignty. Previous studies have also analyzed the influence of local production factors on food sovereignty. For example, Rivera et al. emphasized that strengthening local food production systems and reducing dependence on food imports are key to achieving food sovereignty. Similar results were obtained in this study, showing that high dependence on food imports worsens local food security. This was reflected in the negative influence of the IMP variable on food sovereignty. Keske also showed that food price instability reduced the level of food sovereignty [2]. This study shows that STAB had a significant influence on food sovereignty. Although the variable was not significant in all models, these findings provide important insights into food price volatility that has the potential to increase food insecurity, especially in the archipelago of Indonesia. This region has different consumption spending patterns between provinces, which affects the stability of food prices. This study offers new knowledge by introducing price variations between provinces in Indonesia that can affect the results of the analysis. The results of the analysis using the FEM revealed that significant price variations across provinces showed that regional food sovereignty was also influenced by local factors, such as agricultural infrastructure and local government regulations. Previous studies, which focused more on macro factors and ignored variations at the provincial level, did not

address these findings in detail. Therefore, this study provides a more thorough analysis and significantly contributes to the understanding of the factors affecting food sovereignty in Indonesia.

This research has contributed to providing valuable insights into the factors affecting food sovereignty in Indonesia, but some limitations need to be reviewed.

First, the application of secondary data sourced from government agencies can cause bias due to limited resources in collecting and verifying data on the variables analyzed. The data used in this study include macroeconomic data that does not fully reflect social and cultural aspects, such as household consumption patterns and agricultural policies based on local wisdom.

Second, although the FEM and REM models can overcome heterogeneity between provinces, both approaches continue to face challenges in evaluating immeasurable factors, such as socio-political and policy factors that are not visible in the data. Sociocultural and political factors are variables that are not analyzed because they are difficult to measure with existing data. The analysis using panel data took into account cross-sectional data variation between provinces and changes over time, but the interactions between existing independent variables were not considered. The varying NFARM and the stability of food prices can affect each other. Therefore, it is necessary to test the causality relationship between the two variables. The relationship between the food sovereignty index and its constituent variables can be more complex and non-linear, requiring more up-to-date analytical approaches, such as structural models or non-linear models.

6. Conclusions and Policy Recommendations

In conclusion, this study deeply analyzes the challenges of food sovereignty in Indonesia, focusing on influencing factors such as the production capacity of the NFARM and productivity, the dependence on food imports, the government's food reserves, and STAB. The model shows how data variation among entities from the 34 provinces studied affects food sovereignty. Independent variables, including NFARM, productivity, GFOOD reserves, IMP, and STAB, had no significant effect. The R-squared value is quite high but there is an autocorrelation, so it requires improvement through a strong standard error approach or further model adjustment. The Indonesian government needs to consider policies to increase productivity through the application of technological innovations in the agricultural sector in realizing food sovereignty. This is reflected in the results of this study which shows that PROD, especially rice, does not make a real contribution to food sovereignty in Indonesia.

Based on these results, the implications of international policy can be focused on the need to strengthen policies that support food sovereignty in developing countries, especially in the face of high dependence on food imports. Countries can leverage Indonesia's experience in strengthening local food production capacity through technological innovation and increasing agricultural productivity, which has proven to have a positive impact on food security. Additionally, the government needs to develop policies to ensure the stability of domestic food prices, as well as the use of a food reserve mechanism derived from domestic products to reduce vulnerability to global price fluctuations. Agricultural technology transfer needs to be considered with international cooperation, especially in the Asia-Pacific region, to accelerate the achievement of food self-sufficiency and reduce dependence on international food markets that are vulnerable to instability.

This study highlights the use of macroeconomic data on NFARM, productivity, food imports, and food price stabilization to support sustainable food sovereignty. Future research is recommended to explore more deeply how local government policies, regional characteristics and patterns of local agricultural activities contribute to the realization of food sovereignty in Indonesia.

Author Contributions

The conceptualization of the research was carried out by A.M. and N. The research methodology was developed by N. and R.S., while the software was used and developed by R.S. Validation was carried out by A.M., N., and R.S. Formal analysis was handled by N., and investigation was carried out by A.M. Resources for research were managed by N.H.A., while data curation was carried out by N. and R.S. Writing-preparation of the original draft was carried out by N., and writing—review and editing are done by A.M. and N. Research visualization is done by B., with supervision led by A.M. Project administration is handled by N.H.A., and funding acquisition is managed by F. All authors contribute to the preparation and approval of the final version of the published manuscript.

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Data Availability Statement

Information was taken from the websites of the Indonesian Food Security Agency, the Indonesian Central Statistics Agency, and the Agency for Cooperation and Data Provision.

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

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Conflicts of Interest

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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