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Population Dynamics and Food Security Index on the Island of Java

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Abstract

Food security is a crucial issue in Java due to high demographic pressure and limited land. This study aims to analyze the effects of demographic factors on the Food Security Index (FSI) in six provinces on the island of Java during the period 2020-2024, using a quantitative approach with panel data regression and the Fixed Effects Model (FEM) as the preferred estimation model. The study uses secondary data sourced from BPS and BAPANAS. The analysis shows that population size and density have a significant positive effect on FSI, indicating that areas with larger populations tend to have better food distribution systems, accessibility, and infrastructure. Conversely, population growth has a significant negative effect on the FSI because it can increase pressure on food availability and access.

INTRODUCTION

Food security is a fundamental issue in economic development because it is closely related to social stability, economic security, and community welfare. Food security requires the availability of adequate, safe, nutritious, equitable, and affordable food, accessible to all levels of society, as a prerequisite for inclusive and sustainable development (Bapanas, 2022). In the context of regional development, food security reflects not only production capacity but also the effectiveness of resource management, distribution, and community access to food. Therefore, food security is an important indicator of the success of economic and social development in a region (Prasetya, 2024).

In the context of regional development, food security plays a strategic role in supporting local and regional economic dynamics by connecting production systems, distribution, and community access to food. Empirical research shows that the productivity of the livestock sector and the availability of animal feed, for example, play a key role in determining food security while also influencing the drivers of economic development at the regional level through interactions between local productivity and the broader food system (Zaini & Salim, 2025). As part of Indonesia's national development system, food security management is implemented through a decentralized approach, with local governments playing a strategic role in ensuring food availability and access for their populations.

The urgency of research on food security is growing as the risk of a global food crisis increases due to climate change, geopolitical conflicts, and demographic pressures. The Global Report on Food Crises 2024 notes that hundreds of millions of people worldwide still face acute food insecurity, while extreme weather events and international conflicts, such as the Russia-Ukraine war, have disrupted global food production and prices (UNICEF, 2024). In Indonesia, these challenges are exacerbated by high population growth and low food utilization efficiency, as reflected in the high levels of food loss and waste. This situation has prompted the government to continue strengthening national food security as a strategic agenda to maintain economic stability and community welfare (Kemenkeu, 2024).

Java Island is the most strategically and vulnerably located region in terms of national food security. More than 56 percent of Indonesia's population lives on Java Island, even though this region accounts for only around 7 percent of the total national land area. In addition to being the center of economic activity, Java Island is also the main center of national food production, especially rice commodities in Indonesia (Juanedi et al., 2016). The high population, rapid conversion of agricultural land, and limited productive space have created significant pressure on the balance between food demand and supply in the Java Region.

Table 1. Food Security Index in Java

Food Security Index (FSI)	2020	2021	2022	2023	2024
East Java	79.90	79.70	79.85	82.46	83.86
Central Java	82.31	82.73	82.95	84.80	85.34
West Java	76.78	77.79	77.75	82.19	82.97
Yogyakarta	80.67	81.43	80.88	83.17	84.15
Banten	73.48	74.38	73.78	78.71	79.25
Jakarta	77.97	78.01	78.25	83.80	85.13

Data Source: National Food Agency (BAPANAS) 2024

Based on the data presented in Table 1, the Food Security Index (FSI) data for Java Island during the 2020-2024 period shows an increase in food security across all provinces, albeit with varying degrees of achievement. Central Java and Yogyakarta consistently recorded the highest FSI values in 2024, namely 85.34 and 84.15, reflecting a relatively better ability to ensure food availability, access, and utilization for their populations. In contrast, in 2024, West Java and Banten showed lower FPI scores despite an upward trend, at 82.97 and 79.25, respectively. These differences in achievement indicate that each province faces distinct demographic conditions and resource pressures, particularly in terms of population size, growth rate, and density.

Theoretically, this phenomenon can be explained through Thomas Robert Malthus' Population Growth Theory, which states that the rate of population growth tends to exceed the growth of food production. The imbalance between population growth and food production can lead to food shortages and a decline in community welfare (Syahra et al., 2025). From a sustainable development perspective, the population has a dual role as both the subject and object of development. Rapid population growth, if not accompanied by strengthening environmental carrying capacity, can hinder the achievement of a balance between resource needs and availability (Undang-Undang Republik Indonesia Nomor 52 Tahun 2009 Tentang Perkembangan Kependudukan Dan Pembangunan Keluarga, 2009).

In response to these challenges, the government has initiated various national policies, including the establishment of the National Food Agency, efforts to accelerate food diversification that optimize the potential of local resources, as stipulated in Presidential Regulation No. 81 of 2024, and the strengthening of national food reserves. In food security studies, commodity supply strategies, food diversification, and policy harmonization between regions are the main focus to ensure the continuity of a safe, equitable, and affordable food supply. The demographic conditions and capacity of each region largely determine the effectiveness of implementing the initiated policies.

Despite various policies implemented, food security in Indonesia still faces ongoing structural challenges, particularly in regions with high population density.

Population growth, high population density, and limited productive land are putting pressure on the regional food system. This situation has the potential to create an imbalance between food demand and supply capacity, which contributes to maintaining economic stability and improving community welfare. These challenges are not temporary but rather reflect long-term problems in development management driven by demographic dynamics.

Previous studies have examined food security in Indonesia, but most studies still focus on aspects of agricultural production, food prices, or food distribution. Research (Prasetya, 2024) found that fluctuations in the prices of strategic food commodities have a significant contribution in determining the achievement of the FSI, while demographic factors have not shown a strong partial influence. At the regional level, research by Widada et al. (2017) also included population density but did not simultaneously integrate population growth dynamics. Research by Kurnia & Iskandar (2019) emphasizes the importance of domestic mechanisms and policy coordination in maintaining the stability of the food system at the national and regional levels. However, differences in regional characteristics continue to cause significant variations in food security achievements across provinces in Indonesia.

In a global context, food security is influenced by various interacting structural factors. Cross-country research by Mohamed et al. (2024) shows that the determinants of food security are not only related to food production capacity but are also influenced by a country's population and economic structure across various regional constellations. Population growth is considered a factor that affects food demand and resource availability, thereby directly impacting the stability of a region's food security system (Lestari et al., 2024). Empirical evidence from the Asian region also indicates that the relationship between population growth and food security is strongly influenced by each country's economic structure and food distribution system, leading to differences in food security achievements across regions (Jambor & Elias, 2024).

Although various studies have examined food security from different perspectives, aspects of food production, commodity price stability, and food distribution capacity remain the main focus in most of the literature (Bapanas, 2023). Research linking food security to demographic dynamics remains relatively limited and generally includes only one demographic indicator, such as population density or population size. This condition indicates a research gap, particularly in comprehensively examining the influence of demographic pressures, integrating several population indicators simultaneously, on food security at the regional level.

This study is novel in that it analyzes the relationship among three indicators of demographic pressure: population size, population growth rate, and population density. These three variables reflect the magnitude of food demand, population dynamics, and the intensity of spatial pressure on land resources. This approach provides a deeper perspective for understanding how population dynamics affect regional food security on the island of Java.

Given existing empirical and theoretical gaps, this study examines the extent to which population size, population growth rate, and population density affect the Food Security Index on the island of Java during 2020-2024. This study is expected to make theoretical contributions by enriching the literature on food security in the context of regional development. From a practical perspective, this study is expected to serve as a strategic reference for formulating food security regulations that are better adapted to regional population size, growth, and density dynamics.

RESEARCH METHODS

This empirical study employs a quantitative research design and panel data regression methods to examine the extent to which demographic variables contribute to the food security index on the island of Java. Panel data provides more degrees of freedom and greater variation, and less collinearity among variables (Gujarati et al., 2009).

The analyzed dataset includes observations from six provinces on the island of Java, spanning the period from 2020 to 2024. This period was chosen because the researchers wanted to observe food security on the island of Java using the latest data from the past 5 years, which could have implications for future development policies, particularly in the area of food security. Overall, the data sources for this empirical study were official secondary databases, namely the Central Statistics Agency (BPS) and the National Food Agency (BAPANAS).

After all the data required in this study have been collected, the next step is to conduct a series of data tests. The first stage is the selection of the most appropriate panel regression model, namely among the Common Effect Model (CEM), Fixed Effect Model (FEM), and Random Effect Model (REM). The selection of the appropriate model is carried out through several tests, namely the Chow test, the Hausman test, and the Lagrange Multiplier (LM) test. The Chow test is used to determine whether the more appropriate model is CEM or FEM, while the Hausman test is used to choose between FEM and REM. If the results from the Chow and Hausman tests indicate the same model, the Lagrange Multiplier test does not need to be performed.

After the best research model has been determined, the next step is to conduct the classical assumption tests. These tests aim to ensure that the regression model used meets the criteria of a good linear regression model, namely that it is valid, unbiased, and consistent, commonly referred to as the Best Linear Unbiased Estimator (BLUE (Gujarati et al., 2009). To achieve this objective, this study employs several classical assumption tests, including tests for normality, heteroskedasticity, multicollinearity, and autocorrelation.

Once all classical assumption tests have been conducted and the model meets the required criteria, the next stage is multiple linear regression analysis. The multiple linear regression model is used to analyze the effects of three independent variables on a single dependent variable.

The final stage in the data analysis process is hypothesis testing. This test is conducted to determine whether the independent variables have a significant effect on the dependent variable, both partially and simultaneously. In addition, this stage analyzes the magnitude of the independent variables' contributions to explaining the variation in the dependent variable, as indicated by the coefficient of determination.

The following is an operational description of each variable used in the research model:

Table 2. Operational Definition of Variables

Variable	Definition	Data Unit	Source
Food Security Index	The level of fulfillment of food needs, both for the country and individuals, so that the community can live a healthy, active, and productive lifestyle	Index Score (0-1)	National Food Agency (Bapanas RI)

	sustainably.		
Population	All individuals residing and residing in a particular area during a specific period of time as stipulated by the government regulations	Number of people	Central Statistics Agency (BPS)
Rate Population Growth	Percentage change in population in a given year compared to the previous year	Percentage	Central Central Statistics Agency (BPS)
Population density	Comparison between the population and the area of the territory in which they live	Number of people/km²	Central Statistics Agency (BPS)

Population size can reflect the level of food security required in a region. The population growth rate describes the increase in population over time and may be related to future dynamics in food demand. Population density shows how population pressure can impact space and regional resources, including agricultural land.

The econometric model applied in this study is formulated in the following regression equation:

$$y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + e \quad \text{...}(1)$$

In this study, the regression model uses the Food Security Index (FSI) as the dependent variable (Y), representing the level of food security in the observed area. The FSI is used as an indicator to measure the overall condition of food availability, access, and utilization. Meanwhile, Population Size (X_1), Population Growth Rate (X_2), and Population Density (X_3) serve as independent variables, representing demographic factors assumed to influence food security levels.

In the regression model, the constant (α) represents the value of the Food Security Index when all independent variables are assumed to be equal to zero. This constant reflects the baseline level of food security in the absence of the explanatory variables included in the model. Furthermore, the regression coefficients (β_1, β_2, and β_3) indicate the magnitude and direction of each demographic variable's influence on the Food Security Index. A positive coefficient suggests that an increase in the corresponding variable leads to an increase in the FSI, whereas a negative coefficient indicates the opposite.

Additionally, the error term (ε) represents other factors outside the regression model that may also affect food security but are not explicitly included as explanatory variables in this study.

RESULT AND DISCUSSION

RESULT

Model Selection Test

Table 3. Model Selection Test

No	Type of Test	Statistic	d.f.	Prob.
1	Chow Test	13.3284	(5.21)	0.0000
2	(Cross-section F) Hausman Test	29.9055	3	0.0000

Chow Test

Based on the table, the probability value is 0.0000 < 0.05. The model selected in this Chow test is the Fixed Effect Model (FEM). Therefore, a second test using the Hausman test is needed to determine the best model between the Fixed Effect Model (FEM) and the Random Effect Model (REM).

Hausman Test

The results of the second test show the same probability value, namely 0.0000 < 0.05. Therefore, it can be concluded that the best regression model in this study is the Fixed Effect Model (FEM).

Classical Assumption

Table 4. Normality Test

Standardized Residuals Series Sample 2020 2024 Observations 30	
Mean	-1.78e16
Median	0.28846
Max	2.0913
Minimum	-3.6462
Std. Dev	1.3210
Skewness	-0.7589
Kurtosis	3.1843
Jarque-Bera	2.9227
Probability	0.2319

Based on the results of the normality test, it is known that the Probability value of 0.2319 > 0.05, so it can be concluded that the data is normally distributed.

Table 5. Heterocedasticity Test

Variable	Coefficient	Standard Error	t-Statistic	Probability
C	-20.5102	11.9209	-1.7205	0.1000
Population	5.97E-08	2.87E-07	0.2083	0.8370
Population Growth Rate	-0.0281	0.5291	-0.0523	0.9581
Population density	0.0055	0.0026	2.0481	0.0533

In this study, the Glejser test was used to test for heteroscedasticity. In this test, if the p-value is > 0.05, there is no heteroscedasticity in the research model.

Based on the output results, it is known that the probability value of X1 (Population) is 0.8370 > 0.05, X2 (Population Growth Rate) is 0.9581 > 0.05, and X3 (Population Density) is 0.0533 > 0.05. This means that the three independent variables are not affected by heteroscedasticity.

Table 6. Multicolinearity Test

	Population	Population Growth Rate	Population Density
Population	1	0.0669	-0.3912
Growth Rate Population	0.0669	1	-0.4874
Population Density	-0.3912	-0.4874	1

Based on the output results, the coefficient for X1 on X2 is 0.0669, which is greater than 0.8. The coefficient values for X1 to X3 are -0.3912, which is < 0.8. Moreover, the coefficient for X2 to X3 is -0.4874, which is < 0.8. Therefore, the data in this study are free from multicollinearity.

Table 7. Autocorrelation Test

Cross-section fixed (dummy variables)	
Mean dependent var	80.4746
S.D. dependent var	3.3201
Akaike information	3.9608
criterion Schwarz criterion	4.3811
Hannan-Quinn criterion	4.0953
Durbin-Watson statistic	2.2250

The Durbin-Watson statistic value in the table is 2.2250. With n = 30 and k = 3, the values obtained are DL = 1.2138 and DU = 1.6498. Therefore, the selection falls within the criteria DU < DW < 4 - DU, or 1.6498 < 2.2250 < 2.3502, indicating no autocorrelation.

Based on all the classical assumption tests conducted, the FEM model in this study has passed the tests.

Multiple Linear Regression Analysis

Table 8. Multiple Linear Regression Analysis

Variable	Coefficient	Std. Error	T statistic	R Square	Prob	Prob (F-statistic)	F-statistic
Constanta	-53.2771	27.3672	-1.9467	0.8416	0.0651	0.0000	13.9560
Population	2.97E-06	6.58E-07	4.5169	0.8416	0.0002	0.0000	13.9560
Growth Rate Population	-2.7086	1.2148	-2.2295	0.8416	0.0368	0.0000	13.9560
Population density	0.0164	0.0061	2.6614	0.8416	0.0146	0.0000	13.9560

Based on the data analysis conducted by the researchers, the following multiple linear regression equation was obtained:

$$Y = -53.2771 + 2.97\text{E-}06X_1 - 2.7086X_2 + 0.0164X_3 + e \quad (2)$$

Based on Table 8, it can be interpreted as follows:

1. The constant value of -53.2771 indicates that if the Population, Population Growth Rate, and Population Density are constant, then the Food Security Index is -53.2771.

2. The regression coefficient for variable X1 is 0.00000297, indicating that Population has a positive effect on the Food Security Index. If the Population increases by 1 percent, the Food Security Index will rise by 0.00000297, *ceteris paribus*.
3. The regression coefficient for variable X2 is -2.7086, indicating that Population Growth Rate has a negative impact on the Food Security Index. If Population Growth Rate increases by 1 percent, the Food Security Index will decrease by 2.7086, *ceteris paribus*.
4. The regression coefficient for variable X3 is 0.0164, indicating that Population Density has a positive effect on the Food Security Index. If Population Density increases by 1 percent, the Food Security Index will increase by 0.0164 , *ceteris paribus*.

Hypothesis Testing

Partial Test (t)

Hypothesis testing in this study was conducted using two approaches: comparing the significance value (p-value) and comparing the calculated t-value (t-statistic) with the t-table value. This test aims to determine whether each independent variable has a significant effect on the dependent variable, namely the Food Security Index (FSI).

The Effect of Population Size on the Food Security Index

The test results show that the calculated t-value (t-statistic) is 4.5169, indicating that the t-statistic is greater than the t-table value (4.5169 > 1.7056). In addition, the obtained significance value is 0.0002, which is smaller than the significance level used (0.0002 < 0.05). Based on these results, population size significantly affects the Food Security Index.

The Effect of Population Growth Rate on the Food Security Index

The test results show that the calculated t-value (t-statistic) is -2.2295, indicating that -t-statistic < -t-table (-2.2295 < -1.7056). In addition, the significance value obtained is 0.0368, which is lower than the significance level used (0.0368 < 0.05). Thus, the population growth rate significantly affects the Food Security Index.

The Effect of Population Density on the Food Security Index

Based on the test results, the calculated t-value (t-statistic) is 2.6614, which is greater than the t-table value (2.6614 > 1.7056). The obtained significance value is 0.0146, which is lower than the significance level used (0.0146 < 0.05). These results indicate that population density significantly affects the Food Security Index.

Simultaneous Test (F)

The F-test in this study is conducted to determine whether all independent variables simultaneously have a significant effect on the dependent variable, namely the Food Security Index (FSI). The test is performed using two approaches: comparing the calculated F-value (F-statistic) with the F-table value, and comparing the significance value (p-value) with the predetermined significance level.

Based on these calculations, the F-table value is 2.9750. The test results show that the calculated F-value is 13.9560, indicating that the F-statistic is greater than the F-table value (13.9560 > 2.9750). Furthermore, the significance value obtained is 0.0000, which is lower than the significance level used (0.0000 < 0.05). Therefore, simultaneously, the variables of Population Size, Population Growth Rate, and Population Density have a significant effect on the Food Security Index on the island of Java.

The R-Squared value is 0.8416, or 84.16%. This means that the variables Population Size, Population Growth Rate, and Population Density account for 84.16% of the variation in the Food Security Index on Java Island. Meanwhile, the remaining 15.84% is influenced by other variables not included in this research model.

DISCUSSION

The Effect of Population Size on the Food Security Index

First, variable X1, namely Population Size, has a positive effect on the FSI. This finding shows that an increase in population size does not always pose a threat to food security, especially in regions with adequate food system adaptation capacity. Theoretically, this result is relevant to the theories of Marx and Engels, which hold that science and technology can drive increases in food production, just as population growth can increase food security (Sukamdi, 2012).

Considering the characteristics of Java as a region with a massive population concentration, the high population density creates a stable food market that can encourage investment in agriculture, logistics, and food distribution. This condition has the potential to maintain food availability and access, as reflected in the increase in the Food Security Index value. The population is not merely a subject of food consumption but also a productive asset and social capital that can optimize the productivity and efficiency of the food system (Prasetya, 2024).

The Effect of Population Density on the Food Security Index

Variable X3 Population density shows a positive relationship with the FSI on the island of Java. This finding indicates that areas with high population density generally exhibit better food security. Theoretically, this result is in line with Boserupian Theory (Population-Induced Innovation Theory), which asserts that population density pressure drives agricultural intensification, technological innovation, and land-use efficiency (Sukamdi, 2012).

The results of the Binary Logit Model estimation by Widada et al. (2017) show that population density has a significant positive effect on Indonesia's food security at the 10 percent significance level. The analysis results indicate that provinces with higher population density tend to have better food security than low-density areas, as they are centers of economic growth with more adequate access to food.

A global study (Kousar et al., 2021) shows that regions with high population density tend to have more efficient food accessibility because they are supported by shorter distribution chains, more developed infrastructure, and proximity to consumer markets. The island of Java, with its relatively high population density, provides easy access to markets and food distribution. Therefore, population density is not always synonymous with negative pressure, but it can be a factor that strengthens food security when supported by adequate governance, infrastructure, and technology (Miladinov, 2023).

The Influence of Population Growth Rate on the Food Security Index

Unlike the previous two variables, the Population Growth Rate hampers GDP per capita on the island of Java. In 1798, Thomas Malthus claimed that world resources would be depleted due to population growth (Abbas et al., 2025). This shows that a high population growth rate increases food insecurity. In a study (Hamdani et al., 2023), the population contributed to increased demand for rice. However, rice food security was not achieved because local production did not increase as quickly as demand, due to shrinking production land and a growing population. The study (Putri, 2024) also shows that population growth negatively and significantly affects the food security variable, in line with the theory of Thomas Robert Malthus.

Rapid population growth is one of the main obstacles to economic development and food security in developing countries (Todaro & Smith, 2020). It is not the size of the population, but rather the speed of its growth, that is the main source of pressure on food security. The island of Java has a high population growth rate, while food production capacity, infrastructure, and distribution require time to adapt. As a result, there is pressure on food availability and supply stability. In the long term, this condition can degrade food security in regions with limited natural resources (Hamdani et al., 2023).

The synergy between demographic factors and food security has theoretical implications in supporting the framework of the Demographic and Food Transition Theory. Increases in population size and density can be offset by intensified production, efficient distribution, and strengthened food institutions. The positive influence of population size and density on food security is also consistent with Boserup's Theory, which holds that population pressure can encourage innovation, increased productivity, and the efficient use of resources (Sukamdi, 2012). Conversely, the negative impact of population growth reflects Malthusian pressure, in which uncontrolled growth can weaken food supply capacity.

This finding also bridges two previously distinct research domains, namely demography and food security, by showing that population factors are not merely a source of vulnerability but can also be a source of food security strength when supported by adequate economic and institutional adaptation capacity. This finding enriches the food security literature by emphasizing the importance of a systematic approach that integrates population dynamics and institutional structures.

Implications for national policy, the results of this study confirm that efforts to strengthen food security cannot be separated from government population policies. The government needs to include population growth control in its strategy to overcome the national food crisis. This is because accelerated population growth has been shown to exert negative pressure on food security in Java. Policies on fertility control, improving the quality of human resources, and managing migration are important to maintain a balance between demand and food supply capacity.

On the other hand, the positive effects of population size and density show that densely populated areas are not always synonymous with food vulnerability. Therefore, national policies need to be directed at optimizing the potential of densely populated areas through strengthening food distribution infrastructure, developing efficient logistics systems, and supporting agricultural intensification. This approach aligns with the food security agenda, which is adaptive to changing demographic dynamics.

The implications for national institutions from this study show the importance of strengthening the capacity of food institutions to manage demographic pressures effectively. Institutions such as the National Food Agency, the Ministry of Agriculture, and local governments need to strengthen cross-sectoral coordination between food, population, and spatial planning policies. The positive effect of population density on food security indicates that adaptive, data-driven food institutions have the potential to convert demographic pressures into opportunities through sustainable food distribution and access governance.

CONCLUSION

This study confirms that demographic factors play an important role in determining food security on the island of Java. Population size and density contribute positively to the Food Security Index, indicating that densely populated areas are not necessarily synonymous with food vulnerability when supported by adaptive food infrastructure, distribution, and institutions. Conversely, population growth rates negatively impact food security by increasing pressure on food supply and access systems faster than they can adjust.

These findings indicate that the main challenge to food security on Java Island is not population size but rather the rate of population growth and the region's ability to manage demographic pressures. Therefore, strengthening food security requires integrating population and food policies, particularly population growth control and the optimization of the potential of densely populated areas. The generalization of these research results needs to be done carefully, as they are limited to the provinces on the island of Java and a specific observation period.

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