

Research Article

Female Education, Poverty, and Household Factors in Reducing Stunting in Indonesia

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Abstract: Stunting remains a persistent nutritional challenge that threatens human capital development in Indonesia. This study examines the effects of exclusive breastfeeding, female education, sanitation, access to safe drinking water, inadequate food consumption, and poverty on stunting prevalence across 34 provinces in Indonesia during 2017–2024. The study employs a random-effects Panel EGLS estimator with Panel Corrected Standard Errors (PCSE) to address heteroskedasticity and cross-sectional dependence in provincial panel data. The findings reveal that exclusive breastfeeding, female education, and adequate sanitation significantly reduce stunting prevalence, while poverty significantly increases it. Interestingly, inadequate food consumption is negatively associated with stunting prevalence, potentially reflecting the contribution of government nutritional assistance and social protection programs. In contrast, access to safe drinking water does not show a statistically significant effect. Among the explanatory variables, female education is strongly associated with reductions in stunting. These findings highlight the importance of strengthening women's education, improving sanitation quality, and expanding poverty-alleviation and nutrition-sensitive interventions to accelerate reductions in stunting and support the achievement of Sustainable Development Goal 2 in Indonesia.

Keywords: Stunting Reduction; Household Determinants; Panel Data; EGLS; Panel Corrected Standard Errors.

1. Introduction

Sustainable national development requires a foundation of quality, healthy and productive human resources. The quality of human resources is a key factor in determining a country's competitiveness amidst globalization. There is a reciprocal relationship between economic development and human resource development, where economic progress drives improvements in human resource quality, and conversely, quality human resources will strengthen sustainable economic growth (Rohmah et al., 2025). One of the nutritional problems that remains a serious challenge in Indonesia is stunting. Stunting is a condition of growth failure in children due to chronic malnutrition, repeated infections, and long-term lack of stimulation, especially during the first 1,000 days of life (WHO, 2023). This condition not only impacts physical growth but also reduces cognitive abilities and productivity, and increases the risk of non-communicable diseases in adulthood.

Globally, stunting reduction is part of the Sustainable Development Goals (SDGs) agenda, particularly Goal 2, which focuses on eliminating hunger and improving nutrition. Target 2.2 specifically emphasizes the elimination of all forms of malnutrition, including reducing stunting prevalence, by 2030. However, although Indonesia has shown a downward trend in stunting prevalence, this achievement still falls short of the national target of 14% set in the 2020–2024 National Medium-Term Development Plan (RPJMN). According to Presidential Regulation Number 72 of 2021, stunting is a growth disorder caused by chronic malnutrition and repeated infections that impacts a child's physical and cognitive development. The impact of stunting is not only individual but also has broad implications for social and economic development by reducing the quality of human resources. (Beal et al., 2018; Murwiati, 2021). Therefore, stunting is an important indicator in sustainable development, especially in achieving Goal 2 of the SDGs.

Data from the Indonesian Nutritional Status Survey (SSGI) shows that the prevalence of stunting in Indonesia has decreased in recent years, although the distribution is not uniform across regions. Several provinces, such as East Java, South Sumatra, and

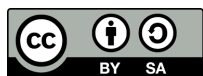
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Lampung, have shown significant declines, while eastern Indonesia, such as East Nusa Tenggara and West Sulawesi, still have high prevalence rates. This indicates unequal access to healthcare, sanitation, clean water, and socioeconomic conditions.

The Indonesian government has implemented various strategies through the National Strategy for the Acceleration of Stunting Reduction (Stranas Stunting) since 2018, utilizing a convergent approach of specific and sensitive nutrition interventions. This program emphasizes the importance of the First 1,000 Days of Life as a critical phase in stunting prevention. Despite showing positive results, the effectiveness of the program still needs to be evaluated because disparities between regions still occur.

Factors influencing stunting can be classified as internal and external to the household. Internal factors include exclusive breastfeeding, maternal education, and adequate food intake. Exclusive breastfeeding has been shown to play a significant role in reducing the risk of stunting.

However, coverage in Indonesia is still below the national target. Maternal education also has a significant influence on the quality of child care and nutritional fulfillment (Willyanto & Ramadhani, 2023).

Meanwhile, external factors include access to proper sanitation, clean drinking water, and economic conditions. Programs such as PAMSIMAS aim to increase access to clean water and sanitation, which plays a role in reducing the risk of infectious diseases that cause stunting (Purnama, 2025). Various studies have shown that access to sanitation and clean water has a significant relationship with reducing stunting.

In addition, economic factors such as poverty and insufficient food consumption also play an important role. Limited purchasing power leads to low consumption of nutritious food, which has an impact on increasing the risk of stunting (Priatmadani et al., 2023). Therefore, handling stunting requires a multidimensional approach involving the health, education, and economic sectors.

Based on this description, this study aims to analyze the influence of internal and external household factors on the prevalence of stunting in Indonesia for the period 2019–2024. The variables used include exclusive breastfeeding, average years of schooling for girls, access to adequate sanitation, access to safe drinking water, inadequate food consumption, and poverty levels. This approach is expected to provide a comprehensive picture to support the achievement of SDG Goal 2.

2. Theoretical Basis

Poverty Theory

Poverty is defined as a condition where an individual or household is unable to meet the minimum basic needs for a decent life, not only in terms of income, but also limited access to education, health, nutrition, clean water, and socio-economic participation (Todaro & Smith, 2011). Poverty is divided into absolute and relative poverty, where absolute poverty relates to the inability to meet basic needs, while relative poverty refers to income inequality in society.

Poverty also reflects limited access to resources such as education, employment, and other basic services (Nansadiqa, 2024). This condition makes individuals vulnerable to malnutrition and food insufficiency, which ultimately impacts the quality of human resources and socio-economic development.

Human Capital Theory

Human capital theory views people as productive assets that can be enhanced through investments in education and health (Schultz, 1961). Education improves skills and job opportunities, while health enables individuals to maximize their productivity potential (Todaro & Smith, 2011). Education and health are essential forms of human capital that influence individual productivity and long-term economic development.

In this context, stunting is an important indicator because it directly impacts the quality of human capital, both physically and cognitively. Stunting during early childhood may reduce cognitive ability, educational attainment, and future labor productivity. Stunting prevention can be seen as a long-term investment in economic development.

UNICEF Framework on Child Malnutrition

This study is grounded in the UNICEF conceptual framework on child malnutrition, which explains that stunting is a multidimensional phenomenon influenced by immediate, underlying, and basic determinants (UNICEF, 1990). The framework emphasizes that child malnutrition is not solely caused by insufficient food intake but is also associated with household socioeconomic conditions, environmental quality, maternal characteristics, and access to public health services.

At the immediate level, the UNICEF framework identifies inadequate dietary intake and infectious diseases as the direct causes of stunting. One of the most important nutritional interventions during early childhood is exclusive breastfeeding. Breast milk contains essential nutrients, antibodies, and immunological components that support optimal child growth and development. (Victora et al., 2016) found that exclusive breastfeeding significantly improves child survival, nutritional status, and cognitive development, particularly in low- and middle-income countries. Similarly, research conducted by Robert Black et al. (2013) showed that inadequate breastfeeding practices contribute substantially to child undernutrition and stunting (Black et al., 2013). In the Indonesian context, studies by Semba et al. (2008) and Beal et al. (2018) also reported that children who do not receive exclusive breastfeeding are more vulnerable to chronic malnutrition and growth failure (Beal et al., 2018; Semba et al., 2008).

Food consumption is another important immediate determinant within the UNICEF framework. Households experiencing food insecurity often face limited access to sufficient calories, protein, and micronutrients necessary for child development. According to Smith and Haddad (2015), inadequate food consumption significantly increases the risk of chronic malnutrition in developing countries (Smith & Haddad, 2015). Likewise, the Food and Agriculture Organization (2022) emphasized that household food insecurity remains one of the main drivers of stunting prevalence globally (FAO, 2022). However, several recent studies suggest that social protection programs, nutritional assistance, and food subsidy policies may reduce the negative effects of household food insecurity on child nutritional outcomes.

At the underlying level, the UNICEF framework highlights the importance of sanitation, clean water, maternal care, and healthcare access. Poor sanitation exposes children to repeated infections, especially diarrhea and environmental enteric dysfunction, which inhibit nutrient absorption and impair growth. Research by Humphrey (2009) explained that inadequate sanitation contributes to chronic intestinal inflammation that ultimately affects child growth outcomes (Humphrey, 2009). Empirical evidence from developing countries also confirms that improved sanitation significantly reduces stunting prevalence (Prüss-Ustün et al., 2019). In Indonesia, Torlesse et al. (2016) found that inadequate sanitation and poor hygiene practices were strongly associated with higher stunting prevalence among children under five years old (Torlesse et al., 2016). Access to safe drinking water is theoretically expected to improve child health outcomes by reducing exposure to waterborne diseases. According to the World Health Organization (2023), access to safe drinking water is an essential component of child nutrition and public health improvement (WHO, 2023). However, empirical findings regarding the direct effect of drinking water access on stunting remain mixed. Some studies indicate a significant relationship, while others suggest that sanitation and hygiene practices have a stronger influence than water access alone.

Maternal education is another critical determinant emphasized in the UNICEF framework. Educated women are generally more capable of understanding nutritional information, maintaining hygiene practices, utilizing healthcare services, and allocating household resources effectively. Amartya Sen (1999) argued that education enhances individual capabilities and improves household welfare outcomes, including child health and nutrition (Sen, 1999). Empirical studies by Frost et al. (2005) and Abuya et al. (2012) confirmed that maternal education significantly reduces the likelihood of child stunting in developing countries (Abuya et al., 2012; Frost et al., 2005). In Indonesia, higher female education has consistently been associated with improved child nutritional outcomes due to better health awareness and childcare practices.

At the basic level, poverty is recognized as a structural determinant of malnutrition. Poor households often experience limited access to nutritious food, education, sanitation, healthcare services, and healthy living environments. According to Amartya Sen (1981), poverty reflects deprivation of basic capabilities necessary to achieve adequate living standards, including nutritional well-being (Sen, 1981). Empirical studies by Lawrence Haddad et al. (2003) and Headey and Hoddinott (2015) found that poverty is strongly associated with higher stunting prevalence in low- and middle-income countries (Haddad et al., 2003; Headey & Hoddinott, 2015). In Indonesia, poor households remain more vulnerable to chronic malnutrition due to limited purchasing power and unequal access to health-supporting facilities. Overall, the UNICEF conceptual framework provides a comprehensive explanation that stunting is influenced not only by nutritional intake but also by broader socioeconomic and environmental conditions. Therefore, this framework is highly relevant for analyzing the effects of exclusive breastfeeding, female education, sanitation, access to safe drinking water, inadequate food consumption, and poverty on stunting prevalence in Indonesia.

3. Proposed Method

Type and Location of Research

This research is a descriptive quantitative study aimed at analyzing the influence of internal and external household factors on stunting prevalence in Indonesia. The method used is multiple linear regression with panel data, combining time series and cross-sectional data. The research objects cover 34 provinces in Indonesia with an observation period from 2017 to 2024, or 272 observations. Location selection is based on the availability of secondary data from official government agencies.

Data Sources and Research Variables

The data are sourced from the Indonesian Nutritional Status Survey (SSGI) conducted by the Ministry of Health and the Central Statistics Agency (BPS). The research variables consist of one dependent variable and six independent variables, namely:

Table 1. List of Variables.

Variables	Symbol	Unit	Data source
Dependent Variable:			
Prevalence of Stunting (Dependent Variable)	PS	Percent	Ministry of Health
Independent Variables:			
Exclusive Breastfeeding	AE	Percent	BPS
Average length of schooling for girls	RP	Year	BPS
Access to Proper Sanitation	SL	Percent	BPS
Access to Safe Drinking Water	AL	Percent	BPS
Prevalence of Insufficient Food Consumption	KP	Percent	BPS
Poor People	PO	Percent	BPS

Econometric Methodology

This study employs panel data regression to analyze the determinants of stunting prevalence across 34 provinces in Indonesia during the 2017–2024 period. Panel data analysis was selected because it allows the integration of both cross-sectional and time-series dimensions, thereby improving estimation efficiency and capturing provincial heterogeneity over time.

The empirical model is specified as follows: $PS_{it} = \beta_0 + \beta_1 AE_{it} + \beta_2 RP_{it} + \beta_3 SL_{it} + \beta_4 AL_{it} + \beta_5 KP_{it} + \beta_6 PO_{it} + \varepsilon_{it}$ (i)
where:

- PS_{it} denotes the prevalence of stunting in the province i during year t ;(ii)

- AE_{it} represents exclusive breastfeeding;(iii)
- RP_{it} denotes female education, measured by the average years of schooling of women;.....
..(iv)
- SL_{it} represents access to adequate sanitation;.....(v)
- AL_{it} denotes access to safe drinking water;.....(vi)
- KP_{it} represents inadequate food consumption;.....(vii)
- PO_{it} denotes poverty level; and.....(viii)
- ε_{it} is the error term.....(ix)

To determine the most appropriate panel data model, the study conducted several specification tests, including the Chow test, Hausman test, and Breusch–Pagan Lagrange Multiplier (LM) test. Based on these tests, the random-effects model was selected as the preferred specification because it better captures unobserved provincial heterogeneity while maintaining estimation efficiency. The estimation was performed using the Estimated Generalized Least Squares (EGLS) approach with cross-sectional random effects. The EGLS estimator is considered appropriate because panel data involving regional observations commonly exhibit heteroskedasticity and serial correlation, which may lead to inefficient estimates under conventional Ordinary Least Squares (OLS) estimation.

Furthermore, this study applies Panel Corrected Standard Errors (PCSE) to address potential heteroskedasticity and cross-sectional dependence across provinces. Cross-sectional dependence is likely to occur because provinces in Indonesia are interconnected through national economic policies, food distribution systems, fiscal transfers, and public health interventions. The PCSE approach produces more robust and reliable standard errors, thereby improving statistical inference in panel data estimation. The estimated model uses balanced panel data consisting of 34 provinces observed over eight years, resulting in 272 observations. All estimations were conducted using EViews statistical software.

Hypothesis Testing

Hypothesis testing in this study was conducted through partial tests (t-test), simultaneous tests (F-test), and the coefficient of determination (R^2) using the Random Effects (REM) model. The partial test aimed to determine the effect of each independent variable on stunting prevalence, while the simultaneous test was used to examine the effect of the independent variables together.

4. Results and Discussion

Descriptive Statistics

Table 2. Descriptive Statistics of Research Variables.

Variables	Mean	Median	Max	Min	Std. Dev
PS	26.07195	26.43000	43.82000	8,000,000	6.606400
AE	63.87048	65.76500	83.07000	24.96000	11.94155
RP	8.375294	8.375000	11.19000	5.440000	1.036629
SL	77.69842	79.56000	97.12000	33.75000	11.97403
AL	83.12831	85.45500	99.96000	43.83000	10.98549
KP	11.23765	9.180000	38.35000	1.430000	8.194874
PO	10.33441	8.645000	27.76000	3.420000	5.315991

Source: Eviews 12 output (processed data).

Based on Table 2, the stunting prevalence (PS) variable has an average value of 26.07%. This indicates that, in general, approximately one-quarter of toddlers in Indonesia experienced stunting during the study period. The exclusive breastfeeding (AE) variable has an average of 63.87%, indicating that most infants in Indonesia have received exclusive breastfeeding. The average years of schooling for girls (RP) variable has an average value of 8.37 years, indicating that, in general, women in Indonesia have completed education up to the junior high school (SMP) level. The access to clean

drinking water (AL) variable has an average value of 83.13%, indicating that the majority of Indonesians have access to clean drinking water. The inadequate food consumption (KP) variable has an average value of 11.24%, indicating that some of the population still experiences food insufficiency. The poor population (PO) variable has an average value of 10.33%, indicating that the poverty rate in Indonesia is still relatively significant.

In addition, the standard deviation values for each variable indicate that there is a significant variation in the data between provinces. This variation indicates the existence of inequality in socio-economic and health conditions between regions in Indonesia. Thus, the results of descriptive statistics show that the data have high heterogeneity between provinces and time. Therefore, the use of panel data in this study is considered appropriate because it can capture variations between individuals (cross-section) and time (time series) simultaneously, thus producing more accurate and informative estimates (Basuki & Prawoto, 2015; Widarjono, 2018).

Panel Data Regression Model Selection Test

Chow Test

Table 3. Chow test results.

Effect Test	Statistics	df	problem
Cross-section F	16. 843477	(33,232)	0.0000
Cross-section Chi-Square	332. 533864	33	0.0000

SouSource: EvIEWS 12 output (processed data)

The Chow test results show that the Cross-section F and Chi-Square probabilities are 0.0000 (<0.05), so H_a is rejected and H_0 is accepted. This means that the Fixed Effect model is more appropriate to use than the Common Effect model.

Hausman test

Table 4. Hausman test results

Test Summary	Chi-Sq Statistic	Chi-Sq. Statistic	Prob
Cross-Section random	6.376129	6	0.3824

Source: EvIEWS 12 output (processed data).

The Hausman test results show a Chi-Square value of 6.376129 with a probability of 0.3824 (>0.05), so H_0 is accepted and H_a is rejected. This means that the Random Effect model is more appropriate to use than the Fixed Effect model.

Lagrange Multiplier Test

Table 5. Lagrange Multiplier Results.

Test Summary	Cross-section	Hypothesis Test Time	Both
Breusch-Pagan	384. 3142 (0.0000)	0. 406158 (0.5239)	384. 7204

Source: EvIEWS 12 output (processed data)

The Lagrange Multiplier test results show a Breusch-Pagan cross-section probability of 0.0000 (<0.05) and a time probability of 0.5239 (>0.05). This means that the individual effect is significant, while the time effect is not. Thus, H_0 is rejected and H_a is accepted, making the Random Effect model better than the Common Effect.

Estimation Results

Based on the Chow, Hausman, and LM tests, the most appropriate model to use is the Random Effect Model (REM). Based on the results of the model selection, this study uses the Random Effect Model (REM). Methodologically, REM is estimated using the EGLS approach (Widarjono, 2018) which is able to overcome heteroscedasticity and error correlation, and produce a robust result. In REM, classical assumption problems such as heteroscedasticity and autocorrelation have been accommodated in the EGLS procedure, so that testing is not a primary requirement (Kosmaryati et al.,

2019). In addition, the use of panel data provides a larger number of observations, increases data variation, reduces collinearity, and increases the degrees of freedom, so that estimation becomes more efficient. Referring to Gujarati & Porter (2009), EGLS is a transformation of OLS that meets the basic assumptions of the least squares method and produces a BLUE estimator. Therefore, this study does not test classical assumptions because it uses REM with the EGLS approach that has met these criteria (Gujarati & Porter, 2009).

Table 6. Model Estimation Results.

Variable	Coefficient	Std.Error	t-Statistic	Prob.
C	62.14039	4.939048	12.58145	0.0000
AE	0.116596	0.025785	4.521773	0.0000
RP	-2.197674	0.609926	-3.603184	0.0004
SL	-0.149918	0.041044	-3.650798	0.0003
AL	-0.002241	0.047432	-0.047252	0.9623
KP	-0.316257	0.701755	-2.384114	0.0138
PO	0.737577	0.505015	1.459490	0.0779

Source: Eviews 12 output (processed data)

Table 7. Effects Specification.

Effect	S.D.	Rho
Cross-section random	4.313219	0.6961
Idiosyncratic random	2.850089	0.3039

Source: Eviews 12 output (processed data)

Table 8. Weighted Statistics.

Statistik	Nilai
Root MSE	2.815172
R-squared	0.535520
Mean dependent var	5.931245
Adjusted R-squared	0.525003
S.D. dependent var	4.138290
S.E. of regression	2.852111
Sum squared resid	4215.652
F-statistic	50.92165
Durbin-Watson stat	1.604258
Prob (F-statistic)	0.000000

Source: Eviews 12 output (processed data).

Table 9. Unweighted Statistics.

Statistik	Nilai
R-squared	0.421970
Mean dependent var	26.07195
Sum squared resid	8636.746

Statistik	Nilai
Durbin-Watson stat	0.505829

Source: Eviews 12 output (processed data)

The panel data regression model in this study requires a cross-section dependence (CSD) test to ensure that the assumption of independence between cross-section units is met.

Model Diagnostic Test

Table 10. CSD Test for REM.

Test	Statistic	Df	Prob
Breusch_Pagan LM	824.7790	561	0.0000
Pesaran Scaled LM	7.874877		0.0000
Pesaran CD Order	4.911130		0.0000

Source: Eviews 12 output (processed data).

The results of the cross-section dependence test show that the probability values of Breusch-Pagan LM, Pesaran scaled LM, and Pesaran CD are each 0.0000 (<5%), so the null hypothesis is rejected. This indicates the presence of cross-section dependence, or the correlation between cross-section units in the model. This condition indicates that errors between regions are not independent and are likely influenced by general factors such as government policies and macroeconomic conditions (Pesaran, 2004).

Methodologically, the presence of cross-section dependence causes conventional models such as the Random Effect Model (REM) to be less efficient and potentially produce biased standard errors (Pesaran, 2004). Therefore, this study uses the Panel Corrected Standard Errors (PCSE) approach to address this problem. The PCSE method is able to accommodate heteroscedasticity and correlation between cross-sections, thus producing more robust estimates.

The use of PCSE is also supported by previous research showing that robust approaches such as PCSE and Driscoll–Kraay are effective in overcoming violations of classical assumptions and increasing the reliability of estimation results (Hakim et al., 2025; Mahrahi et al., 2025; Mahyudin et al., 2024). Thus, the use of PCSE in this study is considered appropriate for producing valid, reliable, and dependable estimates.

Estimation Results of Cross-section weights Panel Corrected Standard Errors (PCSE)

Table 11. Estimation Results of Cross-section weights PCSE.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	52.14039	5.096426	12.12994	0.0000
AE	-0.116596	0.028325	-4.129446	0.0000
RP	-2.197674	0.651383	-3.371504	0.0009
SL	-0.149918	0.044071	3.401702	0.0009
AL	0.002241	0.046079	0.048015	0.9617
KD	-0.107257	0.077136	-1.390385	0.2005
PO	0.338577	0.164103	2.063203	0.0401

Source: Eviews 12 output (processed data).

Table 12. Effects Specification.

Effect	S.D.	Rho
Cross-section random	4.313219	0.6961
Idiosyncratic random	2.850089	0.3039

Source: Eviews 12 output (processed data).

Table 13. Weighted Statistics.

Statistik	Nilai
Root MSE	2.515172
Mean dependent var	9.931245
S.D. dependent var	4.138290
Sum squared resid	1153.652
Durbin-Watson stat	1.604258
R-squared	0.535520
Adjusted R-squared	0.520003
S.E. of regression	2.515111
F-statistic	35.921650
Prob(F-statistic)	0.000000

Source: Eviews 12 output (processed data).

Table 14. Unweighted Statistics.

Statistik	Nilai
R-squared	0.421970
Sum squared resid	8836.746
Mean dependent var	26.07195
Durbin-Watson stat	0.505829

Source: Eviews 12 output (processed data).

The estimation results show the Exclusive Breastfeeding (AE) variable has a negative and significant effect on the prevalence of stunting, with a coefficient of -0.1166 and is statistically significant. This means that a 1% increase in AE will reduce the prevalence of stunting by 0.1166%, assuming other variables are constant. The Average Years of Schooling for Girls (RP) also shows a negative and significant effect, with a coefficient of -2.1977. This means that a one-year increase in the length of schooling for girls can reduce the prevalence of stunting by 2.1974 percent, *ceteris paribus*. Access to Proper Sanitation (SL) has a negative and significant effect with a coefficient of -0.149918, which means that a 1 percent increase in access to proper sanitation will reduce the prevalence of stunting by 0.149918 percent. On the other hand, the Access to Proper Drinking Water (AL) variable does not have a significant effect on the prevalence of stunting, because its probability value is greater than 5 percent. The Prevalence of Insufficient Food Consumption (KP) variable shows a significant effect, but with a negative direction that does not correspond to the initial hypothesis. The coefficient of -0.167257 indicates that a 1 percent increase in insufficient food consumption is actually followed by a decrease in stunting prevalence of

0.167257 percent. Meanwhile, the Poor Population (PO) variable has a positive and significant effect on stunting prevalence, with a coefficient of 0.338577. This indicates that a 1 percent increase in the number of poor people will increase stunting prevalence by 0.338577 percent, assuming other variables remain constant.

Hypothesis Testing

Hypothesis Test (t-test)

Based on the estimation results, the variables Exclusive Breastfeeding (AE), Average Years of Schooling for Girls (RP), and Proper Sanitation (SL) have a negative and significant effect on stunting prevalence ($p < 0.05$). Meanwhile, Access to Proper Drinking Water (AL) has no significant effect ($p > 0.05$). The variable Inadequate Food Consumption (KP) has a negative and significant effect, but the direction of the relationship does not align with the theory. On the other hand, Poor Population (PO) has a positive and significant effect on stunting prevalence ($p < 0.05$).

Hypothesis Test (F-test)

Based on the estimation results of the Random Effect Model, the calculated F-value was 50.92165, greater than the F-table of 2.14 at a significance level of 0.05, so H_0 was rejected. This indicates that the variables of exclusive breastfeeding, average length of schooling for girls, proper sanitation, access to proper drinking water, insufficient food consumption, and the poor population simultaneously have a significant effect on the prevalence of stunting in Indonesia for the period 2017–2024. Thus, the model used is considered feasible.

Coefficient of Determination (R^2)

The coefficient of determination (R^2) is used to measure the ability of independent variables to explain variations in dependent variables. Based on the estimation results of the EGLS Panel model with Random Effect Model (REM) and PCSE correction, the Adjusted R-squared value was obtained at 0.525003. This indicates that 52.50% of the variation in stunting prevalence can be explained by the variables Exclusive Breastfeeding, Average Years of Schooling for Women, Adequate Sanitation, Access to Adequate Drinking Water, Insufficient Food Consumption, and Poor Population, while the remaining 47.50% is influenced by other factors outside the model like health service access, maternal health, etc.

Discussion

The results of the study showed that exclusive breastfeeding had a negative and significant effect on the prevalence of stunting. This is in line with the concept of the First 1,000 Days of Life (HPK), which emphasizes the importance of fulfilling nutrition from the beginning of a child's life. Breast milk contains complete nutrients, enzymes, and antibodies that function to improve the baby's immune system and prevent infectious diseases that can inhibit nutrient absorption (UNICEF & World Health Organization, 2021). Previous research shows that babies who do not receive exclusive breastfeeding have a higher risk of experiencing stunting than babies who receive exclusive breastfeeding (Madhe et al., 2021). Also emphasized that suboptimal breastfeeding practices are one of the main factors causing stunting in Indonesia.

The female education variable has a negative and significant effect on the prevalence of stunting. This suggests that increased maternal education contributes to improved parenting patterns, nutritional fulfillment, and access to healthcare. Theoretically, this aligns with human capital theory and the UNICEF framework, which states that education improves an individual's ability to make more rational decisions (Becker, 1964). Furthermore, the World Bank (2020) states that mothers with low levels of education tend to have limited access to health and nutrition information, thereby increasing the risk of stunting in children.

Furthermore, adequate sanitation reduces stunting prevalence. Sanitation is a crucial determinant of environmental health that directly impacts children's nutritional status. Poor sanitation can increase the risk of infectious diseases such as diarrhea, worms, and other gastrointestinal infections that inhibit nutrient absorption. Found that children living in environments with inadequate sanitation have a higher risk of stunting compared to children living in conditions with good sanitation. This finding is also supported by Shofiyulloh

& Wasil (2024). (Shofiyulloh & Wasil, 2024) which shows that sanitation has a negative and significant effect on stunting in Indonesia.

Unlike other variables, access to safe drinking water does not significantly influence the prevalence of stunting. Theoretically, safe drinking water plays an important role in preventing water-based diseases such as diarrhea, which can lead to malnutrition (UNICEF & World Health Organization, 2021). However, the results of this study indicate that increasing access is not necessarily followed by an increase in the quality of water consumed. This is in line with the findings of Putri (2023), who stated that the quality of drinking water in Indonesia has decreased despite increasing access (Putri, 2023). In addition, the Ministry of Health (2022) emphasized that the main problem of drinking water in Indonesia lies not only in availability, but also in the quality and sanitation behavior of the community. Research by Hasan et al. (2025) and Adityaningrum et al. (2023) also found that access to safe drinking water does not significantly influence stunting, because this factor is more indirect through infectious diseases (Adityaningrum et al., 2023; Hasan et al., 2025).

The variable of inadequate food consumption shows a negative and significant effect on stunting prevalence, although this result is inconsistent with the theory. Theoretically, inadequate food consumption should increase the risk of stunting because it reflects insufficient nutrient and energy intake. However, this finding may indicate the effectiveness of government interventions, particularly food assistance programs and accelerated stunting reduction policies that are concentrated in food-insecure areas. As a result, several regions with high levels of food insufficiency have experienced declining stunting prevalence.

This condition is also supported by the increase in Indonesia's health budget, which reached approximately IDR 186.4 trillion in 2024, an increase of around 8.1% compared to the previous year. The larger allocation strengthened nutrition-specific and nutrition-sensitive programs, including supplementary feeding, nutritional supplementation, and maternal and child healthcare services. These interventions contributed to the decline in national stunting prevalence from 27.7% in 2019 to approximately 19.8% in 2024.

Nevertheless, inadequate food consumption remains a challenge due to fluctuating food prices and limited household purchasing power. This indicates that reductions in stunting are influenced not only by food consumption itself, but also by the effectiveness of government health and social protection policies. Therefore, although inadequate food consumption statistically shows a negative relationship with stunting prevalence, this pattern likely reflects the strong role of policy interventions in mitigating the adverse effects of food insecurity. These findings suggest that public policy interventions, including increased health spending and integrated stunting reduction programs, play a more substantial role in reducing stunting prevalence than food consumption alone.

Meanwhile, poverty has a positive and significant effect on stunting prevalence, indicating that poverty remains a major determinant of child malnutrition. Theoretically, poverty restricts household access to nutritious food, healthcare, education, and sanitation facilities. Previous studies by Karyati and Julia (2019), Sutarto et al. (2018), and Ramadhan and Ramadhan (2017) also confirmed that poverty significantly increases the risk of stunting (Karyati & Julia, 2019; Sutarto et al., 2018). Regions with higher poverty levels generally exhibit poorer health conditions and higher stunting prevalence.

Overall, the findings confirm that stunting is a multidimensional problem influenced by nutritional, educational, environmental, and economic factors. Therefore, reducing stunting in Indonesia requires integrated and sustainable policies that strengthen health interventions, improve education and sanitation, and accelerate poverty alleviation programs.

5. Conclusion

The results of this study indicate that exclusive breastfeeding, female education, and adequate sanitation significantly reduce stunting prevalence in Indonesia during 2017–2024, while poverty significantly increases it. Among these factors, female education emerges as the most dominant determinant in reducing stunting, followed by sanitation and exclusive breastfeeding. Access to safe drinking water shows a negative but insignificant effect on stunting prevalence. Interestingly, inadequate food consumption is negatively associated with stunting prevalence, suggesting the possible influence of government

nutrition and social protection interventions. Simultaneously, all independent variables significantly affect stunting prevalence, confirming that stunting is a multidimensional problem influenced by nutritional, educational, environmental, and economic factors. Therefore, integrated policies focusing on women's education, sanitation improvement, poverty reduction, and nutrition-sensitive interventions are essential to accelerate stunting reduction in Indonesia.

6. Recommendation

Based on the findings of this study, several policy recommendations can be proposed. (1) The government is encouraged to strengthen stunting reduction programs through a more sustainable and integrated approach by prioritizing factors proven to significantly reduce stunting prevalence. Female education, as the most influential determinant, should be enhanced through broader access to education, improved educational quality, and strengthened health and nutrition literacy among women. In addition, improving sanitation infrastructure and promoting clean and healthy living behaviors remain essential, given the significant contribution of adequate sanitation to reducing stunting. Efforts to increase exclusive breastfeeding coverage should also continue through education campaigns and stronger support from healthcare providers. (2) Although access to safe drinking water shows a negative relationship with stunting prevalence, its effect is not statistically significant. Therefore, further evaluation is needed regarding water quality, distribution, accessibility, and utilization. Policies should focus not only on the availability of safe drinking water but also on improving environmental health practices to maximize their contribution to stunting reduction. (3) The unexpected negative relationship between inadequate food consumption and stunting prevalence suggests the possible influence of government food assistance and social protection programs. Nevertheless, improving the effectiveness, targeting accuracy, and sustainability of food security programs remains important to ensure that vulnerable households receive adequate nutritional support. (4) Since poverty significantly increases stunting prevalence, stunting reduction policies should be integrated with broader poverty alleviation strategies, including income improvement, employment creation, and expanded social protection programs. Finally, future studies are recommended to incorporate additional variables such as healthcare access and quality, parenting practices, maternal nutritional status, and regional disparities. Further research may also apply more advanced analytical approaches to distinguish short-term and long-term effects on stunting prevalence in Indonesia.

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