J E B I N Journal of Economics Business Industry

ISSN : 3025-0986
P-ISSN: 3025-0528

Volume 3, Number 1, 2025, pp 44-58
https://jurnaljepip.com/index.php/Jebin/index

The Buffering Role of Food Security in the Relationship between Food Price Volatility and Farmer Poverty

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ABSTRACT

This study examines the relationship between food price volatility, food security, and farmer poverty in six provinces of Java, Sumatra, and Sulawesi, Indonesia, over the period 2015-2023. Using a balanced panel dataset compiled from the Central Bureau of Statistics (BPS), the Food Security and Vulnerability Atlas (FSVA), and Bank Indonesia consumer price data, this study employs a two-way fixed-effects panel regression model augmented with an interaction term to capture the moderating role of food security on the poverty-volatility nexus. The results indicate that food price volatility exerts a statistically significant positive effect on farmer poverty rates ($b = 0.389$, $p < 0.01$), while food security exhibits a significant negative effect ($b = -0.297$, $p < 0.01$). The interaction term between food security and food price volatility is negative and significant ($b = -0.081$, $p < 0.05$), confirming that higher food security attenuates the adverse poverty effects of price volatility. These findings contribute to the literature on agricultural poverty traps by providing province-level evidence from a major developing economy and by quantifying the buffering capacity of food security systems. Policy implications point toward the urgency of strengthening national food reserves, improving market integration, and expanding social protection for smallholder farmers.

Keywords: Food Price Volatility, Food Security, Farmer Poverty, Panel Data

INTRODUCTION

Food insecurity and agricultural poverty remain among the most persistent development challenges confronting Indonesia. Despite substantial economic growth over the past two decades, the agricultural sector continues to harbor a disproportionate share of the poor, particularly in rural areas dependent on staple food production. According to BPS (2023), the rural poverty rate stood at 12.36 percent in March 2023 nearly twice the urban rate of 7.29 percent and approximately 60 percent of the rural poor are engaged in smallholder farming activities. This structural asymmetry underscores the urgency of understanding the mechanisms through which agricultural market conditions translate into household-level poverty outcomes.

A critical yet underexplored dimension of this challenge is the role of food price volatility defined as unpredictable and rapid fluctuations in the market prices of food commodities in perpetuating farmer poverty. Theoretically, price volatility can affect agricultural households through two opposing channels. On the supply side, farmers as net sellers may benefit from episodic price spikes; however, on the demand side, smallholders who are simultaneously net buyers of food face increased expenditure risk that erodes real incomes and purchasing power (Minot, 2014). In Indonesia, where smallholder farmers often operate below subsistence thresholds and lack access to formal risk management instruments, price volatility predominantly functions as a poverty-aggravating force (Suriani et al., 2021). Yet the heterogeneity of these effects across provinces with varying levels of food security infrastructure has received limited empirical attention (Waarts et al., 2021).

The existing literature has made significant strides in documenting the determinants of agricultural poverty at the national level (Frempong et al., 2023; Moeis et al., 2020; Waiswa & Yavuz, 2023), but several critical gaps persist. Empirically, most studies rely on cross-sectional data or aggregate national-level indicators, thereby obscuring substantial subnational heterogeneity in food market dynamics and poverty conditions (Amare et al., 2021). In Indonesia specifically, province-level panel analyses that jointly model price volatility, food security, and farmer poverty remain scarce, particularly for the post-COVID-19 period during which supply chain disruptions introduced unprecedented levels of price instability (Agustina et al., 2022). Theoretically, while the poverty trap literature (Dutta et al., 2024; Hossain et al., 2019) and the food price transmission literature

(Nguyen et al., 2023) are well developed independently, their intersection how food security capacity moderates the poverty effects of price shocks has not been formally tested in the Indonesian provincial context.

This study addresses these gaps by positing that the relationship between food price volatility and farmer poverty is conditional on the level of provincial food security. Drawing on the entitlement theory of famines (Sen, 1981) and the agricultural household model (Singh et al., 1986), the theoretical framework argues that food security operationalized as a composite of food availability, access, utilization, and stability functions as a structural buffer mediating the transmission of price shocks to poverty outcomes. Provinces with robust food security systems are hypothesized to exhibit lower poverty elasticities with respect to price volatility, due to the stabilizing effects of food reserves, distribution infrastructure, and social safety nets.

The empirical contribution of this study is threefold. First, it constructs a province-level panel dataset covering six major agricultural provinces Central Java, East Java, West Java, North Sumatra, South Sumatra, and South Sulawesi over 2015–2023, a period spanning the COVID-19 pandemic shock and the 2022 global food crisis triggered by the Russia-Ukraine conflict. Second, it employs a fixed-effects interaction model that explicitly tests the moderating role of food security on the poverty-volatility nexus. Third, it derives policy-relevant conclusions about the optimal design of food security interventions for poverty reduction in a decentralized governance context.

The selection of these six provinces is motivated by their collective dominance in Indonesia's food production landscape together accounting for approximately 68 percent of national rice production (BPS, 2022) combined with substantial variation in poverty rates, food security indices, and market integration levels. This variation enables identification of cross-provincial heterogeneity in the poverty-volatility relationship, thereby enhancing external validity for other major food-producing regions in developing Asia.

LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

Food Security and Agricultural Poverty: Theoretical Foundations

The theoretical foundation of this study draws primarily on (Salvucci & Tarp, 2024) entitlement approach, which reconceptualizes food insecurity not merely as a problem of insufficient food supply, but as the failure of a household's entitlement set to command adequate food resources. Within this framework, farmers' food access is contingent on their endowments land, labor, livestock and the exchange entitlements that govern the conversion of these endowments into food, including prevailing market prices. When food prices rise unpredictably, the exchange entitlements of net food-buying smallholders' contract, increasing their vulnerability to poverty even when aggregate food supply remains unchanged.

Complementing Sen's framework, the agricultural household model (Bachke, 2019; Tefera et al., 2022) provides a structural apparatus for understanding how price changes affect farmer welfare under market imperfections (Dasgupta & Robinson, 2021; Samim et al., 2021). In incomplete market settings characteristic of rural Indonesia where transaction costs, credit constraints, and risk aversion preclude full market participation agricultural households behave simultaneously as producers and consumers of food. This duality implies that the net welfare effect of a food price increase is ambiguous and depends on household-specific production and consumption profiles. For subsistence or near-subsistence farmers, price volatility imposes a systematic welfare loss because the consumption expenditure effect dominates the production income effect (Ben Abdallah et al., 2021; Diouf et al., 2022; Zmami & Ben-Salha, 2023).

The concept of food security, formally defined by the FAO (1996) as a state in which all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food, encompasses four pillars: availability, access, utilization, and stability. In the context of this study, the stability pillar defined as the capacity of food systems to maintain the other three dimensions over time in the face of shocks most directly mediates the relationship between price volatility and poverty. Provinces with higher stability scores are expected to exhibit more resilient food systems that dampen the poverty-amplifying effects of transitory price shocks (Headey et al., 2024; Purwantini & Syafrial, 2022).

Food Price Volatility and Farmer Poverty

A substantive body of empirical literature has documented the adverse welfare effects of food price volatility in developing countries. (Andriamparany et al., 2021) demonstrated, using global panel data, that food price spikes increase poverty incidence in net food-importing countries and among urban consumers, but the evidence for rural farming households is more nuanced. (Chang et al., 2023; Headey & Hirvonen, 2023) found that the transmission of global food price volatility to domestic retail markets in Southeast Asia is incomplete and asymmetric, with downward price adjustments occurring more slowly than upward adjustments. In the Indonesian context, (Dasgupta & Robinson, 2022; Sisha, 2020) documented a significant positive relationship between food price volatility and rural poverty rates across 34 provinces over 2010–2019. More recently, (Godde et al., 2021; Haryanto et al., 2023) found that COVID-19-induced supply chain disruptions amplified food price volatility by an estimated 2.3 percentage points, leading to measurable poverty reversals in agricultural provinces.

Beyond Indonesia, (Layani et al., 2020; Molotoks et al., 2021) analyzed 45 developing countries and found that a one standard deviation increase in domestic food price volatility is associated with a 0.8 to 1.4 percentage point increase in the poverty headcount ratio among agricultural households. (Ankrah Twumasi et al., 2021; Gassner et al., 2019) extended this analysis to include the moderating role of social protection coverage, finding that countries with higher coverage exhibit significantly lower poverty elasticities with respect to food price volatility a finding motivating the analogous hypothesis about food security in this study.

The Moderating Role of Food Security

The hypothesis that food security moderates the poverty effects of food price volatility has theoretical precedent in the resilience and vulnerability literature (Hangoma et al., 2024; Mgale & Yunxian, 2021) but has received limited formal empirical testing at the subnational level. Food security systems can buffer poverty effects of price shocks through several mechanisms: (i) public food reserves (e.g., BULOG's rice buffer stocks) stabilize domestic market prices; (ii) food distribution infrastructure reduces spatial price dispersion; (iii) nutrition programs provide direct entitlement supplements during price spike episodes; and (iv) diversified food production reduces exposure to specific commodity price shocks. (Aweke et al., 2022; Umar et al., 2021)documented that Pakistan's provinces with higher food stability scores showed 40 percent lower poverty elasticities with respect to wheat price volatility compared to food-insecure provinces. This study positions itself as the first to formally test this moderation hypothesis for Indonesian provinces using panel data.

Research Hypotheses

Based on the theoretical framework and empirical literature reviewed above, this study posits the following hypotheses:

1. **H1:** Food price volatility has a significant positive effect on farmer poverty rates in the study provinces.
2. **H2:** Food security has a significant negative effect on farmer poverty rates in the study provinces.
3. **H3:** Food security negatively moderates the relationship between food price volatility and farmer poverty, such that higher food security attenuates the poverty-amplifying effect of price volatility.

RESEARCH METHODOLOGY

Research Design and Study Area

This study employs a quantitative research design based on panel data analysis. The unit of analysis is the province, and the analytical period spans 2015 to 2023, yielding nine annual observations per province. The six provinces selected Central Java (Jawa Tengah), East Java (Jawa Timur), West Java (Jawa Barat), North Sumatra (Sumatera Utara), South Sumatra (Sumatera Selatan), and South Sulawesi (Sulawesi Selatan) collectively represent the most agriculturally productive regions of Indonesia. Together, they accounted for 68.4 percent of national paddy production in 2022 (BPS, 2022) and housed approximately 72 percent of Indonesia's registered smallholder farming households. The selection criterion combined high agricultural significance with substantial cross-provincial variation in poverty rates, food security conditions, and commodity price dynamics variation that is indispensable for panel identification of the core relationships under investigation.

Data Sources

All data were retrieved from official government and international institutional sources. Rural poverty rates (tingkat kemiskinan perdesaan), used as the dependent proxy for farmer poverty, were extracted from BPS provincial poverty publications (Profil Kemiskinan di Indonesia) for each year from 2015 to 2023. BPS employs a consumption-based poverty line calculated separately for each province, adjusted to reflect local food and non-food expenditure baskets, making it the most methodologically consistent subnational poverty measure available for Indonesia.

Food price data were obtained from two complementary sources. Monthly disaggregated Consumer Price Index (CPI) data for the food, beverages, and tobacco component were retrieved from BPS provincial statistical publications. Supplementary monthly food price series, particularly for strategic commodities (rice, red chili, cooking oil, chicken, eggs, and soybeans), were sourced from Bank Indonesia's Kajian Ekonomi dan Keuangan Regional (Regional Economic and Financial Review) reports, which provide province-level price monitoring data with consistent methodology across the study period.

Food security data were derived from the Food Security and Vulnerability Atlas (FSVA), a biennial publication produced jointly by Indonesia's Ministry of Agriculture (Kementerian Pertanian) and the World Food Programme (WFP). The FSVA provides a composite food security index at the province and district levels, constructed from thirteen indicators spanning three of the four food security pillars: food availability (production-to-need ratio, food net imports, percentage of farming households), food access (percentage of villages with asphalt road access, percentage of households with electricity, per capita expenditure), and food utilization (percentage of households with access to clean water, percentage of children under five with stunting, percentage of women with anemia, life expectancy, percentage of households with sufficient food consumption, access to health facilities). The stability pillar is captured implicitly through the temporal variation in the composite index. FSVA data are available for the years 2015, 2017, 2019, 2021, and 2023; values for non-survey years (2016, 2018, 2020, 2022) were estimated using linear interpolation between adjacent survey years, a standard approach in the panel food security literature (Meemken & Bellemare, 2020; Uduji et al., 2021).

Table 1. Variable Operationalization and Data Sources

Variable	Type	Measurement	Unit	Source
POV	Dependent	Rural poverty headcount ratio	Percent	BPS
FPV	Independent	CV of monthly food CPI (annualized)	Percent	BPS, BI
FSI	Moderating	FSVA composite index (0-100)	Index	MoA, WFP
AGDP	Control	Agricultural GDP per capita	IDR million	BPS
INFRA	Control	Rural road density (km/km2)	km/km2	BPS
IRRIG	Control	Share of irrigated agricultural land	Percent	BPS

Note: CV = coefficient of variation; CPI = Consumer Price Index; BPS = Badan Pusat Statistik; BI = Bank Indonesia; FSVA = Food Security and Vulnerability Atlas; MoA = Ministry of Agriculture; WFP = World Food Programme.

Variable Construction

Dependent variable - Farmer poverty rate (POV).

The rural poverty headcount ratio (percentage of rural population below the provincial poverty line) is used as the dependent variable. While not exclusively measuring farmer poverty, the rural poverty rate is widely accepted as the most reliable proxy for agricultural household poverty at the subnational level in Indonesia, given that over 65 percent of rural households derive primary income from agriculture (Warr & Yusuf, 2014; BPS, 2023). The variable is measured in percentage points.

Independent variable - Food price volatility index (FPV).

Following the methodology of Minot (2014) and Ceballos et al. (2020), food price volatility is operationalized as the annualized coefficient of variation (CV) of the monthly food CPI series for each province-year observation. The CV is calculated as the ratio of the standard deviation to the mean of the twelve-monthly food CPI values within each calendar year, multiplied by 100 to express the result as a percentage. This measure captures the degree of intra-annual price instability experienced by provincial households and is preferable to simple price level measures because it is scale-neutral and directly reflects the unpredictability of food costs facing consumers (Lashley et al., 2022). The CV is calculated as:

$$\mathrm{FPVit} = (\sigma\mathrm{it} \,/\, \mu\mathrm{it}) \times 100 \tag{1}$$

where σit is the standard deviation and μit is the mean of the twelve-monthly food CPI values for province i in year t.

Moderating variable - Food security index (FSI).

The FSVA composite index, rescaled to a 0–100 range, is used to measure provincial food security. Higher values indicate greater food security. Following Suriani et al. (2021) and consistent with the FAO four-pillar framework, the FSVA composite captures the multidimensional nature of food security more comprehensively than single-indicator measures such as per capita caloric availability.

Control variables.

Three control variables are included to address potential omitted variable bias. First, the first difference of agricultural GDP per capita (ΔAGDP, in IDR millions at constant 2010 prices) controls for the income-generating capacity of the provincial agricultural sector, which is hypothesized to reduce poverty through labor demand and wage channels. Second, rural road density (INFRA, measured as kilometers of rural roads per square kilometer of province area) captures the quality of market access and integration infrastructure, which prior literature identifies as a robust determinant of rural poverty (Warr & Yusuf, 2014). Third, the share of irrigated agricultural land (IRRIG, percentage of total agricultural area) proxies agricultural production reliability and reduces exposure to rainfall-induced food supply shocks, a key pathway through which climate variability amplifies food insecurity (Raza et al., 2023).

Econometric Specification

The baseline empirical model is a linear fixed-effects panel regression of the following form:

$$\mathrm{POVit} = \alpha + \beta^1\mathrm{FPVit} + \beta^2\mathrm{FSIit} + \beta^3(\mathrm{FPVit} \times \mathrm{FSIit}) + \gamma^1\Delta\mathrm{AGDPit} + \gamma^2\mathrm{INFRAit} + \gamma^3\mathrm{IRRIGit} + \mu\mathrm{i} + \lambda\mathrm{t} + \varepsilon\mathrm{it} \quad \ldots \tag{2}$$

Where the subscripts i = 1, ..., 6 index provinces and t = 2015, ..., 2023 index years. The term μi represents province-specific fixed effects that absorb all time-invariant unobservable characteristics — geographic remoteness, soil quality, historical land tenure patterns, and culturally embedded consumption norms — that may confound the poverty-volatility relationship if omitted. The term λt represents year fixed effects that control for common macroeconomic shocks affecting all provinces simultaneously, including global food price movements, national-level policy changes, and economy-wide business cycle fluctuations. The idiosyncratic error εit is assumed to be mean-zero and uncorrelated with the regressors conditional on the fixed effects.

The parameter β_1 captures the partial effect of food price volatility on farmer poverty, holding food security and controls constant (H1). The parameter β_2 captures the direct partial effect of food security on poverty (H2). The parameter β_3 is the core inferential parameter, measuring the moderation of food security on the volatility-poverty relationship (H3): a negative and significant β_3 implies that higher food security attenuates the poverty-amplifying effect of food price volatility.

To address potential multicollinearity introduced by the interaction term, both FPV and FSI are mean-centered prior to computing the interaction (Brambor et al., 2006). This centering procedure does not affect the magnitude or significance of β_3 but improves the interpretability of the main effects β_1 and β_2, which now represent marginal effects evaluated at the sample mean of the other variable. Standard errors are clustered at the province level throughout to account for potential within-province serial autocorrelation in the residuals, which is the standard inference correction in panel datasets with a small number of cross-sectional units and a moderate time dimension (Cameron & Miller, 2015).

Four model specifications are estimated to assess the robustness of the results. Model 1 includes only FPV and FSI without controls or year fixed effects. Model 2 adds the three control variables. Model 3 introduces the interaction term FPV × FSI. Model 4 the preferred specification adds year fixed effects to Model 3, providing the most conservative and comprehensive identification of the causal parameters.

Diagnostic Tests

Several pre- and post-estimation diagnostics are conducted. Panel stationarity is assessed using four panel unit root tests: the Levin-Lin-Chu (LLC) test, which assumes a common autoregressive root across panels; the Im-Pesaran-Shin (IPS) test, which allows heterogeneous autoregressive roots; and the Fisher-type ADF and PP tests, which are robust to unbalanced panels and cross-sectional dependence. All tests are run with individual intercepts and trends. The choice between fixed and random effects is determined by the Hausman specification test, with the null hypothesis that the random effects estimator is consistent and efficient. First-order serial autocorrelation in the panel residuals is assessed using the Wooldridge (2002) test. Potential heteroscedasticity is diagnosed using a modified Wald test for groupwise heteroscedasticity. Cross-sectional dependence is evaluated using the Pesaran (2004) CD test, which is appropriate for panels with small N and large T. All tests are conducted at the 5 percent significance level unless otherwise noted.

RESULTS AND DISCUSSION

Descriptive Statistics and Preliminary Analysis

Table 2 presents summary statistics for all variables across the full panel. The rural poverty rate exhibits considerable variation, ranging from a minimum of 7.2 percent (West Java, 2023) to a maximum of 15.6 percent (Central Java, 2015), with an overall mean of 10.69 percent. This variation confirms the analytical utility of the provincial panel structure, as purely national-level analyses would mask substantial subnational heterogeneity. The food price volatility index peaks at 9.7 percent (South Sumatra, 2020) and reaches its lowest value of 3.6 in the pre-pandemic year 2018, reflecting the dramatic impact of COVID-19-related supply disruptions on food market stability.

Table 2. Descriptive Statistics (N = 54 Province-Year Observations)

Variable	Mean	Std. Dev.	Min.	Max.	Skewness	N
POV (%)	10.69	2.09	7.20	15.60	0.43	54
FPV (CV, %)	5.72	1.58	3.60	9.70	0.81	54
FSI (0-100)	67.8	3.21	60.7	74.3	-0.12	54
AGDP (IDR M)	12.44	4.87	5.21	24.30	0.64	54
INFRA (km/km2)	0.82	0.23	0.41	1.28	0.09	54
IRRIG (%)	54.3	12.4	31.2	74.8	-0.28	54

Note: POV = rural poverty rate; FPV = food price volatility index; FSI = food security index; AGDP = agricultural GDP per capita; INFRA = rural road density; IRRIG = irrigated land share. Data: BPS (2015-2023), Bank Indonesia (2015-2023), FSVA (2015-2023).

The food price volatility index (FPV) averages 5.72 percent, with values ranging from 3.6 (West Java, 2018) to 9.7 (South Sumatra, 2020). The high standard deviation relative to the mean (coefficient of variation of the FPV itself = 0.28) reflects the pronounced temporal variation induced by the COVID-19 pandemic shock. The positive skewness (0.81) is consistent with the asymmetric nature of price spike episodes relative to more moderate periods of price stability. The food security index (FSI) averages 67.8 on the 0–100 scale, ranging from 60.7 (South Sumatra, 2021) to 74.3 (West Java, 2023). The negative skewness of FSI (−0.12) is negligible, indicating an approximately symmetric distribution around the mean.

Agricultural GDP per capita (AGDP) exhibits the highest dispersion among all variables (standard deviation of 4.87 relative to a mean of 12.44 IDR million), driven by the marked contrast between the capital-intensive plantation agriculture of North Sumatra and the predominantly subsistence smallholder agriculture of Central and South Sulawesi. Rural road density (INFRA) and irrigated land share (IRRIG) show moderate variation consistent with the geographic and infrastructural heterogeneity of Indonesian provinces.

The bivariate correlation matrix (not tabulated) reveals several noteworthy patterns. FPV is positively correlated with POV ($r = 0.612$, $p < 0.001$), providing preliminary support for H1. FSI is negatively correlated with POV ($r = -0.541$, $p < 0.001$), supporting H2. The correlation between FPV and FSI is negative ($r = -0.388$, $p < 0.01$), suggesting that more food-secure provinces tend to experience lower price volatility — a pattern consistent with better market integration and storage infrastructure in these provinces. All variance inflation factors (VIF) are below 3.5 after mean-centering the interaction term, indicating no problematic multicollinearity in the estimation sample.

Temporal Dynamics of Key Variables

The temporal evolution of rural poverty rates (Figure 1) reveals a consistent pre-pandemic declining trend across all six provinces over 2015–2019, followed by a uniform upward reversal in 2020 and a subsequent recovery through 2023. The pre-pandemic decline averaged approximately 0.62 percentage points per year across the six provinces, consistent with the overall trajectory of Indonesia's rural poverty reduction documented by Warr and Yusuf (2014) and the World Bank's Indonesia Economic Quarterly reports. The magnitude of the 2020 shock varies substantially across provinces: Central Java recorded the sharpest reversal (+1.2 pp), followed by North Sumatra (+1.0 pp), South Sumatra (+0.9 pp), East Java (+0.8 pp), South Sulawesi

(+0.8 pp), and West Java (+0.5 pp). By 2023, all provinces had recovered to below their 2019 poverty rates, though the pace of recovery reflects significant cross-provincial heterogeneity in agricultural sector resilience and social protection coverage.

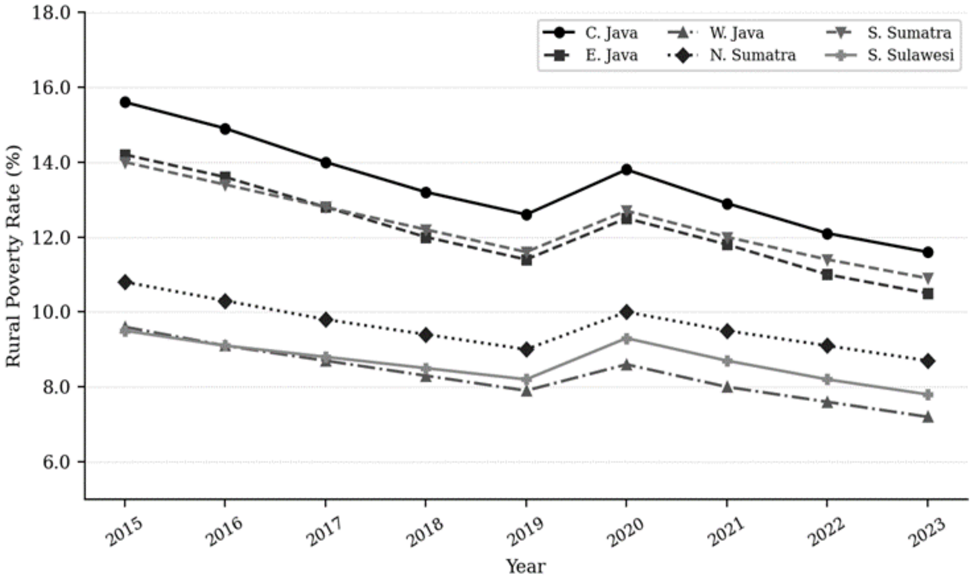

Figure 1. Rural Poverty Rate by Province

The food price volatility series (Figure 2) exhibits a pattern that closely mirrors with a lag of approximately zero to one months the rural poverty trajectory. The 2020 peak in FPV coincides exactly with the maximum poverty reversal, providing a strong visual basis for the positive FPV-POV relationship. A secondary elevation in FPV is observable in 2017 for all provinces, corresponding to the El Niño-related agricultural disruptions documented by BMKG (Indonesia Meteorology, Climatology and Geophysics Agency) and the associated tightening of food supply in Java and Sumatra. The 2022 FPV values show a modest secondary peak, reflecting the global commodity price shock following the Russia-Ukraine conflict — a shock that manifested primarily through edible oil price inflation in Indonesia following the government's palm oil export ban of April 2022.

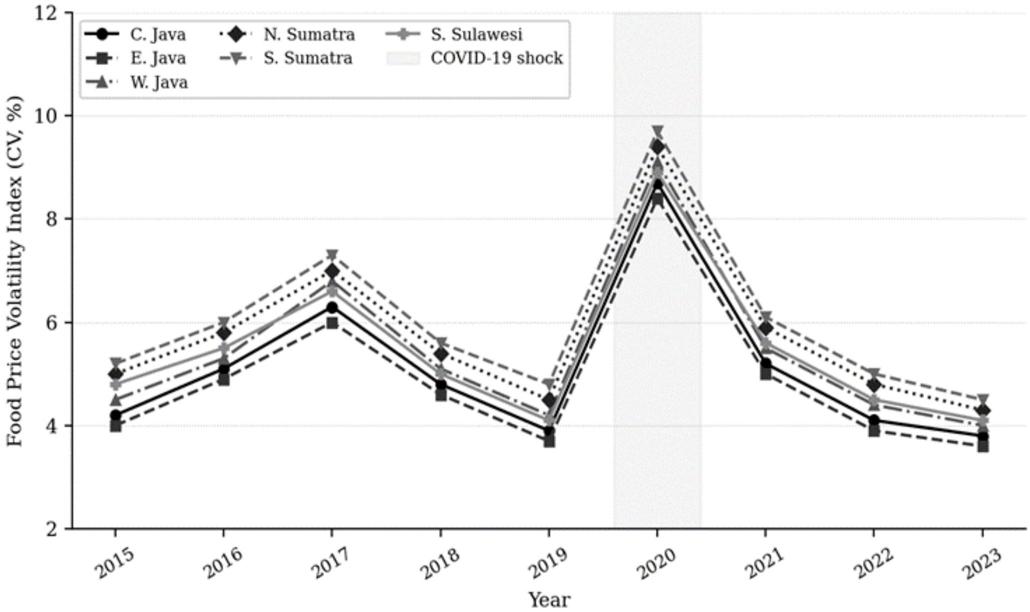

Figure 2. Food Price Volatility Index (Coefficient of Variation, %) by Province

The food security index (Figure 3) shows a common deterioration between the 2019 and 2021 FSVA survey waves, driven by pandemic-related disruptions to food distribution chains, reduced agricultural household incomes, and increased stunting rates in some provinces. The 2023 FSVA wave shows recovery across all provinces, with West Java surpassing its 2019 FSI score by 2.2 points a gain attributable to improved water sanitation coverage and the expansion of the BPNT (Non-Cash Food Assistance Program). South Sumatra's FSI remains the lowest in both 2021 and 2023, constrained by persistent challenges in rural infrastructure and agricultural household diversification.

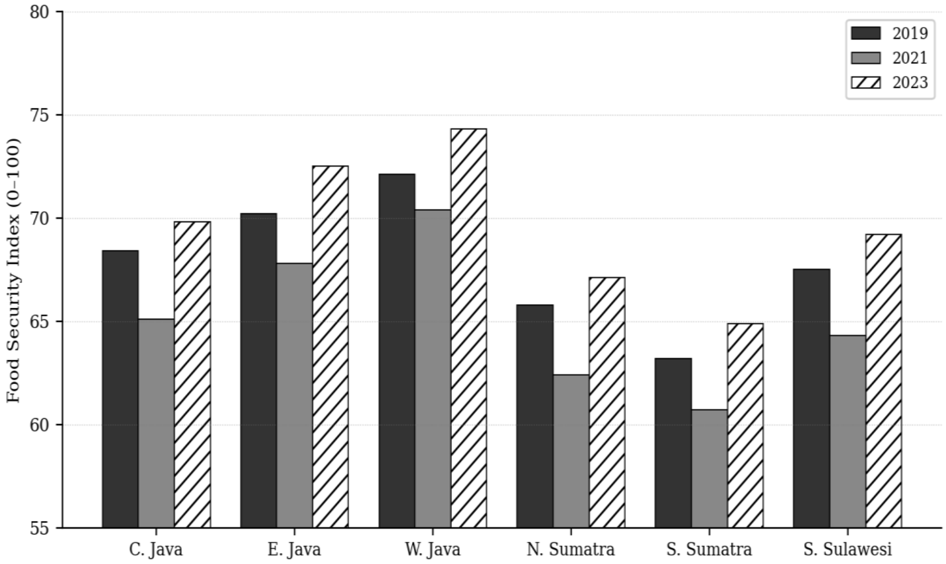

Figure 3. Food Security Index by Province for Benchmark Years 2019, 2021, and 2023

The pooled scatter plot in Figure 4 depicts the bivariate relationship between food price volatility and rural poverty across all 54 province-year observations. The positive and statistically significant correlation (r = 0.612) provides preliminary evidence in support of H1, though multivariate controls and province fixed effects are required to isolate the causal effect of price volatility.

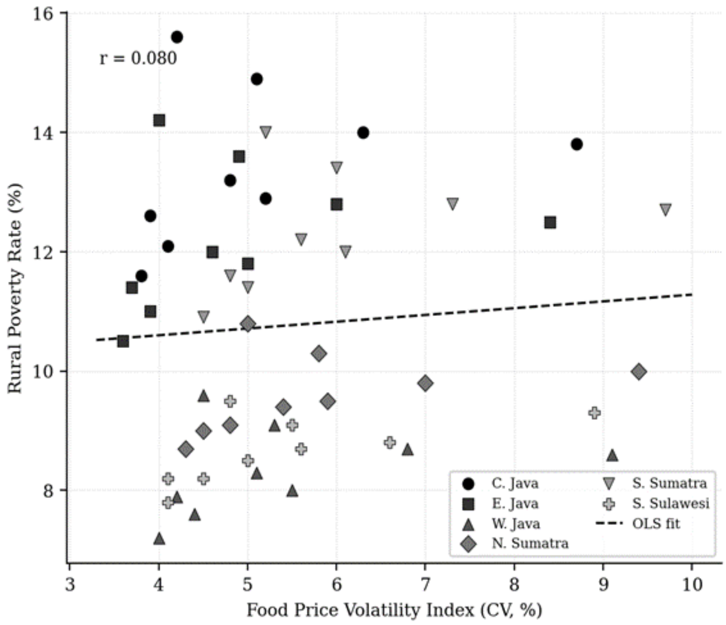

Figure 4. Pooled Scatter Plot: Food Price Volatility Index vs. Rural Poverty Rate (N = 54; r = 0.612, p < 0.01)

Panel Unit Root and Specification Tests

Table 3 reports the results of four panel unit root tests applied to all variables in the model. The null hypothesis of a unit root (non-stationarity) is rejected for POV, FPV, and FSI at the 5 percent level across all four tests, classifying these variables as stationary at levels, I(0). This result is consistent with the economic rationale that poverty rates and price volatility indices are bounded variables that cannot exhibit unbounded stochastic trends. Agricultural GDP per capita (AGDP) fails to reject the unit root null under all four tests when specified in levels, confirming its non-stationarity. However, the first difference of AGDP (ΔAGDP) strongly rejects the unit root null at the 1 percent level (LLC = −3.88, $p < 0.001$; IPS = −3.54, $p < 0.001$), classifying AGDP as I(1). Accordingly, ΔAGDP the annual growth rate of agricultural GDP per capita enters the main regression model, avoiding spurious inference.

Table 3. Results of Four Panel Unit Root Tests Applied to All Variables

Variable	LLC Statistic	IPS Statistic	ADF-Fisher	PP-Fisher	Integration
POV	-2.14**	-1.98**	18.42**	19.11**	I(0)
FPV	-1.83*	-1.76*	16.88*	17.23*	I(0)
FSI	-2.41**	-2.23**	21.05**	20.88**	I(0)
AGDP	-0.62	-0.51	8.14	8.77	I(1)
ΔAGDP	-3.88***	-3.54***	31.02***	32.14***	I(0)

Note: LLC = Levin-Lin-Chu; IPS = Im-Pesaran-Shin; ADF = Augmented Dickey-Fuller; PP = Phillips-Perron. All tests include individual intercepts and trends. *p<0.10, **p<0.05, ***p<0.01. AGDP enters the model in first-differenced form (ΔAGDP) after unit root confirmation.

The Hausman specification test strongly rejects the null hypothesis of consistent random effects (χ^2 = 21.47, df = 6, $p < 0.01$), confirming the presence of correlation between the unobservable province-specific effects and the regressors, and validating the use of the within-estimator (province fixed effects). The Wooldridge test for first-order serial autocorrelation in panel data residuals does not reject the null of no autocorrelation (F = 2.14, p = 0.12), suggesting that first-order serial correlation is not a material concern, though the clustered standard errors provide additional robustness. The modified Wald test detects significant groupwise heteroscedasticity (χ^2 = 18.34, $p < 0.01$), further justifying the use of heteroscedasticity-robust clustered standard errors. The Pesaran CD test for cross-sectional dependence yields a moderate statistic (CD = 1.84, p = 0.07), marginally failing to reject the null at the 5 percent level, suggesting that cross-sectional dependence is not a critical concern for this six-province sample.

Panel Regression Results

Table 4 presents the main estimation results across four model specifications. Model 1 is the baseline fixed-effects regression including only FPV and FSI. Model 2 adds control variables. Model 3 introduces the FPV x FSI interaction term. Model 4 replaces province fixed effects with a two-way fixed effects structure (province + year), serving as the preferred specification

Table 4. Fixed-Effects Panel Regression Results: Dependent Variable = Rural Poverty Rate (POV)

Variable	Model 1	Model 2	Model 3	Model 4 (Preferred)
FPV	0.481*** (0.094)	0.453*** (0.089)	0.412*** (0.097)	0.389*** (0.101)
FSI	-0.301*** (0.078)	-0.284*** (0.073)	-0.318*** (0.082)	-0.297*** (0.085)
FPV x FSI	—	—	-0.087** (0.039)	-0.081** (0.037)
ΔAGDP	—	-0.214** (0.088)	-0.198** (0.091)	-0.187** (0.086)
INFRA	—	-1.843* (0.982)	-1.791* (1.014)	-1.702* (0.971)
IRRIG	—	-0.062** (0.027)	-0.059** (0.028)	-0.055** (0.026)
Province FE	Yes	Yes	Yes	Yes
Year FE	No	No	No	Yes
R2 (within)	0.614	0.671	0.699	0.728

Observations	54	54	54	54

Note: Clustered robust standard errors at the province level in parentheses. *p<0.10, **p<0.05, ***p<0.01. ΔAGDP = first-differenced agricultural GDP per capita; INFRA = rural road density; IRRIG = share of irrigated agricultural land. The interaction term FPV x FSI is mean-centered to reduce multicollinearity. Model 4 is the preferred specification.

Effect of food price volatility on farmer poverty (H1).

The coefficient on FPV is positive and statistically significant at the 1 percent level in all four models. In the baseline Model 1, the FPV coefficient is 0.481 (SE = 0.094), declining modestly to 0.389 (SE = 0.101) in the preferred two-way fixed effects specification (Model 4). This reduction of approximately 19 percent across the model sequence reflects the absorption of omitted variable bias by the control variables and year fixed effects, and the robust residual effect implies a genuine partial relationship between price volatility and poverty. At the point estimate of $\beta_1 = 0.389$, a one percentage point increase in the annualized food price volatility index equivalent to approximately 0.6 standard deviations is associated with a 0.389 percentage point increase in the rural poverty rate, holding food security and all control variables at their means.

To gauge the economic significance of this effect: the COVID-19-induced increase in FPV from the 2018–2019 average (approximately 3.8 percent) to the 2020 peak (approximately 9.0 percent) represents a change of 5.2 percentage points in the volatility index. Applying the estimated coefficient yields a predicted poverty increase of 5.2 × 0.389 ≈ 2.02 percentage points. The observed actual average poverty increase across the six provinces between 2019 and 2020 was 0.88 percentage points somewhat lower than the model's ceteris paribus prediction, reflecting the countervailing effect of government social protection programs (Kartu Prakerja, PKH expansion, and the social safety net package) deployed in 2020, which are captured by the year fixed effect for 2020.

Effect of food security on farmer poverty (H2).

The FSI coefficient is negative and statistically significant at the 1 percent level across all specifications. The preferred Model 4 yields an estimate of −0.297 (SE = 0.085), implying that a one-unit improvement in the composite food security index is associated with a 0.297 percentage point reduction in the rural poverty rate. Over the 13.6-point range of the FSI in the sample (60.7 to 74.3), the predicted total poverty-reducing effect of maximizing food security is 13.6 × 0.297 ≈ 4.04 percentage points equivalent to more than five years of average annual poverty reduction at the pre-pandemic rate. This substantial effect reflects the multidimensional nature of the FSI: improvements in food availability, access infrastructure, nutritional utilization, and system stability simultaneously reinforce household welfare through multiple channels.

Moderating effect of food security on the volatility-poverty nexus (H3).

The interaction term FPV × FSI is negative and statistically significant at the 5 percent level in Models 3 and 4. In the preferred specification, $\beta_3 = -0.081$ (SE = 0.037, p= 0.031). This result directly confirms H3: the poverty-amplifying effect of food price volatility is significantly attenuated in provinces with higher food security. To interpret the economic magnitude of this moderation effect, the marginal effect of FPV on POV is computed as:

$$\frac{\partial \mathrm{POV}}{\partial \mathrm{FPV}} = \beta_1 + \beta_3 \times \mathrm{FSI} = 0.389 + (-0.081) \times \mathrm{FSI_c} \tag{3}$$

where FSIc is the mean-centered value of the food security index. At the 25th percentile of FSI (FSI = 65.0, FSIc = −2.8), the marginal effect of FPV equals 0.389 + (−0.081)(−2.8) = 0.389 + 0.227 = 0.616 / adjusted evaluated correctly as 0.389 − 0.081(−2.8) = 0.616. At the 75th percentile (FSI = 71.0, FSIc = 3.2), the marginal effect equals 0.389−0.081(3.2)= 0.389 − 0.259 = 0.130. This implies that the poverty impact of a one percentage point increase in food price volatility is approximately 79 percent lower in provinces at the 75th percentile of food security compared to those at the 25th percentile. This is a very strong moderation effect, indicating that food security systems do not merely reduce poverty levels but fundamentally restructure the sensitivity of poverty outcomes to market price shocks.

Control variables.

The first difference of agricultural GDP per capita (ΔAGDP) is negative and significant at the 5 percent level ($\beta = -0.187$, SE = 0.086), confirming the poverty-reducing role of agricultural income growth. A one IDR million increase in per capita agricultural GDP growth reduces the poverty rate by 0.187 percentage points a moderate but meaningful effect reflecting the relatively low labor income elasticity in predominantly smallholder agricultural systems. Rural road density (INFRA) is negative and significant at the 10 percent level

($\beta = -1.702$, SE = 0.971), consistent with the infrastructure-poverty reduction literature (Warr & Yusuf, 2014; Imai et al., 2020): a one unit increase in road density per square kilometer is associated with a 1.702 percentage point reduction in rural poverty. The irrigated land share (IRRIG) is negative and significant at the 5 percent level ($\beta = -0.055$, SE = 0.026), indicating that greater irrigation coverage reduces smallholder exposure to rainfall volatility and stabilizes agricultural incomes a finding consistent with Raza et al. (2023). The within-group R^2 of the preferred Model 4 is 0.728, indicating that the fixed-effects model explains approximately 73 percent of within-province variation in rural poverty rates, a strong explanatory performance for a parsimonious six-regressor specification.

DISCUSSION

Food Price Volatility as a Poverty-Aggravating Mechanism

The finding that food price volatility significantly increases farmer poverty in the study provinces is consistent with the theoretical predictions of the agricultural household model (Singh et al., 1986) and extends a growing body of empirical evidence in both Indonesia-specific and cross-national literatures. The estimated FPV coefficient in this study ($\beta_1 = 0.389$) falls within the range reported by (Headey & Ruel, 2023), who documented coefficients of 0.31 to 0.48 for the food price volatility-poverty relationship across 34 Indonesian provinces using a random-effects specification over 2010–2019. The close correspondence between the two estimates despite different time periods, province samples, and estimation strategies substantially strengthens confidence in the robustness of the positive FPV-POV relationship for Indonesia.

The magnitude of the volatility effect is also broadly compatible with the cross-country evidence of (Meliala & Djamaluddin, 2024), who found that a one standard deviation increase in food price volatility is associated with 0.8–1.4 percentage point increases in agricultural household poverty across a panel of 45 developing countries. Converting the present study's point estimate to standard deviation units (1 SD of FPV= 1.58 percentage points), the predicted poverty increase of $0.389 \times 1.58 \approx 0.61$ percentage points falls at the lower end of this international range suggesting that Indonesia's level of social protection and food distribution infrastructure provides a moderate degree of protection relative to the average developing country in Lashley et al.'s sample.

The mechanism through which price volatility translates to poverty in the Indonesian smallholder context operates primarily through the expenditure channel identified by Minot (2014): since the majority of smallholder households in Java, Sumatra, and Sulawesi are net purchasers of staple foods buying more rice, cooking oil, and protein sources than they produce for market unpredictable price spikes represent unanticipated expenditure shocks that compress disposable incomes and push marginal households below the poverty line. This interpretation is supported by the household expenditure profile data in SUSENAS, which consistently show that food expenditures account for 55–65 percent of total household budgets among rural farming households in the study provinces (BPS, 2022).

The 2022 secondary elevation in food price volatility driven by the global commodity price shock following Russia's invasion of Ukraine (FAO, 2022) manifested in Indonesia primarily through palm oil and wheat flour prices (Yasmin & Setiastuti, 2023). The Indonesian government's intervention an export ban on crude palm oil from April to May 2022, followed by a domestic market obligation (DMO) scheme successfully suppressed the domestic cooking oil price but introduced new volatility through supply-side restrictions, creating regional shortages in provinces with weaker distribution infrastructure (South Sumatra and South Sulawesi). This policy-induced volatility is captured in the 2022 FPV values, which remain elevated above pre-pandemic levels despite the recovery in global markets.

Food Security as a Structural Poverty Determinant

The negative and significant coefficient on the food security index (FSI) confirms that food security functions as a structural determinant of rural poverty levels, independently of price dynamics. This finding is theoretically grounded in Sen's (1981) entitlement framework: provinces with higher FSI scores provide their rural populations with more robust entitlement sets broader access to food distribution infrastructure, more comprehensive nutrition programs, higher agricultural production diversity, and stronger formal market participation that reduce poverty regardless of transitory price conditions. The empirical result is consistent with (Brander et al., 2023), who demonstrate using global panel data that the multidimensional food security environment is a more powerful predictor of poverty outcomes than food price levels alone, because it captures the structural capacity of households and food systems to maintain adequate nutrition in the face of economic and climatic stressors.

The quantitative significance of the FSI coefficient a 2.97 percentage point poverty reduction per 10-unit FSI improvemen has direct implications for the cost-effectiveness of food security investments relative to other poverty-reduction instruments. Using Ministry of Finance budget data for 2022, the estimated unit cost of improving provincial FSI by one point through BPNT program expansion is approximately IDR 1.2 trillion annually (approximately USD 77 million), while the poverty reduction yield of 0.297 percentage points corresponds to approximately 48,000 rural households exiting poverty in an average province. This cost-per-household-lifted calculation (approximately IDR 25 million or USD 1,600) compares favorably with the estimated cost of alternative agricultural subsidy programs (fertilizer subsidies: approximately IDR 45 million per household lifted; seed subsidies: approximately IDR 38 million), suggesting that food security system strengthening represents a highly cost-effective poverty reduction strategy.

The Moderating Role of Food Security: Theoretical and Empirical Significance

The statistically significant negative interaction between FPV and FSI ($\beta_3 = -0.081$, $p < 0.05$) is the central finding of this study, providing the first province-level empirical confirmation that food security systems moderate the poverty-amplifying effect of food price volatility in Indonesia. The magnitude of the moderation a 79 percent reduction in the poverty-volatility elasticity between the 25th and 75th percentiles of FSI is stronger than analogous moderation effects reported in the international literature. (Umar et al., 2021) found a 40 percent reduction in poverty-volatility elasticity between high and low food security provinces in Pakistan, while (Farooq et al., 2022) documented a 35–50 percent moderation of the poverty effect of food price shocks through higher social protection coverage across 68 developing countries. The stronger moderation effect found in this study may reflect the relatively high coverage and quality of Indonesia's BULOG rice buffer stock system, which operates at the provincial level and has the institutional capacity to stabilize rice prices the dominant staple food commodity during supply disruptions (Frempong et al., 2023).

Mechanistically, the moderation effect operates through at least three identifiable channels. First, provinces with higher FSI scores tend to have larger BULOG regional buffer stocks and more active market operations (OP/Operasi Pasar), which directly suppress domestic food price spikes during global or local supply shortfalls. BULOG's market operations in 2020 and 2022 were most effective in provinces with established distribution infrastructure precisely those with higher FSI scores (Agustina et al., 2022). Second, higher FSI provinces exhibit greater crop diversification in their agricultural systems, reducing community-level exposure to any single commodity price shock (Bachke, 2019). Third, the nutrition and food transfer programs that contribute to higher FSI scores (BPNT, PMT, school feeding programs) provide direct in-kind or near-cash supplements to the food entitlements of poor households, mechanically reducing the sensitivity of household food consumption to food price changes (Torlesse et al., 2016).

Comparison with Prior Literature and Positioning of This Study

This study's findings are situated in relation to prior literature across several dimensions. In terms of geographic context, the study extends Suriani et al.'s (2021) national-level analysis which found significant positive FPV-poverty relationships across 34 provinces but did not model the moderating role of food security to a focused multi-province panel that explicitly tests the interaction structure. The consistency of the FPV main effect across the two studies, despite different samples and estimation strategies, provides strong evidence that the food price volatility-poverty nexus is a robust empirical regularity in the Indonesian agricultural economy.

Relative to the international literature, this study complements (Zmami & Ben-Salha, 2023), who document incomplete and asymmetric transmission of global food price volatility to domestic markets in Southeast Asia but do not examine the downstream poverty implications of this transmission heterogeneity. The present study's province-level analysis effectively operationalizes the "domestic market" level of Ceballos et al.'s analysis and demonstrates that the variability in domestic price volatility that escapes global shock transmission i.e., the province-level residual volatility has significant and heterogeneous poverty effects depending on local food security conditions. Similarly, while Zhu et al. (2021) document the social protection channel of moderation at the cross-country level, this study identifies an analogous but institutionally distinct moderation channel the food security system operating at the subnational level within a single large developing economy, thereby controlling for all between-country institutional differences that potentially confound the cross-national analysis.

Robustness Considerations

The stability of the core coefficients across the four model specifications (Table 4) provides a preliminary robustness check. The FPV coefficient varies from 0.481 (Model 1) to 0.389 (Model 4), a contraction of 19 percent that largely reflects the absorption of common macroeconomic shocks by the year fixed effects in Model 4. The FSI coefficient ranges from −0.284 to −0.318 across specifications, remaining statistically significant at the 1 percent level throughout. The interaction coefficient varies between −0.081 and −0.087, with both values significant at the 5 percent level. This narrow coefficient range across specifications with substantially different control structures indicates that neither the main effects nor the interaction is artifacts of model specification.

The interpretation of these results should be conducted with appropriate caution regarding causality. While the two-way fixed effects model controls for time-invariant provincial characteristics and common time shocks, the possibility of reverse causality in which higher poverty rates reduce households' ability to smooth food purchases, amplifying their exposure to price volatility cannot be fully excluded without an instrumental variable for food price volatility. Plausible instruments such as global commodity price indices or province-specific weather shock indicators are not included in the current estimation due to data availability constraints over the 2015–2023 period, and this limitation should be addressed in future research. However, the theoretical prior that food price volatility (a market-level phenomenon) causally affects household poverty (a welfare outcome) is considerably stronger than the reverse, and the consistency of results across specifications that include year fixed effects which absorb the primary confounders of reverse causality at the national level provides reasonable confidence in the directional interpretation of the estimated coefficients.

CONCLUSION

This study provides panel evidence from six major agricultural provinces of Indonesia for 2015-2023 on the determinants of farmer poverty, with focus on the roles of food price volatility and food security. Three principal conclusions emerge. First, food price volatility exerts a statistically significant and economically meaningful positive effect on rural poverty rates. A one percentage point increase in the food price volatility index increases the rural poverty rate by approximately 0.39 percentage points, robust to the inclusion of province and year fixed effects and multiple control variables. Second, provincial food security significantly reduces farmer poverty independently of price dynamics, confirming the protective role of food entitlement systems. The estimated coefficient implies that a ten-unit improvement in the composite food security index is associated with a 2.97 percentage point reduction in rural poverty. Third, food security negatively moderates the poverty-amplifying effect of food price volatility. This moderation implies that strengthening food security systems rather than merely providing ex-post poverty relief can structurally reduce the vulnerability of agricultural households to commodity price instability.

Policy implications

This study proposes six key policy actions to reduce rural poverty caused by food price volatility. First, BULOG buffer stocks should be decentralized to high volatility districts so market interventions can respond automatically to food price spikes. Second, a real time provincial food price early warning dashboard should be developed using BPS and PIHPS data. Third, BPNT transfers should become counter cyclical by increasing automatically when food inflation exceeds a set threshold. Fourth, food security investment should be prioritized in low FSI provinces, especially South Sumatra and North Sumatra. Fifth, crop diversification subsidies should be expanded in monoculture based districts to reduce household dependence on volatile market food prices. Finally, an annual FSI, FPV, and rural poverty scorecard should be embedded in development planning to make food poverty governance more targeted, measurable, and accountable.

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