Univariate vs. Multivariate: Comparing Univariate Panel Data and Panel SUR Approaches in Modeling Stunting, Wasting, and Underweight in Indonesia

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ABSTRAK

Guna mendukung capaian target SDG Zero Hunger di Indonesia, penelitian ini membandingkan kinerja model regresi data panel univariat dengan model Panel Seemingly Unrelated Regression (Panel SUR) dalam menganalisis stunting, wasting, dan underweight (2007–2023). Metode: Menggunakan pendekatan two-way Feasible Generalized Least Squares (FGLS), studi ini mengestimasi sistem persamaan malnutrisi secara simultan untuk mengakomodasi korelasi error antar indikator. Hasil: Hasil analisis menunjukkan bahwa Panel SUR lebih baik dari model univariat dengan mengoreksi ketidakkonsistenan arah koefisien Berat Badan Lahir Rendah (BBLR) yang berubah dari negatif menjadi positif dan meningkatkan daya jelas model (R^2) pada persamaan *wasting*, serta menghasilkan estimasi yang lebih efisien yang ditunjukkan oleh *Mean Square Error* (MSE) yang lebih rendah. Implikasi: Perbaikan metodologis ini krusial secara substantif; koreksi tanda koefisien BBLR memastikan bahwa intervensi kebijakan dapat secara akurat memprioritaskan gizi prenatal sebagai determinan kunci malnutrisi akut, menghindari kesimpulan bias yang sering dihasilkan oleh pemodelan terpisah. Kesimpulan: Panel SUR memberikan hasil empiris yang lebih kuat dan valid untuk perumusan kebijakan gizi terpadu dibandingkan metode univariat konvensional.
Kata kunci: Malnutrition;Multivariat; Panel Data; Panel-SUR

ABSTRACT

Objective: *To support Indonesia's progress toward the SDG Zero Hunger target, this study compares the performance of univariate panel data regression against the Panel Seemingly Unrelated Regression (Panel SUR) model in analyzing stunting, wasting, and underweight (2007–2023).* ***Method:*** *Using a two-way Feasible Generalized Least Squares (FGLS) approach, the study simultaneously estimates the malnutrition system to account for cross-equation error correlations.* ***Results:*** *The results demonstrate that Panel SUR outperforms the univariate model by correcting the theoretical inconsistency of the Low Birth Weight (LBW) coefficient—switching it from a counterintuitive negative to a positive sign while significantly increasing the explanatory power for the wasting equation and achieving superior estimation efficiency as evidenced by a lower Mean Square Error (MSE).* ***Implications:*** *These methodological improvements are substantively critical; correcting the LBW sign ensures that policy interventions accurately prioritize prenatal nutrition as a determinant of acute malnutrition, avoiding misleading inferences common in isolated modeling approaches.* ***Conclusion:*** *Consequently, Panel SUR offers a more robust empirical framework for formulating integrated nutrition policies than traditional univariate methods.*
Keywords: *Malnutrition; Multivariate Panel Data; Panel-SUR*

INTRODUCTION

Indonesia's national development agenda, including the SDGs Zero Hunger target and the "Indonesia Emas 2045" vision, emphasizes the improvement of early childhood nutrition and health as a foundation for long-term human capital development [1,2]. Despite sustained policy commitments, child malnutrition remains a persistent challenge in Indonesia, with substantial implications for cognitive development, productivity, and health outcomes later in life [3]. This persistence highlights a critical empirical problem: improvements in policy coverage have not fully translated into the elimination of child undernutrition across regions.

This study focuses on three core indicators of child malnutrition stunting, wasting, and underweight which represent chronic, acute, and composite forms of nutritional deprivation [4]. National data indicate that while the prevalence of these indicators has declined over time, progress has been uneven across provinces. Stunting decreased from 36.8% in 2007 to 21.5% in 2023, wasting declined from 13.6% to 8.5%, and underweight from 18.4% to 15.7% over the same period [5-8]. However, these levels remain above the World Health Organization (WHO) public health thresholds (under 20%), indicating that child malnutrition continues to pose a significant risk to Indonesia's long-term human capital formation despite measurable progress [3]. These persistent gaps motivate a closer empirical examination of the determinants of child malnutrition within a dynamic regional context.

Panel data regression methods are widely used in nutrition and health economics research because they integrate cross-sectional and time-series dimensions, allowing researchers to control for unobserved regional heterogeneity such as institutional capacity, cultural practices, and local policy implementation [9]. Most existing panel-based studies, however, rely on univariate regression frameworks that estimate each malnutrition indicator separately [10-13]. This dominant approach implicitly assumes that stunting, wasting, and underweight are independently generated outcomes. Such an assumption is problematic because these indicators are influenced by overlapping socioeconomic, environmental, and maternal health factors, which can induce correlation among the unobserved shocks affecting each outcome [4]. Ignoring this correlation may lead to inefficient estimates and, in some cases, substantively misleading coefficient signs.

This methodological limitation constitutes a key gap in the empirical literature on child malnutrition. While panel data techniques have been extensively applied to analyze nutritional outcomes across countries and regions [10-13], very limited attention has been given to modeling malnutrition as a system of interrelated outcomes with correlated error structures. In contrast, the Seemingly Unrelated Regression (SUR) framework has been successfully applied in other multidimensional empirical contexts such as food insecurity, climate impacts, and mortality analysis where outcomes are jointly determined by shared structural factors [14-17]. Despite its clear relevance, the application of Panel SUR to child malnutrition analysis in Indonesia remains scarce.

Accordingly, this study addresses the following research question: does a multivariate Panel Seemingly Unrelated Regression (Panel SUR) model provide more efficient and structurally consistent estimates than univariate panel data models when analyzing stunting, wasting, and underweight in Indonesia? The central hypothesis is that accounting for correlated error terms across malnutrition outcomes improves estimation efficiency. The expected contribution of this study is twofold: methodologically, it demonstrates the advantages of Panel SUR over conventional univariate panel models; empirically, it provides more reliable evidence on key determinants such as low birth weight and sanitation that are essential for designing integrated and coordinated nutrition policies in Indonesia.

METHOD

Data and Research Variables

This study utilizes secondary data from the Basic Health Research (Riskesdas) conducted by the Indonesian Ministry of Health, covering the period 2007–2023. The dataset is structured as an unbalanced provincial panel across 34 provinces. The selection of predictor variables is grounded in the conceptual framework of child malnutrition determinants. Chronic Energy Deficiency (CED) in pregnant women (X1) and Antenatal Care (K1) coverage (X4) are included to capture maternal nutritional status and early health monitoring, which are critical for fetal development and birth outcomes. Low Birth Weight (LBW) (X3) is selected as a proxy for prenatal nutritional shocks that directly impact postnatal growth trajectories. Furthermore, basic immunization completeness (X2) and access to improved sanitation (X5) represent the environmental and healthcare factors influencing infection risks, which act as immediate determinants of nutrient absorption and utilization.

It is important to note the limitations inherent in this dataset. As Riskesdas is a cross-sectional survey aggregated to the provincial level, the analysis is subject to potential ecological fallacy, where aggregate relationships may not perfectly reflect individual-level dynamics. Additionally, variations in data availability across survey years result in an unbalanced panel structure, necessitating the use of estimation methods robust to missing time periods. The variables used in this research are summarized in Table 1.

Table 1. Research Variables

Variable type	Code	Description
Response Variables	Y1	Prevalence of stunting among children under five by province
	Y2	Prevalence of wasting among children under five by province
	Y3	Prevalence of underweight among children under five by province
Predictor Variables	X1	Prevalence of chronic energy deficiency (CED) among pregnant women
	X2	Proportion of children aged 12–23 months with complete basic immunization
	X3	Proportion of children aged 0–59 months with Low birth weight (<2.500g)
	X4	Proportion of women aged 10–54 years who received first antenatal care (K1) during pregnancy
	X5	Proportion of households with access to improved sanitation facilities

Assumption Diagnostics

Assumption Diagnostics Before estimation, a series of diagnostic tests were conducted to ensure the validity of statistical inferences [18]. Multicollinearity is assessed using the Variance Inflation Factor (VIF), which evaluates whether explanatory variables are excessively correlated and may inflate standard errors [19]. Normality of residuals is examined using the Anderson–Darling test to verify distributional assumptions underlying statistical inference [20]. Heteroscedasticity tests are conducted to assess whether error variances remain constant across cross-sections and time, which is particularly important for determining the appropriateness of GLS-based estimators [21]. Autocorrelation tests evaluate serial dependence in the error terms, while the Breusch–Pagan LM test for contemporaneous correlation examines whether error terms are correlated across equations [22]. Finally, multivariate normality is assessed using the Henze–Zirkler test to validate the joint distribution of residuals in the multivariate Panel SUR framework [19].

Univariate Panel Data Regression

The univariate approach models each malnutrition indicator independently. The general two-way error component model is specified as [23]:

$$y_{it} = \alpha_i + \lambda_t + \beta' \boldsymbol{x}_{it} + \varepsilon_{it}. \quad (1)$$

Where y_{it} represents the dependent variable (stunting, wasting, or underweight) for province i at time t, α_i denotes unobserved individual heterogeneity, λ_t captures time-specific effects, and ε_{it} is the idiosyncratic error term.

Model Selection

To determine the most appropriate estimation technique among Pooled Ordinary Least Squares (OLS), Fixed Effects Model (FEM), and Random Effects Model (REM), three standard specification tests were employed: (1) the Chow Test to choose between Pooled OLS and FEM; (2) the Hausman Test to compare FEM and REM; and (3) the Lagrange Multiplier (LM) Test to decide between Pooled OLS and REM. Based on these tests (detailed in Results), the REM specification was selected for all outcomes. [23].

Multivariate Panel Data Regression (Panel SUR)

The Panel Seemingly Unrelated Regression (SUR) framework extends the univariate model by estimating the three equations simultaneously to account for contemporaneous correlation of error terms. The system is defined as [12]:

$$\boldsymbol{y}_{it,m} = \boldsymbol{X}_{it,m}\boldsymbol{\beta}_m + \boldsymbol{\mu}_{it,m} \quad (2)$$

Where $m = 1,2,3$ corresponds to the equations for stunting, wasting, and underweight, respectively. The key feature of this model is that while error terms are assumed to be independent over time ($E\left[\mu_{it,m}\mu_{is,m}\right] = 0$ for $t \neq s$). they are correlated across equations at the same point in time ($E\left[\mu_{it,m}\mu_{is,m}\right] = \sigma_{mn}$.

Estimation Procedure

Given that the true covariance matrix of the system errors ($\boldsymbol{\Omega}$) is unknown, we employ the Feasible Generalized Least Squares (FGLS) estimator. This two-step procedure first estimates the residuals from equation-by-equation OLS to construct a consistent estimate of the covariance matrix ($\widehat{\boldsymbol{\Omega}}$), which is then used to compute the efficient GLS parameters. This method ensures asymptotic efficiency improvements over univariate estimation when cross-equation correlations are significant [12].

Model Evaluation and Efficiency Testing

Model performance is assessed based on goodness-of-fit and estimation efficiency criteria. In univariate models, the coefficient of determination (R^2) measures explanatory power, while in multivariate (Panel SUR) models, a system-wide R^2 evaluates overall model strength. Efficiency improvements are mainly observed through reduced cross-equation residual variance rather than higher R^2 values. Additionally, the Mean Square Error (MSE) serves as a key indicator of estimation accuracy, where smaller MSE values reflect better efficiency and predictive stability across individuals and time.

RESULT AND DISCUSSION

Descriptive Statistics

The analysis begins with descriptive statistics to provide an initial overview of the dynamics of the response variables and predictor variables across Indonesian provinces from 2007 to 2023. The provincial panel dataset exhibits substantial spatial heterogeneity and notable temporal variation, capturing the complex interplay of nutritional outcomes over time and across regions. These descriptive statistics serve as a fundamental basis for understanding data behavior prior to implementing the univariate and multivariate frameworks under Panel Data and Panel SUR approaches.

Table 2. Description of Variable

Variables	Year	Mean	St. Dev	Min		Max	
Stunting (Y1)	2007	37.68	5.6	26.1	Riau Island	46.7	East Nusa Tenggara
	2013	38.22	6.09	26.3	Riau Island	51.7	East Nusa Tenggara
	2018	32.3	5.47	21.84	Bali	42.6	Lampung
	2023	23.15	4.88	7.2	Bali	31.8	East Nusa Tenggara
Wasting (Y2)	2007	15	3.07	9	West Java	22.1	Riau
	2013	12.58	2.33	8.8	Bali	18.7	Kalimantan Barat
	2018	11.7	2.45	6.3	Bali	16.5	East Nusa Tenggara
	2023	7.93	2.13	3.4	DI Yogyakarta	13.6	North Kalimantan
Underweight (Y3)	2007	20.41	5.3	10.9	DI Yogyakarta	33.6	East Nusa Tenggara
	2013	21.68	5.22	13.2	Bali	33	East Nusa Tenggara
	2018	18.01	3.89	10.2	DKI Jakarta	25.1	East Nusa Tenggara
	2023	14.12	4.33	5.7	Bali	24.3	Aceh

Variables	Year	Mean	St. Dev	Min		Max	
CED of Pregnant Women (X1)	2007	12.78	4.33	5.8	North Sulawesi	24.6	East Nusa Tenggara
	2013	24.47	6.64	10.1	Riau	45.5	East Nusa Tenggara
	2018	17.98	6.88	1.7	North Kalimantan	36.8	East Nusa Tenggara
	2023	16.01	5.54	5.2	North Kalimantan	28	Southeast Sulawesi
Complete Immunization (X2)	2007	46.66	11.5	17.3	West Sulawesi	73.9	Bali
	2013	55.56	15.15	29.3	Papua	83.2	DI Yogyakarta
	2018	52.7	20.03	18.32	Aceh	92.1	Bali
	2023	61.03	15.22	18.9	West Papua	84.5	DI Yogyakarta
Low Birth Weight (X3)	2007	12.6	4.97	5.8	Bali	27	Papua
	2013	10.67	2.45	7.2	West Sulawesi	16.8	Central Sulawesi
	2018	6.24	1.33	2.6	Jambi	8.9	Bengkulu
	2023	5.87	1.34	2.7	Jambi	7.9	North Sulawesi
Antenatal Care (X4)	2007	85.63	9.01	67	Papua	97.1	DKI Jakarta
	2013	93.5	5.76	71.7	Papua	99.6	Bali
	2018	94.43	5.83	66.8	Papua	98.8	Central Java
	2023	95.8	3.46	86.7	West Papua	99.6	Bali
Improved Sanitation (X5)	2007	42.22	11.27	17.9	Papua	64.1	DKI Jakarta
	2013	58.38	11.6	30.5	East Nusa Tenggara	78.2	DKI Jakarta
	2018	68.7	12.94	33.75	Papua	91.14	Bali
	2023	82.68	9.46	43	Papua	96.42	DI Yogyakarta

Base on Table 4, The analysis of provincial panel data (2007–2023) reveals distinct temporal and spatial patterns in Indonesia's malnutrition landscape. Nationally, all three indicators exhibit a downward trajectory, reflecting the success of health interventions over the past decade. Stunting (Y1) showed the most rapid improvement, declining from a peak of 38.2% in 2013 to 21.5% in 20231. However, the prevalence of Wasting (Y2) and Underweight (Y3) has shown more fluctuation, indicating that acute malnutrition remains sensitive to short-term shocks compared to the steady decline of chronic stunting. Spatially, persistent inequality is evident. East Nusa Tenggara (NTT) consistently appears as the province with the highest burden across all indicators throughout the observation period, highlighting deep-rooted structural challenges in that region. In contrast, Bali and DKI Jakarta consistently perform as the best-performing provinces, benefiting from superior health infrastructure and sanitation access. This pronounced regional disparity supports the need for panel data methods that can account for unobserved individual heterogeneity (α_i).

Assumption Diagnostics

Following the descriptive analysis, classical and diagnostic assumption tests were conducted to ensure the validity and efficiency of the regression estimates. These included univariate assumption tests for the Panel Data Regression model and multivariate diagnostics for the Panel Seemingly Unrelated Regression (SUR) model, with a 5% significance level. The results show that the univariate models satisfy all key assumptions, as indicated by acceptable Variance Inflation Factor (VIF) values (1.07–2.36), normally distributed residuals (Anderson–Darling p-values > 0.05), and homoscedasticity (heteroscedasticity test p-values > 0.05). Although one equation exhibited autocorrelation (p-value = 0.000), the multivariate diagnostics justify the use of the Panel SUR model. The test for contemporaneous correlation yielded a p-value of 0.000, confirming significant cross-equation correlation and validating the efficiency gains of the SUR approach, while the Henze–Zirkler test (p = 0.094) verified multivariate normality. Overall, these findings confirm that the statistical assumptions are met and that employing the Panel SUR model provides a robust methodological foundation for enhancing estimation efficiency in modeling malnutrition outcomes across Indonesian provinces.

Estimation of Univariate and Multivariate Panel Data Regression

Univariate vs. Panel SUR To evaluate the hypothesis that malnutrition indicators are interdependent, we compared the Univariate Random Effects Model (REM) against the Multivariate Panel SUR model. Table 3 presents a compact comparison of key coefficients, significance levels, and model performance metrics.

Table 3. Result of Univariate and Multivariate Panel Data Regression

Predictor	Stunting				Wasting				Underweight			
	Univ.		Mult.		Univ.		Mult.		Univ.		Mult.	
(Intercept)	48.446	***	41.644	***	26.898	***	27.333	***	26.928	***	20.836	***
X1					0.005	ns	-0.103	**	0.127	***	0.072	*
X2	-0.061	***	-0.046	*	-0.031	***	-0.04	*				
X3	0.154	***	0.504	**	-0.103	**	0.255	**	0.022	ns	0.252	*
X4					-0.137	***	-0.15	***				
X5	-0.218	***	-0.172	***					-0.173	***	-0.092	***
Model Fit												
R-Square	0.65		0.406		0.279		0.602		0.514		0.572	
MSE	16.553 (Univariate) 15.749 (Multivariate)											

Significant code: p<0.0001 '***' p<0.001 '**' p<0.01 '*' p<0.05 '.' p<0.1

Based on Table 5, The most critical finding from this comparison is the correction of the Low Birth Weight (LBW/X3) coefficient in the Wasting equation. In the Univariate model, LBW showed a counterintuitive negative significant effect (-0.103), implying that lower birth weight reduces the risk of wasting. However, the Panel SUR model corrected this sign anomaly to a positive significant effect (0.255).

Furthermore, the Panel SUR framework demonstrated superior efficiency. The explanatory power (R^2) for the Wasting equation more than doubled from 0.279 in the univariate model to 0.602 in the multivariate model, indicating that the wasting model borrows strength from the stunting and underweight equations. Overall, the System Mean Square Error (MSE) decreased from 16.553 (Univariate) to 15.749 (Panel SUR), confirming that the multivariate approach yields more precise estimators by exploiting cross-equation correlations.

Discussion

This study aims to empirically demonstrate that child malnutrition indicators—stunting, wasting, and underweight should be modeled as an interconnected system rather than isolated outcomes. The comparison between the Univariate Random Effects Model (REM) and the Multivariate Panel Seemingly Unrelated Regression (Panel SUR) confirms the central hypothesis: accounting for contemporaneous correlations significantly improves estimation efficiency and structural consistency.

The most fundamental contribution of this study is the empirical validation of the Panel SUR framework in the context of nutritional epidemiology in Indonesia. While univariate models yielded decent goodness-of-fit (R^2), they suffered from inefficiency due to neglected cross-equation correlations. The diagnostic test for contemporaneous correlation provided strong evidence that the error terms of the three equations are not independent. This implies that unobserved shocks affecting stunting in a province simultaneously affect wasting and underweight. By exploiting this correlation structure, the Panel SUR model "borrowed information" across equations, resulting in a lower System Mean Square Error (MSE). This gain in efficiency is not merely a statistical artifact; it translates to more precise standard errors, giving policymakers greater confidence that the estimated effects are real and not products of random noise.

The most striking finding is the correction of the Low Birth Weight (LBW) coefficient in the wasting equation. The univariate model produced a sign anomaly, suggesting that LBW is negatively associated with wasting a finding that contradicts biological mechanisms. This anomaly likely arose from omitted variable bias where the shared variance between acute and chronic malnutrition was wrongly attributed to the error term.

The Panel SUR model successfully corrected this sign to positive, aligning the statistical results with clinical reality. Biologically, LBW infants are born with reduced muscle mass and fat stores, making them hypersensitive to postnatal nutritional deficits and infection, thereby increasing the risk of acute wasting [24]. The ability of Panel SUR to recover this theoretical consistency demonstrates its robustness in handling complex epidemiological data where variables are highly collinear and interdependent.

The Role of Environmental and Health Service DeterminantsBeyond LBW, the results highlight the robust role of environmental health and maternal care. Access to improved sanitation (X5) emerged as a consistent protective factor across equations, particularly for stunting and underweight. This supports the "environmental enteropathy" hypothesis, where chronic exposure to fecal pathogens damages the gut lining, inhibiting nutrient absorption regardless of food intake [25]. The significance of sanitation in the multivariate framework reinforces that nutrition interventions cannot succeed without parallel investments in water, sanitation, and hygiene (WASH) infrastructure. Similarly, Antenatal Care (X4) showed a significant protective effect against wasting. This suggests that early contact with health services allows for the timely detection of maternal risks that could lead to acute malnutrition in infants. The consistency of these findings across the system validates the government's focus on the "First 1000 Days of Life" (HPK) strategy but emphasizes that implementation must be integrated across sectors.

Current nutrition policies in Indonesia often operate in silos, with specific programs targeting stunting separately from wasting management. The findings of this study argue for a system-based policy approach. Since the determinants (LBW, sanitation, maternal care) are structurally linked across all three outcomes, interventions must be convergent. Programs aimed at reducing stunting must explicitly include protocols for wasting management, as the risk factors (like LBW) are shared. The strong impact of sanitation implies that the Ministry of Health cannot work alone; collaboration with the Ministry of Public Works (PUPR) to improve sanitation infrastructure is a direct nutritional intervention. The correction of the LBW coefficient underscores that preventing acute malnutrition (wasting) begins in the womb. Strengthening maternal nutrition programs (PMT-Bumil) is as critical for preventing wasting as it is for stunting.

CONCLUSION

This study confirms that the Panel Seemingly Unrelated Regression (Panel SUR) framework provides a more robust and efficient methodological approach for analyzing child malnutrition in Indonesia compared to traditional univariate models. By explicitly accounting for the contemporaneous correlations between stunting, wasting, and underweight, the multivariate model successfully corrected theoretical inconsistencies—most notably the sign reversal of Low Birth Weight (LBW) in the wasting equation—and achieved superior estimation efficiency as evidenced by a lower System Mean Square Error (MSE).

Substantively, the results highlight the critical interdependence of nutritional determinants. LBW and maternal Chronic Energy Deficiency (CED) emerged as powerful structural risks across the malnutrition system, confirming that prenatal conditions are fundamental to both acute and chronic outcomes. Furthermore, improved sanitation consistently served as a significant protective factor across all equations, reinforcing the importance of environmental health in nutrient absorption. These findings imply that effective nutrition policy cannot be designed in silos; instead, it requires an integrated approach where maternal health interventions (prenatal nutrition) are synchronized with infrastructure development (sanitation) to address the shared root causes of multiple malnutrition forms simultaneously.

Several limitations of this study point toward realistic avenues for future research. First, the reliance on aggregated provincial-level data may obscure intra-regional inequality; future studies should employ household-level microdata to capture individual heterogeneity and minimize potential aggregation bias. Second, while the model addresses cross-equation correlation, it does not account for spatial dependencies between neighboring provinces; extending this work to a Spatial Panel SUR framework would provide deeper insights into regional spillover effects. Finally, the unbalanced nature of the panel and the limited set of predictors restricted the analysis to health-specific variables; future research could incorporate broader indicators, such as specific policy indices or economic shock variables, to further enhance the model's explanatory power.

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