Food Security and Trade in Regional ASEAN

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Abstract. This study investigates the relationship between trade and food security in ASEAN countries by employing a panel data approach with the Common Effect Model (CEM) as the preferred specification. Food security is measured using the prevalence of undernourishment, while trade serves as the main independent variable, complemented by control variables including access to safely managed water and sanitation, water use efficiency, nutrient balance, and GDP per capita. The analysis is based on annual data from ASEAN member countries, providing a comprehensive overview of regional dynamics. The results indicate that trade has a significant negative effect on undernourishment, highlighting its role in improving food security by enhancing food availability and accessibility. Water use efficiency and GDP per capita are also found to contribute significantly to reducing undernourishment, emphasizing the importance of sustainable resource management and inclusive economic growth. However, access to water and sanitation, as well as nutrient balance, do not exhibit significant direct effects, suggesting their impact may be more indirect or mediated by other socio-economic conditions. Country effect estimations further reveal heterogeneity among ASEAN nations, with the Philippines and Laos experiencing stronger unobserved influences on food insecurity, while Malaysia demonstrates a relatively lower baseline effect. These findings underscore the multidimensional nature of food security and the need for tailored policy responses. Strengthening trade cooperation, improving resource efficiency, promoting inclusive growth, and addressing structural disparities are essential to achieve sustainable food security in the region.

Keywords: Food Security, Undernourishment, Trade, ASEAN Countries, Panel Data Analysis

1 Introduction

Food security is a fundamental pillar in achieving sustainable development, directly linked to poverty reduction, the improvement of human capital, and socio-economic stability [1]. Within the framework of economic development theory, food functions not only as a basic human need but also as a strategic instrument that drives labor productivity, supports economic growth, and maintains social cohesion [2]. Food security serves as a key indicator of the success of inclusive economic governance, as it reflects a country's ability to provide food that is equitably distributed, affordable, and sustainable for its entire population [3].

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The Food and Agriculture Organization (FAO) defines food security through four main dimensions: availability, access, utilization, and stability [4]. Failure in any one of these dimensions can have serious implications for societal well-being, particularly among vulnerable groups such as poor households and populations in remote areas [5]. This framework highlights that food security does not solely depend on domestic production but also on income distribution, infrastructure development, and adequate market access [6].

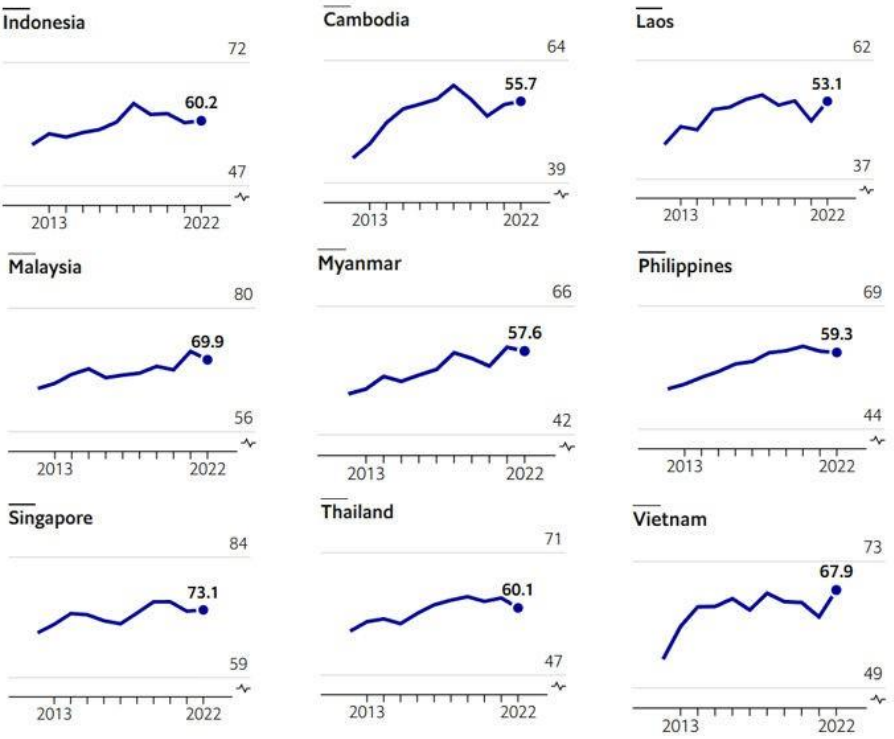

Fig. 1. Trend of Food Security Index in ASEAN Countries, 2013-2022

The trend of the Food Security Index in ASEAN countries from 2013 to 2022 in Figure 1 shows noticeable variations across nations, reflecting differences in economic development, governance, and agricultural resource management. Singapore consistently records the highest score throughout the period, indicating strong performance in ensuring food availability, accessibility, and stability. Malaysia and Vietnam also demonstrate relatively high and stable scores, suggesting that sustained economic growth and trade integration contribute positively to their food security outcomes.

On the other hand, countries such as Laos, Cambodia, and Myanmar show lower index levels, highlighting persistent challenges in achieving broad-based food security. While some improvements are visible in the early years, fluctuations in recent periods suggest vulnerabilities related to economic shocks, limited infrastructure, or resource

constraints. Meanwhile, Indonesia, Thailand, and the Philippines fall into the middle range, showing gradual improvements but still facing notable gaps compared to the topperforming countries.

The uneven progress of food security within ASEAN. It emphasizes that while some member states have advanced toward greater stability and resilience in their food systems, others continue to struggle with structural limitations [7]. These disparities underline the importance of regional cooperation, policy alignment, and investment in sustainable agricultural practices to reduce gaps and ensure equitable food security across the region [8].

One of the significant external variables influencing Indonesia's food security is international trade, particularly within the framework of the Association of Southeast Asian Nations (ASEAN) economic integration [9]. Since the implementation of the ASEAN Economic Community (AEC) in 2015, member states have committed to establishing a single market through tariff liberalization, regulatory harmonization, and strengthened connectivity. Trade liberalization can enhance resource allocation efficiency and provide access to food at more competitive prices through the mechanism of comparative advantage [10, 11].

In this context, Indonesia's agricultural trade with ASEAN countries such as Thailand, Malaysia, the Philippines, and Vietnam has experienced substantial growth. UN Comtrade data indicates that Indonesia's total agricultural trade with ASEAN increased from USD 2.1 billion in 2015 to USD 4.8 billion in 2022. Theoretically, this growth in trade can function as a buffer mechanism for domestic food supply while simultaneously serving as a means to improve efficiency and diversify food access.

However, trade liberalization may also pose risks if not accompanied by efforts to strengthen domestic production capacity [12]. Food security could be undermined in the face of international price fluctuations, logistical disruptions, or geopolitical crises in supplying countries [13]. The impact of trade on food security largely depends on income distribution and the ability of households to access the benefits of such trade [14].

Trade openness only has a positive impact on food security when accompanied by strengthened domestic production capacity and equitable income distribution [15]. Trade can pose risks to food security in countries dependent on staple imports, particularly during periods of global price volatility [16]. Discovered that although the value of agricultural trade has increased, food security has not shown significant improvement due to weak distribution systems and stagnant local production [17]. The potential of the AEC has not been fully utilized for technology transfer and food logistics efficiency [18]. These studies highlight the complexity of the relationship between international trade and food security, requiring deeper empirical analysis.

Although food security has been widely discussed in the literature, research specifically examining the impact of trade with ASEAN countries on the national food security of each member state remains limited. Furthermore, studies that employ the prevalence of undernourishment (PoU) as a food security indicator while also considering other relevant factors are still scarce [19, 20].

This research seeks to fill this gap by conducting an empirical analysis of the impact of trade within ASEAN on food security. A quantitative approach with an econometric

model is applied to analyze the causal relationships among variables. The study is expected to contribute theoretically to the literature on development economics and food security while also offering practical insights for formulating integrated and sustainable food policies in the era of ASEAN economic integration.

2 Literature Review

The theory of food security serves as a fundamental conceptual framework in development economics, positioning food as a vital element in economic growth, poverty alleviation, and social stability. World Bank (2025) describes food security as a condition in which all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food to meet their dietary needs for an active and healthy life [21]. This concept was further refined by FAO (2006) into four key pillars: availability, access, utilization, and stability [22].

As an aggregate indicator of food security, the Prevalence of Undernourishment (PoU) is officially used by FAO and also serves as a key indicator within the Sustainable Development Goals (SDGs), particularly Goal 2: Zero Hunger. PoU measures the percentage of the population whose habitual energy intake is chronically below the minimum dietary energy requirement necessary to maintain a healthy and active life [23]. This minimum threshold is calculated based on the average minimum energy requirements, which vary across countries depending on demographic structure, average body weight, and levels of physical activity within the population.

PoU is regarded as a macro-level measure that reflects the quality and distribution of a country's food system [24]. A higher PoU value indicates greater inequality in food access or inefficiencies in food distribution systems. Importantly, PoU does not only capture issues of food availability but also reveals disparities in purchasing power, market failures, and weaknesses in social protection. Therefore, this indicator is highly relevant for evaluating national food security performance and for assessing the impacts of trade policies, food subsidies, and other economic development interventions on household food consumption [25].

In the context of economic development, Food security is not merely a social instrument but also a primary driver of labor productivity, educational quality, and national competitiveness [26]. A country that fails to ensure food security will face stagnating productivity, high health burdens, and heightened vulnerability to social instability and political conflict [27]. Thus, food security should not be viewed solely as a technical agricultural issue but as an integral component of strategic, cross-sectoral national economic planning [28].

International trade is one of the key determinants of food security, as explained by the theory of comparative advantage [29]. This theory posits that countries gain from trade when they produce and export goods in which they have a relative cost advantage, while importing goods that are more efficiently produced elsewhere [30]. In the context of food, trade enhances the availability and stability dimensions of food security by providing supplies that cannot be fully met through domestic production.

Based on these theoretical perspectives and empirical findings, ASEAN agricultural trade is expected to have a positive impact on Indonesia's food security by increasing food availability and stabilizing prices, although its effectiveness still depends on adequate distribution infrastructure.

3 Data and Methodology

3.1 Data

This study employs panel data from ASEAN countries to analyze the determinants of food security based on trade activity. The data covers the period from 2010 to 2023 and is sourced from the World Development Indicators published by the World Bank and gg index-simtool organization. Panel data is chosen because it provides more varied information and greater efficiency in estimating model parameters. This type of data enables a more in-depth analysis by accounting for variations across individuals over time, offering advantages in increasing degrees of freedom, reducing multicollinearity among variables, and improving the efficiency of parameter estimation [31]. The study focuses on seven ASEAN countries, excluding Singapore and Brunei Darussalam, as they are already classified as high-income, developed nations. Myanmar is also excluded due to data limitations, leaving seven countries from the ten ASEAN member states included in this study. This selection allows for a more relevant analysis of food security and trade dynamics among developing member states.

In this study, food security is measured using the Prevalence of Undernourishment, which indicates the proportion of the population whose dietary energy intake is insufficient. This indicator provides a direct assessment of undernutrition and the overall food security status in each country. Table 1 presents the variables employed in the analysis.

Table 1. Variable Used

Variables	Sym-bol	Description	Data Source
Dependent Variable			
Food Security	PoU	Measured by the Prevalence of Undernourishment (%), indicating the proportion of the population whose dietary energy intake is insufficient.	gg indexsimtool organization
Independent Variable			
Trade	Tr	Measured by the sum of exports and imports as a percentage of GDP, reflecting the openness and trade activity of a country	World Bank
Control Variables			
Population with Access to Safely Managed Water and Sanitation	AWS	Percentage of the population with access to safely managed water and sanitation facilities, affecting health and nutrition outcomes	gg indexsimtool organization
Water Use Efficiency	WUE	Ratio of agricultural or total water output to water input, indicating efficient use of water resources for production	gg indexsimtool organization
Nutrient Balance per Unit Area	NB	Balance of nutrients in agricultural land per unit area, reflecting soil fertility and sustainability of food production	gg indexsimtool organization
GDP Per Capita	GDPC	Gross Domestic Product per capita (constant US$), representing the economic capacity of the population to access food.	World Bank

3.2 Methodology

Panel data regression is one of the developments of the regression analysis method. Panel data regression is a regression technique that combines cross-sectional data and time-series data, thus naturally resulting in a greater number of observations compared to using only cross-sectional or time-series data. In general, the use of panel data offers many advantages, both statistically and in economic theory. One of these advantages is that panel data can explicitly account for individual heterogeneity by allowing individual-specific variables to be incorporated into the econometric equation. The general model of panel data regression is expressed in the following equation [32].

$$Y_{it} = \alpha + \beta_1 X_{1it} + \beta_2 X_{2it} + \beta_3 X_{3it} + \cdots + \beta_k X_{kit} + \varepsilon_{it} \quad (1)$$

Where, i=1,2,…,n represents the cross-sectional units, while t=1,2,…,T denotes the time-series observations, α is the constant coefficient, $\beta_1, \beta_2, \cdots, \beta_k$ are the coefficients of the independent variables, and ε_{it} is the regression error term for the i-th unit at time t. Subsequently, the modeling is carried out using panel data regression.

Common Effect Model (CEM). The CEM approach uses the same value of α for each individual and at each point in time. In other words, the data behavior for each individual is assumed to be identical across different time periods. The regression equation using the CEM approach can be expressed as follows [33].

$$Y_{it} = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \cdots + \beta_k X_k + \varepsilon_{it} \quad (2)$$

To estimate the parameters in the CEM method, the Ordinary Least Squares (OLS) method is applied.

Fixed Effect Model (FEM). The FEM method can be expressed by the following equation.

$$Y_{it} = \alpha_1 + \sum_{k=2}^{N} \alpha_k D_{ki} + \beta X_k + \varepsilon_{it} \quad (3)$$

This method assumes that the intercept value differs for each individual, while the slope remains the same across individuals. To differentiate one individual from another, dummy variables are used. This model is often referred to as the Least Squares Dummy Variables (LSDV) model [33].

Random Effect Model (REM). The REM approach assumes that the intercept varies across individuals. Thus, there are two error components: the overall model error and the individual-specific error. The overall model error is a combination of the time-series and cross-sectional data, whereas the individual-specific error is the error term for each cross-sectional unit. This method can be expressed as follows [33].

$$Y_{it} = \alpha + \beta_1 X_{1it} + \beta_2 X_{2it} + \beta_3 X_{3it} + \cdots + \beta_k X_{kit} + \varepsilon_{it} + \mu_i \quad (4)$$

Where μ_i is the error component from the cross-sectional data. The parameters in the REM can be estimated using the Generalized Least Squares (GLS) method.

The selection of the best panel data regression model is determined through the Chow test, Hausman test, and Breusch–Pagan test [34].

Chow Test. The Chow test is used to choose between the Common Effect Model (CEM) and the Fixed Effect Model (FEM). The Chow test statistic is expressed as follows.

$$F_{hitung} = \frac{(SSE_1 - SSE_2)(nT - n - K)}{SSE_2(n-1)} \quad (5)$$

The hypotheses are:

- H_0: $\alpha_1 = \alpha_2 = \cdots = \alpha_n = 0$ (Indicating that CEM is accepted)
- H_1: $\alpha_i \neq 0; i = 1,2,\cdots,n$ (Indicating that FEM is accepted)

Hausman Test. This is a follow-up test to determine whether the FEM or REM is more appropriate after conducting the Chow test. The test statistic is expressed as follows.

$$W = \hat{q}'[var(\hat{q}')]^{-1}\hat{q}'$$
$$W = (\hat{\beta}_{MET} - \hat{\beta}_{MEA})' [var((\beta_{MET} - \beta_{MEA}))]^{-1} (\hat{\beta}_{MET} - \hat{\beta}_{MEA}) \quad (6)$$

The hypotheses are:

- H_0: REM is accepted
- H_1: FEM is accepted

Breusch-Pagan Test. To determine whether the REM is better than the CEM, the Lagrange Multiplier (LM) test developed by Breusch–Pagan can be used. This test is based on the residual values from the CEM. The LM statistic is calculated using the following formula.

$$LM = \frac{nT}{2(T-1)}\left[\frac{\sum_{i=1}^{n}(\sum_{t=1}^{T} e_{it})^2}{\sum_{i=1}^{n}\sum_{t=1}^{T} e_{it}^2} - 1\right]^2 \quad (7)$$

4 Results

4.1 Statistic Descriptive

Based on the descriptive statistics in Table 2, the prevalence of undernourishment as an indicator of food security shows considerable variation across ASEAN countries, with some countries experiencing very low levels while others still face relatively high levels of food insecurity. Trade also exhibits wide disparities, reflecting differences in openness and economic capacity among the countries in the region.

Meanwhile, the control variables such as access to safely managed water and sanitation, water use efficiency, nutrient balance, and GDP per capita also display substantial variation. This indicates a significant gap in socio-economic and environmental conditions across ASEAN, which may influence the level of food security in each country.

Table 2. Summary Statistic

Variable	Mean	Variance	Std. Dev	Minimum	Maximum
PoU	7.094897959	8.600540711	2.932667849	1.1	15.6
TR	103.495445	1573.86896	39.67201735	32.9721754	186.6758328
AWS	63.03102041	227.5321288	15.08416815	24.18	93.3
WUE	10.90428571	288.2990722	16.97937196	1.36	58.6
NB	41.44214286	961.1190479	31.00192007	3.88	129.74
GDPC	4343.058304	8622272.868	2936.370697	952.2746163	11748.09193

The scatter plot in Figure 1 illustrates the relationship between trade and the prevalence of undernourishment across ASEAN countries. The distribution of data points shows a downward trend, as indicated by the fitted regression line, suggesting that higher levels of trade are generally associated with lower levels of undernourishment. The spread of observations indicates variability among countries, but the overall pattern reflects a negative association between trade performance and food insecurity.

The correlation matrix in Table 3 shows that the prevalence of undernourishment has a negative association with most independent and control variables. Strong negative correlations are observed with access to safely managed water and sanitation, water use efficiency, and GDP per capita, indicating that improvements in these factors are generally aligned with lower levels of undernourishment. Trade also has a negative relationship with undernourishment, though the strength of this correlation is more moderate compared to the other socio-economic variables.

Among the explanatory variables, water use efficiency and access to water and sanitation are highly correlated, as are GDP per capita and these two indicators, suggesting that better economic conditions are often accompanied by improved infrastructure and resource management. Nutrient balance, on the other hand, shows only a weak relationship with undernourishment and other variables, indicating that its variation may not be strongly connected to food security or the broader socio-economic factors captured in this study.

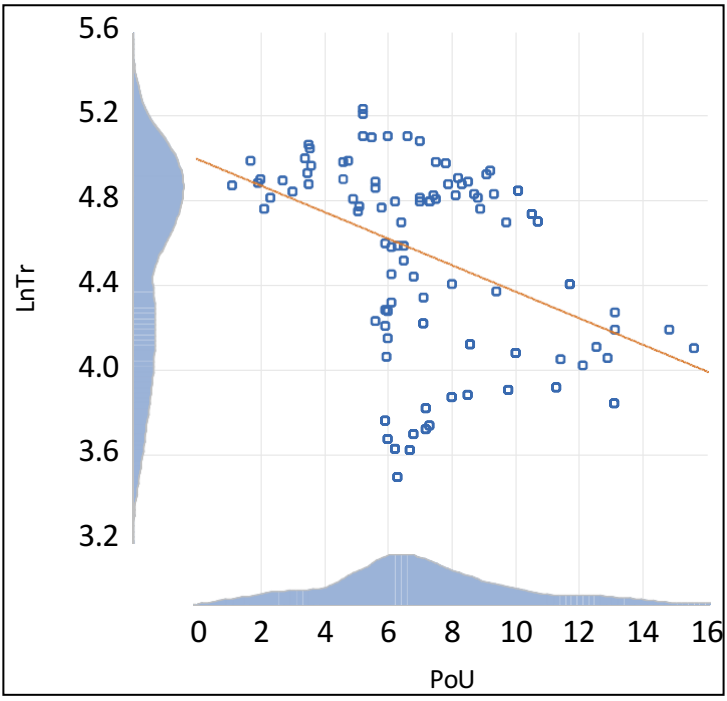

Fig. 2. Scatter Plot Towards Dependent Variabel and Independent Variable

Table 3. Matrix Correlation

	PoU	LnTR	AWS	WUE	NB	LnGDPC
PoU	1.000000					
LnTR	-0.410693	1.000000				
AWS	-0.609401	0.153981	1.000000			
WUE	-0.657553	0.354966	0.765939	1.000000		
NB	-0.070613	0.410631	0.121070	-0.181107	1.00000	
LnGDPC	-0.638702	0.219528	0.682530	0.724932	0.065246	

4.2 Results Analysis

In order to further examine the relationship between trade and food security in ASEAN countries, panel regression models were employed using different estimation techniques. The analysis begins with the Common Effect Model (CEM), which provides a baseline estimation without accounting for individual heterogeneity across countries. This serves as a starting point to observe the overall association between trade and undernourishment prevalence.

Subsequently, the Fixed Effect Model (FEM) is applied to control for unobserved country-specific characteristics that remain constant over time, allowing the estimation to better capture within-country variations. Finally, the Random Effect Model (REM)

is introduced as an alternative approach, assuming that individual heterogeneity is random and uncorrelated with the explanatory variables. The combination of these three models enables a comprehensive assessment of the robustness and consistency of the results before proceeding to model selection tests such as Chow, Hausman, and Lagrange Multiplier tests.

By presenting these models sequentially, the analysis provides a clearer understanding of how trade and control variables influence food security under different assumptions regarding country-specific effects. The comparison across models ensures that the findings are not only statistically valid but also meaningful in explaining the dynamics of food security in the ASEAN context. The results of each model analysis are presented in Tables 4, 5, and 6 below.

Table 4. Common Effect Mode

Variable	Coefficient	Std. Error	Prob.	Conclusion
LnTr	-1.508544	0.696437	0.0329**	Significant
AWS	-0.018418	0.037393	0.6235	Not Significant
WUE	-0.049601	0.028200	0.0819*	Significant
NB	0.000254	0.010194	0.9802	Not Significant
LnGDPC	-1.387914	0.702979	0.0513*	Significant
Constanta	26.99806	5.273238	0.0000***	Significant
R-Square			0.530861	
Adjusted R-Square			0.505365	
S.E Regression			2.062555	
Log Likelihood			-206.9069	
F-Statistic			20.82081	
Prob (F-Statistic)			0.000000***	

** p <.10, ** p <.05, *** p <.01*

Table 5. Fixed Effect Mode

Variable	Coefficient	Std. Error	Prob.	Conclusion
LnTr	-4.950322	1.052568	0.0000***	Significant
AWS	-0.186608	0.033839	0.0000***	Significant
WUE	0.327416	0.046302	0.0000***	Significant
NB	0.069519	0.016996	0.0001***	Significant
LnGDPC	4.456384	1.190938	0.0004*	Significant
Constanta	-1.497778	7.272218	0.8374	Not Significant
R-Square			0.951869	
Adjusted R-Square			0.936045	
S.E Regression			0.741651	
Log Likelihood			-95.33512	
F-Statistic			60.15405	
Prob (F-Statistic)			0.000000***	

** p <.10, ** p <.05, *** p <.01*

Table 6. Random Effect Mode

Variable	Coefficient	Std. Error	Prob.	Conclusion
LnTr	-2.322690	0.874897	0.0093***	Significant
AWS	-0.066825	0.046570	0.1547	Not Significant
WUE	0.009245	0.033934	0.7860	Not Significant
NB	0.011957	0.013300	0.3710	Not Significant
LnGDPC	-2.168084	0.914117	0.0198**	Significant
Constanta	39.00582	6449524	0.0000***	Significant
R-Square			0.471419	
Adjusted R-Square			0.442692	
S.E Regression			1.890933	
F-Statistic			16.41020	
Prob (F-Statistic)			0.000000***	

** p <.10, ** p <.05, *** p <.01*

Next, tests were conducted to determine the most appropriate model to be used in this study. Three tests were employed, namely the Chow test, the Hausman test, and the Breusch–Pagan test. The results of these three tests are presented in Table 7 below.

Table 7. Test Results Testing

Test Statistics	P-Value	Criterion
Chow Test	0.27146	Accept H_0: The corresponding CEM Model
Hausman Test	0.33725	Accept H_0: The corresponding CEM Model
Breusch-Pagan Test	0.35591	Accept H_0: Homoskedasticity supports CEM Model

The results of the model specification tests indicate that the Common Effect Model (CEM) is the most appropriate approach for this study. The Chow Test result suggests that there is no significant difference between the CEM and the Fixed Effect Model, meaning that controlling for unobserved country-specific effects does not provide additional explanatory power. Similarly, the Hausman Test confirms that the assumption of no correlation between the individual effects and explanatory variables holds, further supporting the use of the CEM rather than the Random Effect Model.

In addition, the Breusch-Pagan Test result indicates that the assumption of homoskedasticity is not violated, which strengthens the reliability of the CEM estimation. Taken together, these tests consistently point to the CEM as the preferred specification for analyzing the relationship between trade and food security in ASEAN countries. This finding implies that country-specific unobserved factors do not significantly bias the results, and the common structure of the model is sufficient to capture the variation in the data.

Since the model selection tests indicated that the Common Effect Model (CEM) is the most appropriate specification, the analysis proceeds with the results presented in Table 4. This table provides the estimated coefficients, standard errors, and significance levels of the explanatory variables in explaining the prevalence of undernourishment as

an indicator of food security in ASEAN countries. The model also reports the overall goodness-of-fit and diagnostic statistics to assess the reliability of the estimation.

The results show that trade (LnTR) has a negative and statistically significant effect on undernourishment, suggesting an important role of trade in improving food security across ASEAN. Water use efficiency (WUE) also displays a negative and significant relationship, though at a weaker significance level, highlighting its contribution to reducing undernourishment. GDP per capita (LnGDPC) further exhibits a negative effect, significant at the 10 percent level, indicating that higher income levels are associated with lower prevalence of undernourishment.

On the other hand, access to safely managed water and sanitation (AWS) does not present a statistically significant effect in this model, despite its expected role in supporting better food and nutrition outcomes. Similarly, nutrient balance (NB) shows no significant influence on food security, suggesting that its variation across countries may not directly translate into improvements in reducing undernourishment.

The overall performance of the model is reflected in the R-squared and adjusted Rsquared values, which indicate that a substantial proportion of the variation in undernourishment can be explained by the included variables. The F-statistic is highly significant, confirming the joint significance of the model. These results provide an empirical foundation for understanding the determinants of food security in ASEAN within the framework of the Common Effect Model.

Table 7 presents the country effects obtained from the panel regression framework, capturing the unobserved characteristics specific to each ASEAN country included in the study. These values represent the fixed component associated with individual countries that may influence the prevalence of undernourishment beyond the explanatory variables in the model. The figures reflect differences in country-specific conditions such as policy frameworks, institutional capacity, and structural factors that are not directly measured in the regression.

Among the countries, the Philippines and Laos record the highest country effects, indicating that these nations tend to experience a relatively stronger influence of unobserved factors associated with undernourishment. This suggests that beyond trade, economic, and resource-related indicators, there are underlying national characteristics that contribute to higher food insecurity levels in these countries.

Indonesia, Thailand, and Viet Nam show moderately high country effects, suggesting the presence of country-specific influences, though not as pronounced as those observed in the Philippines and Laos. These effects highlight that while the explanatory variables play an important role, national conditions still shape food security outcomes across these countries. Malaysia, in contrast, records the lowest country effect among the sample, implying that unobserved national characteristics contribute less to food insecurity compared to its ASEAN counterparts. This relatively lower value indicates a more favorable baseline condition, which aligns with the country's overall stronger socio-economic structure. Collectively, the country effects underscore the heterogeneity across ASEAN nations in terms of their structural and institutional contributions to food security.

Table 8. Country Effect

Country	Effect
Indonesia	7.878571429
Malaysia	2.700000000
Philippiness	8.792857143
Thailand	7.378571429
Viet Nam	7.221428571
Laos	8.850000000
Cambodia	6.842857143

5 Discussion

The findings of this study provide several important insights into the relationship between trade and food security in ASEAN countries. The negative and significant association between trade and undernourishment suggests that greater participation in international markets can serve as a pathway to improve food availability and accessibility. In the context of ASEAN, where economic integration has been deepening through regional frameworks such as the ASEAN Economic Community (AEC), this result highlights the potential of trade liberalization and cross-border flows in addressing persistent challenges of undernourishment. Trade not only facilitates the inflow of diverse food products but also stimulates economic growth, which in turn can strengthen household purchasing power and resilience.

At the same time, the significant role of water use efficiency points to the importance of natural resource management in promoting food security. The result underlines that ensuring sufficient and sustainable water utilization is critical for agricultural productivity, especially in regions where agriculture remains a primary source of livelihood and nutrition. ASEAN countries face varying degrees of water stress, and inefficiencies in water allocation can exacerbate food insecurity. This finding suggests that technical improvements, investments in irrigation infrastructure, and policies that support sustainable water use may help mitigate undernourishment.

The influence of GDP per capita further reinforces the economic dimension of food security. Higher income levels provide households with the ability to access adequate and nutritious food, thereby lowering undernourishment rates. However, the relatively weaker significance level also indicates that income alone may not fully capture disparities in food access, as issues such as inequality, rural-urban divides, and food price volatility can mediate this relationship. Therefore, while economic growth remains important, complementary measures are needed to ensure that its benefits reach vulnerable populations.

Interestingly, variables such as access to safely managed water and sanitation as well as nutrient balance did not show significant effects in the model. This does not necessarily mean that these factors are irrelevant but rather suggests that their influence may be indirect or conditional on other socioeconomic and environmental contexts. For instance, improvements in sanitation may take time to translate into measurable changes in undernourishment, while nutrient balance at the national level may not directly

reflect dietary quality or individual nutritional outcomes. This points to the complexity of food security, which is shaped by multidimensional and interrelated drivers.

The heterogeneity observed in the country effects further emphasizes that ASEAN nations differ in their structural and institutional conditions influencing food security. Countries such as the Philippines and Laos demonstrate higher country effects, suggesting the existence of unobserved factors—such as governance quality, agricultural policies, or cultural food consumption patterns—that continue to shape undernourishment outcomes. By contrast, Malaysia's relatively low country effect highlights the role of stronger institutional frameworks, economic diversification, and more developed food systems in mitigating food insecurity. This heterogeneity underscores the need for context-specific approaches rather than a one-size-fits-all policy solution.

From a policy perspective, the results highlight the dual importance of external drivers such as trade and internal capacity-building through efficient resource management and income growth. Regional cooperation in trade should be complemented by national policies that enhance agricultural resilience, promote inclusive economic development, and address systemic inequalities. Moreover, ASEAN can benefit from cross-country learning, where best practices in resource efficiency, food distribution systems, and social protection programs are shared and adapted to local contexts.

This study illustrates that food security in ASEAN is not solely determined by economic growth or agricultural capacity but rather emerges from the interaction of trade, resource efficiency, and country-specific factors. Strengthening these dimensions simultaneously may provide a more sustainable pathway toward reducing undernourishment in the region. Future research could further explore the role of institutional quality, climate change, and regional cooperation mechanisms to better capture the multidimensional nature of food security in ASEAN.

From a policy standpoint, the results imply that ASEAN food security strategies should treat trade not as a standalone instrument but as part of a coordinated package that links market integration to distribution capacity and sustainable production. Given that food security is multidimensional and that PoU captures chronic deficits in dietary energy intake, policy attention should prioritise mechanisms that translate regional trade gains into reliable household access, particularly through logistics, price stabilisation, and targeted safety nets [22,23,25]. At the same time, regional integration should be aligned with environmental sustainability, because growth-oriented trade expansion can intensify resource pressures and emissions unless accompanied by coherent green financing and regulatory frameworks [35]. This reinforces the case for policy convergence that simultaneously strengthens intra-ASEAN food flows and safeguards longrun resilience through investment in efficient, climate-compatible infrastructure.

For future research, the heterogeneity evident in country effects indicates that pooled estimates may conceal dynamic adjustments and structural breaks in trade–food security relationships. Methodological extensions that account for persistence and evolving trade structure, including dynamic panel specifications, would be well suited to capture these trajectories and to test whether export sophistication and broader structural transformation condition the food security dividend from trade [36]. In addition, rigorous pre-estimation diagnostics should be adopted to address non-stationarity and improve inference in long panels, including established panel unit root procedures [37]. These

steps would strengthen causal credibility and allow subsequent work to integrate institutional quality, climate shocks, and evolving regional agreements into a more comprehensive empirical account of food security in ASEAN.

6 Conclusion

This study provides empirical evidence that trade plays a crucial role in reducing undernourishment across ASEAN countries, demonstrating that greater integration into international markets contributes positively to food security. Alongside trade, water use efficiency and income levels also emerge as important determinants, reinforcing the interplay between economic and environmental factors in shaping nutritional outcomes. The results indicate that while some variables did not show direct significance, the overall framework highlights the multidimensional nature of food security.

The country effects analysis reveals that ASEAN nations differ significantly in their structural and institutional conditions, with some countries experiencing stronger unobserved influences on food insecurity than others. This underscores the heterogeneity of the region and suggests that food security challenges are not uniform, but instead shaped by unique national characteristics.

The findings emphasize that food security in ASEAN cannot be addressed solely through economic growth but requires a combination of policies that leverage trade opportunities, improve resource efficiency, and address structural disparities. A regional approach complemented by national-level interventions will be necessary to ensure sustainable progress in reducing undernourishment.

ASEAN countries should continue to strengthen regional trade cooperation to ensure a stable and diverse food supply. Reducing trade barriers, improving cross-border logistics, and harmonizing food safety standards can facilitate smoother flows of agricultural products, making food more affordable and accessible. At the same time, regional trade agreements should be designed to safeguard vulnerable groups by ensuring that food imports do not undermine local farmers' livelihoods.

Improving water use efficiency must be prioritized, particularly in agricultural production, which consumes the majority of water resources. Investments in modern irrigation systems, adoption of water-saving technologies, and promotion of sustainable farming practices can enhance productivity while conserving water. Regional cooperation in sharing technology and best practices could accelerate progress in this area.

Economic growth policies should be inclusive, ensuring that rising incomes translate into better access to food for all population groups. Social protection programs such as targeted subsidies, food vouchers, or conditional cash transfers can help vulnerable households overcome barriers to adequate nutrition. Additionally, policies addressing rural-urban disparities are critical, given that food insecurity often persists in rural communities despite overall income growth.

The insignificant effect of sanitation and nutrient balance suggests the need for more integrated and long-term approaches. Governments should invest in health and sanitation infrastructure, nutrition education programs, and food fortification initiatives to

ensure that improvements in access to food are complemented by better dietary quality and public health outcomes.

Given the variation in country-specific effects, ASEAN should promote cross-country learning and tailored policy approaches. Countries with stronger institutional frameworks, such as Malaysia, can serve as models for others by sharing successful strategies in governance, food distribution, and social safety nets. Meanwhile, countries with higher food insecurity should focus on strengthening institutional capacity and governance to address underlying structural weaknesses. By combining regional cooperation with national reforms, ASEAN can make more effective progress toward achieving food security for all its members.

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