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Article

# Do Income Growth and Agricultural Value Added Reduce Undernourishment? Panel Evidence from Developing Countries

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## Abstract

Food insecurity and undernourishment remain persistent challenges in developing countries, particularly under conditions of economic volatility, income inequality, food price instability, and increasing pressure on food systems. This study examines the macroeconomic and structural determinants of undernourishment in developing countries within the broader framework of sustainable food systems. The analysis focuses on GDP per capita, agricultural value added, and inflation, while urbanization and trade openness are included as control variables. An unbalanced panel dataset covering 72 developing countries over the period 2010–2023 is employed. Fixed effects and random effects panel models are estimated to assess the robustness of the empirical relationships. The Hausman test does not reject the random effects specification, suggesting that the random effects estimator is statistically acceptable. Nevertheless, fixed effects results are also reported to account for unobserved country- and time-specific heterogeneity. The empirical findings show that GDP per capita has a negative and statistically significant effect on undernourishment across both model specifications, indicating that higher income levels are associated with improved food access and better nutritional outcomes. Inflation has a positive and statistically significant effect, suggesting that rising prices may weaken household purchasing power and increase undernourishment. Agricultural value added is positive but statistically insignificant, implying that agricultural expansion alone may not be sufficient to reduce undernourishment unless supported by improvements in productivity, distribution, food access, and institutional efficiency. Urbanization and trade openness generally show negative associations with undernourishment, although their statistical significance varies across model specifications. From a sustainability perspective, reducing undernourishment requires more than aggregate income growth or agricultural expansion. Policies should strengthen resilient food systems, improve agricultural productivity, enhance social protection mechanisms, stabilize food prices, and ensure equitable access to affordable and nutritious food. This study contributes to the literature by providing recent panel-based evidence on the joint role of income, agricultural structure, inflation, urbanization, and trade openness in explaining undernourishment, and by offering policy-relevant insights for designing sustainable and inclusive food systems in developing countries.

**Keywords:** food security; undernourishment; GDP per capita; inflation; agricultural value added; urbanization; trade openness; panel data; sustainable food systems; developing countries

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## 1. Introduction

Food insecurity and undernourishment remain persistent global challenges, particularly in developing countries facing rapid population growth, income inequality, economic instability, climate change, and increasing pressure on food systems. According to the Food and Agriculture Organization (FAO, 2025), approximately 673 million people worldwide suffered from hunger in 2024, representing about 8.2% of the global population, while nearly 2.3 billion individuals

experienced moderate or severe food insecurity. These figures indicate that food insecurity is not merely a problem of food availability, but a multidimensional development challenge shaped by economic, agricultural, demographic, institutional, and sustainability-related factors. Therefore, reducing undernourishment requires integrated policy responses that simultaneously address income constraints, agricultural production capacity, price stability, structural transformation, and equitable access to affordable and nutritious food.

Food security is shaped by the interaction of income, agricultural production, price dynamics, demographic transformation, and market integration. Income determines households' ability to access sufficient and nutritious food, while agricultural production affects food availability and the functioning of domestic food systems. At the same time, food prices and inflation directly influence purchasing power, particularly among low-income households whose food expenditures account for a large share of total income. Urbanization may affect food security through infrastructure, employment opportunities, market access, and access to basic services, whereas trade openness may influence food availability and price stability through international market integration.

GDP per capita is widely recognized as one of the most important determinants of food access. Higher income levels enable households to improve both the quantity and quality of food consumption (World Bank, 2023a; FAO, 2022). In low- and middle-income countries, insufficient purchasing power remains a primary driver of food insecurity, whereas income growth facilitates dietary diversification and improved nutritional intake (Darmon & Drewnowski, 2008; Smith & Haddad, 2015). Nevertheless, income growth alone may not be sufficient to reduce undernourishment if it is not accompanied by inclusive distribution mechanisms, social protection policies, and improved access to affordable and nutritious food.

Agricultural production and agricultural value added also play an important role in food security. Theoretically, increases in agricultural output are expected to enhance food availability and reduce undernourishment. However, empirical evidence suggests that this relationship is not always direct or uniform across countries. The impact of agricultural growth depends on structural factors such as productivity, income distribution, rural infrastructure, market access, and the capacity of food systems to deliver affordable and nutritious food to vulnerable populations (Fan & Brzeska, 2014; Headey & Ruel, 2023). Therefore, in developing countries, agricultural value added should be interpreted not only as an indicator of production capacity, but also within the broader context of rural poverty, structural transformation, food distribution, and food system efficiency.

Food prices and inflation represent another key dimension of food security. Rising prices can significantly reduce household purchasing power, particularly among vulnerable groups, thereby increasing the risk of undernourishment. Previous studies have shown that global food price increases can exacerbate poverty and food insecurity (Ivanic & Martin, 2008). Similarly, the World Bank (2024) highlights that domestic food price inflation remains high in many low- and middle-income countries. However, the effects of inflation may vary across countries depending on domestic food markets, policy interventions, social protection systems, and institutional capacity. This suggests that the relationship between inflation and undernourishment should be examined within a broader macroeconomic and structural framework.

Urbanization and trade openness are also relevant for understanding undernourishment in developing countries. Urbanization can improve access to infrastructure, food markets, education, health services, and employment opportunities. However, it may also create new vulnerabilities when urban growth is accompanied by inequality, informal employment, inadequate housing, or insufficient social protection. Similarly, trade openness can improve food availability by facilitating access to imported food products and integrating domestic markets with global supply chains. At the same time, its effects may depend on exposure to global price volatility, domestic production capacity, exchange rate movements, and the ability of vulnerable households to access food. Therefore, both urbanization and trade openness may have context-dependent effects on food security outcomes.

Although previous studies have examined income, agricultural production, food prices, urbanization, and trade openness in relation to food security, fewer studies jointly assess these

macroeconomic and structural factors within a recent multi-country panel framework for developing economies. This gap is important because undernourishment is shaped not by a single determinant, but by the interaction of purchasing power, production capacity, price dynamics, demographic transformation, and market integration. A comprehensive empirical approach is therefore needed to capture the multidimensional nature of food security and to link macroeconomic determinants with sustainable food system outcomes.

This study addresses this gap by examining the effects of GDP per capita, agricultural value added, and inflation on undernourishment in 72 developing countries over the period 2010–2023. Urbanization and trade openness are included as control variables to reduce omitted variable bias and to better capture the structural determinants of food security. Fixed effects and random effects panel data models are estimated, and the Hausman test is used to compare alternative model specifications. In this study, the sustainable food systems perspective is used as an interpretive framework for understanding how income, agricultural structure, price stability, urbanization, and trade openness jointly shape food security outcomes.

The study contributes to the literature in three main ways. First, it jointly examines income, agricultural production, price dynamics, urbanization, and trade openness within a unified empirical framework. Second, it employs a recent unbalanced panel dataset covering 72 developing countries over the period 2010–2023, allowing for cross-country comparisons. Third, it provides empirical evidence showing that income growth and price stability are more consistent determinants of undernourishment than agricultural value added alone, thereby offering policy-relevant insights for designing inclusive, resilient, and sustainable food systems.

## 2. Literature Review

### 2.1. Income and Food Security

Income level is widely recognized as one of the most fundamental determinants of food security, particularly in developing countries where household access to food largely depends on purchasing power. In such contexts, income fluctuations may directly affect the ability of households to obtain sufficient, safe, and nutritious food. The International Monetary Fund (2024) identifies income volatility as an important factor influencing food insecurity in recent years. Similarly, Shumiye et al. (2026) demonstrate that income growth enhances households' resilience to food insecurity by improving their capacity to cope with economic shocks.

However, the relationship between income and food security should not be interpreted solely through aggregate economic growth. The extent to which income growth translates into improved food security depends on distributional conditions, financial access, institutional quality, and social protection mechanisms. Mahase-Forgenie and Forgenie (2025) show that increases in GDP per capita significantly reduce food insecurity, but this effect becomes stronger when accompanied by improved financial access and institutional quality. These findings suggest that income growth is a necessary but not sufficient condition for reducing undernourishment. Therefore, the income–food security relationship should be evaluated within a broader socioeconomic and institutional framework that considers both purchasing power and the inclusiveness of growth.

### 2.2. Agricultural Production and Food Supply

Agricultural production capacity represents a key determinant of the supply dimension of food security. From a conventional perspective, increases in agricultural output are expected to enhance food availability and reduce undernourishment. However, recent empirical evidence indicates that this relationship is more complex and context-dependent, particularly in developing countries where agricultural systems are often characterized by low productivity, limited infrastructure, unequal access to markets, and vulnerability to climatic shocks.

Islam (2025) emphasizes that sustainable agricultural practices not only increase production but also strengthen long-term food security by enhancing system resilience. Similarly, Omay et al. (2025)

demonstrate that food production, land use, and climate conditions jointly influence food security outcomes, underscoring the importance of environmental and structural factors. These studies indicate that agricultural production cannot be evaluated only in terms of output levels; rather, its contribution to food security depends on how effectively production is linked to access, affordability, distribution, and sustainability.

Furthermore, Dardeer and Shaheen (2025) argue that the effects of agricultural production on food security vary depending on country-specific structural conditions. This suggests that agricultural growth alone is insufficient to guarantee food security unless it is supported by institutional quality, infrastructure, productivity improvements, efficient markets, and inclusive distribution mechanisms. Consequently, agricultural value added in developing countries should be interpreted carefully. A higher agricultural share may reflect production potential, but it may also indicate structural dependence on agriculture, low productivity, rural poverty, and limited economic diversification. Therefore, the relationship between agricultural value added and undernourishment is expected to be conditional rather than automatically negative.

### *2.3. Food Prices, Inflation and Food Security*

Food prices and inflation constitute critical determinants of the demand dimension of food security. Low-income households are disproportionately affected by increases in food prices because food expenditures account for a relatively large share of their total income. As a result, inflationary pressures may reduce real purchasing power, limit access to nutritious food, and increase vulnerability to undernourishment. The literature generally provides strong evidence that inflation has an adverse effect on food security.

Gahamanyi and Tchouassi (2026) find that inflation significantly reduces food security in African countries. Likewise, numerous studies show that rising food prices erode purchasing power and increase the risk of undernourishment. However, the effect of inflation is not necessarily uniform across countries. Its impact may be mediated by policy interventions, market structures, social protection systems, and institutional capacity. Mahase-Forgenie and Forgenie (2025) report that inflation is not always statistically significant in empirical models, although it may still exert indirect effects on food systems.

These findings indicate that the relationship between inflation and food security should be interpreted within a broader macroeconomic and institutional framework rather than as a purely direct price effect. In developing countries, where households are more vulnerable to food price shocks and social protection systems may be weaker, inflation can play an important role in worsening undernourishment by reducing the affordability of adequate and nutritious food.

### *2.4. Urbanization, Trade Openness and Food Security*

Urbanization and trade openness are increasingly important structural factors in food security research. Urbanization may improve food security by expanding access to infrastructure, employment opportunities, health services, education, and food markets. In urban areas, households may benefit from more diversified food supply chains and better access to public services. However, rapid urbanization may also generate new vulnerabilities, particularly when it is accompanied by income inequality, informal employment, inadequate housing, and weak social protection systems. Therefore, the effect of urbanization on food security is likely to be context-dependent.

Trade openness may also influence food security through several channels. Greater integration into international markets can improve food availability by increasing access to imported food products and diversifying food supply. It may also contribute to price stabilization when domestic production is insufficient. However, trade openness can expose countries to external price volatility, exchange rate fluctuations, and global supply chain disruptions. Therefore, the food security effects of trade openness depend on domestic production capacity, market integration, institutional quality, macroeconomic stability, and the ability of vulnerable households to access food.

Although urbanization and trade openness are not always treated as core determinants in food security models, their inclusion is important for reducing omitted variable bias and capturing broader structural differences across developing countries. In the context of this study, these variables are included as control variables to account for demographic transformation, market access, infrastructure conditions, and international economic integration.

### 2.5. Sustainability and Food Systems

In recent years, food security research has increasingly incorporated a sustainability perspective. This approach emphasizes that food security should be evaluated not only in terms of production and access, but also in relation to environmental sustainability, resource efficiency, resilience, and social inclusion. From this perspective, reducing undernourishment requires more than increasing aggregate food production; it also requires food systems that are inclusive, resilient, affordable, and capable of delivering nutritious food to vulnerable populations.

Islam (2025) highlights the critical role of sustainable agricultural practices in ensuring long-term food security, while Moretti et al. (2025) demonstrate that the interactions between food demand, production, and environmental sustainability are central to the future of global food systems. These findings underline that sustainable food systems are essential not only for improving food security but also for maintaining ecological balance and ensuring intergenerational equity.

Although the existing literature provides substantial evidence on the individual effects of income, agricultural production, and inflation on food security, studies that jointly examine these factors together with urbanization and trade openness within a sustainability-oriented panel framework remain relatively limited. This gap is particularly important because undernourishment is shaped by the combined effects of purchasing power, agricultural structure, price dynamics, demographic transformation, and market integration.

This study addresses this gap by jointly analyzing GDP per capita, agricultural value added, inflation, urbanization, and trade openness within a unified empirical framework. By employing a panel dataset covering developing countries, the study offers a comparative perspective and contributes to the literature by providing a more integrated understanding of the macroeconomic and structural determinants of undernourishment within a sustainability-oriented food systems framework.

## 3. Materials and Methods

### 3.1. Data and Sample

The dataset used in this study consists of annual observations for 72 developing countries over the period 2010–2023. The data were obtained from the World Development Indicators (WDI) database of the World Bank, which provides internationally comparable macroeconomic and development indicators (World Bank, 2023b). The WDI database is widely used in empirical studies examining the macroeconomic determinants of food security, undernourishment, and related development outcomes (Headey, 2013; Bellemare, 2015; Timmer, 2010).

The sample is restricted to developing economies because these countries are generally more vulnerable to food insecurity, income instability, agricultural constraints, and food price fluctuations. In many developing countries, structural economic limitations, high dependence on agriculture, and the relatively large share of food expenditures in household budgets make food security highly sensitive to changes in income, agricultural performance, and inflationary pressures (Friedman & Thomas, 2008; Headey & Fan, 2008). Therefore, focusing on developing countries provides an appropriate empirical setting for examining the macroeconomic and structural determinants of undernourishment.

Due to missing observations across some countries and years, the dataset has an unbalanced panel structure. Rather than excluding all countries with incomplete observations, the analysis retains available data in order to preserve cross-country variation and avoid unnecessary information

loss. This approach is appropriate because the exclusion of countries with partial data could reduce the representativeness of the sample and weaken the comparative nature of the analysis. The final estimation sample includes 976 panel observations. The use of unbalanced panels is common in cross-country empirical research and is appropriate when missingness does not prevent reliable estimation of model parameters (Baltagi, 2021; Wooldridge, 2010).

The dependent variable of the study is undernourishment, which is used as a proxy for food insecurity. The main explanatory variables are GDP per capita, agricultural value added, and inflation. GDP per capita represents the income dimension of food security and reflects household purchasing power. Agricultural value added captures the contribution of agriculture, forestry, and fishing to the economy and reflects the structural role of agriculture in developing countries. Inflation represents price-related pressures that may affect food access by reducing real purchasing power. In the extended model, urbanization and trade openness are included as control variables to reduce omitted variable bias and account for broader structural differences across developing countries. These variables are widely used in the literature examining the determinants of food security and undernourishment (Headey, 2013; Bellemare, 2015; Smith & Haddad, 2015).

The definitions, measurements, expected effects, and data sources of the variables used in the empirical analysis are presented in Table 1. Descriptive statistics are reported in Table 2.

**Table 1.** Variable Definitions and Expected Signs.

Variable	Symbol	Definition	Measurement / Proxy	Expected Effect on Undernourishment	Data Source
Undernourishment	UNDERNOURISHMENT	Dependent variable representing the prevalence of food insecurity and inadequate dietary energy intake	Prevalence of undernourishment (% of population)	Dependent variable	FAO / World Bank WDI
GDP per capita	GDP_PER	Represents income level and household purchasing power	GDP per capita, preferably constant US\$	Negative	World Bank WDI
Agricultural value added	AGRI	Captures the contribution of agriculture, forestry, and fishing to the economy	Agriculture, forestry, and fishing, value added (% of GDP)	Negative or context-dependent	World Bank WDI
Inflation	INFLATION	Represents price instability and pressure on household purchasing power	Inflation rate or food inflation (annual %)	Positive	World Bank WDI
Urbanization	URBAN	Controls for demographic structure, market access, infrastructure, and urban food access conditions	Urban population (% of total population)	Ambiguous / context-dependent	World Bank WDI

Variable	Symbol	Definition	Measurement / Proxy	Expected Effect on Undernourishment	Data Source
Trade openness	TRADE	Controls for integration into international markets and exposure to external supply and price shocks	Trade (% of GDP)	Ambiguous / context-dependent	World Bank WDI

Table 2. Descriptive Statistics.

Variable	Obs.	Mean	Std. Dev.	Minimum	Maximum
UNDERNOURISHMENT	976	9.301	7.949	2.500	41.600
GDP_PER	976	4,411.982	3,360.427	422.924	16,877.150
AGRI	976	12.966	8.515	0.966	44.331
INFLATION	976	7.167	13.481	-3.749	221.342
URBAN	976	55.005	19.080	15.963	92.682
TRADE	976	71.723	31.655	20.598	186.676

**Note:** UNDERNOURISHMENT denotes the prevalence of undernourishment; GDP\_PER represents GDP per capita; AGRI refers to agricultural value added; INFLATION denotes inflation; URBAN represents urban population; and TRADE refers to trade openness.

Table 2 summarizes the distributional characteristics of the variables used in the empirical analysis. The variation observed across countries and years supports the use of panel data methods, as the dataset captures both cross-country differences and temporal changes in undernourishment and its macroeconomic and structural determinants. The mean value of undernourishment is 9.301, with a minimum of 2.500 and a maximum of 41.600, indicating considerable heterogeneity in food insecurity across the sampled developing countries.

GDP per capita also exhibits substantial variation, with an average value of 4411.982 and a standard deviation of 3360.427. This dispersion reflects the income heterogeneity among the countries included in the sample. Agricultural value added has a mean value of 12.966, suggesting that agriculture remains an important component of economic activity in many developing countries. However, the relatively large standard deviation indicates substantial differences in the structural role of agriculture across countries.

Inflation displays considerable variability, with an average value of 7.167 and a maximum value of 221.342, reflecting the presence of severe price instability in some country-year observations. Urbanization averages 55.005, indicating that the sample includes countries at different stages of demographic and structural transformation. Trade openness has a mean value of 71.723, suggesting a relatively high degree of integration into international markets, although the wide range between the minimum and maximum values points to notable cross-country differences in external economic integration.

Overall, the descriptive statistics indicate substantial heterogeneity across the sampled developing countries. This heterogeneity supports the use of panel data techniques that can account for both country-specific characteristics and time-related variation in the determinants of undernourishment.

### 3.2. Research Hypotheses

Based on the theoretical arguments and empirical evidence discussed in the literature review, this study develops five hypotheses concerning the macroeconomic and structural determinants of undernourishment in developing countries. The hypotheses reflect the income-related, agricultural, price-related, demographic, and trade-related dimensions of food security.

**H1:** *GDP per capita is expected to have a negative effect on undernourishment in developing countries.*

Higher income levels are expected to reduce undernourishment by increasing household purchasing power and improving access to sufficient, safe, and nutritious food. Therefore, an increase in GDP per capita is expected to be associated with lower levels of undernourishment.

**H2:** *Agricultural value added is expected to be associated with undernourishment; however, the direction and magnitude of this relationship may depend on the structural characteristics of developing economies.*

Although agricultural value added may improve food availability, its effect on undernourishment is not necessarily direct. The relationship may depend on agricultural productivity, income distribution, rural infrastructure, market access, food distribution systems, and the inclusiveness of agricultural growth. Therefore, the effect of agricultural value added is expected to be context-dependent.

**H3:** *Inflation is expected to have a positive effect on undernourishment in developing countries.*

Inflation may increase undernourishment by reducing real household purchasing power and limiting access to affordable and nutritious food. This effect is expected to be particularly important in developing countries where food expenditures constitute a relatively large share of household income.

**H4:** *Urbanization is expected to be associated with undernourishment, but its effect may vary depending on urban development conditions.*

Urbanization may reduce undernourishment by improving access to infrastructure, employment opportunities, public services, food markets, health services, and education. However, rapid or unequal urbanization may also increase vulnerability when accompanied by informal employment, inadequate housing, income inequality, or weak social protection. Therefore, the effect of urbanization on undernourishment is expected to be context-dependent.

**H5:** *Trade openness is expected to be associated with undernourishment, but the direction and strength of this relationship may depend on domestic and international market conditions.*

Trade openness may reduce undernourishment by improving food availability, facilitating access to imported food products, and supporting market integration. However, it may also increase exposure to global price volatility, exchange rate fluctuations, and supply chain disruptions. Therefore, the effect of trade openness is expected to depend on domestic production capacity, market stability, and the ability of vulnerable households to access food.

Together, these hypotheses provide a comprehensive framework for examining the macroeconomic and structural determinants of undernourishment in developing countries. By incorporating income, agricultural structure, inflation, urbanization, and trade openness within a unified empirical model, the study evaluates food security outcomes from a multidimensional perspective.

### 3.3. Model Specification and Estimation Strategy

To examine the relationship between macroeconomic and structural determinants and undernourishment, this study specifies a panel data model in which undernourishment is explained

by income level, agricultural value added, inflation, urbanization, and trade openness. The baseline empirical model is expressed as follows:

$$\begin{aligned} \text{UNDERNOURISHMENT}_{it} = & \beta_0 + \beta_1 \text{GDP\_PER}_{it} + \beta_2 \text{AGRI}_{it} + \beta_3 \text{INFLATION}_{it} + \beta_4 \text{URBAN}_{it} \\ & + \beta_5 \text{TRADE}_{it} + \mu_i + \lambda_t + \varepsilon_{it} \end{aligned}$$

where  $i$  denotes countries and  $t$  denotes time periods. UNDERNOURISHMENT represents the prevalence of undernourishment. GDP\_PER denotes GDP per capita, AGRI represents agricultural value added, INFLATION denotes inflation, URBAN represents urbanization, and TRADE denotes trade openness. The term  $\mu_i$  represents country-specific effects,  $\lambda_t$  captures time effects, and  $\varepsilon_{it}$  is the idiosyncratic error term.

The inclusion of country-specific effects is important because developing countries differ substantially in terms of geographical conditions, institutional structures, agricultural systems, historical development paths, policy environments, and long-term socioeconomic characteristics. These unobserved factors may influence both the explanatory variables and undernourishment outcomes. By accounting for country-specific heterogeneity, the model reduces the risk that time-invariant country characteristics bias the estimated relationships. In addition, time effects are included to control for common shocks affecting all countries in a given year, such as global food price movements, international economic disruptions, climate-related pressures, and broad macroeconomic fluctuations. This specification is particularly appropriate for macro-panel data settings in which both cross-country heterogeneity and time-specific shocks may affect food security outcomes (Baltagi, 2021; Wooldridge, 2010).

Both fixed effects (FE) and random effects (RE) estimators are employed to examine the robustness of the empirical relationships. The fixed effects estimator allows unobserved country-specific characteristics to be correlated with the explanatory variables and is therefore useful when country-level heterogeneity may influence the estimated coefficients. In contrast, the random effects estimator assumes that unobserved country-specific effects are uncorrelated with the regressors and provides more efficient estimates when this assumption holds (Baltagi, 2021; Wooldridge, 2010). Estimating both specifications allows the study to evaluate whether the signs, magnitudes, and statistical significance of the key coefficients are sensitive to alternative assumptions regarding unobserved heterogeneity.

To determine the statistically appropriate model specification, the Hausman test is applied (Hausman, 1978). The Hausman test evaluates whether the random effects estimator is consistent by testing whether there is a systematic difference between the fixed effects and random effects estimates. The null hypothesis states that the random effects estimator is consistent and efficient. If the null hypothesis is rejected, the fixed effects estimator is preferred because the random effects assumption is violated. If the null hypothesis is not rejected, the random effects estimator may be considered statistically acceptable. In this study, the Hausman test is used as the main model selection criterion, while both FE and RE results are reported to provide a robustness-oriented comparison.

Panel data models may be affected by heteroskedasticity, serial correlation, and cross-sectional dependence, all of which can bias standard errors and lead to misleading statistical inference. This concern is particularly relevant in cross-country macro-panel datasets, where countries may differ in size, institutional capacity, economic structure, and exposure to common external shocks. To improve the reliability of statistical inference, heteroskedasticity-consistent covariance estimators are employed following Huber (1967) and White (1980). Robust standard errors help produce more reliable inference in the presence of non-constant error variance and potential misspecification of the error structure (Stock & Watson, 2008). Although the dataset has an unbalanced panel structure, the use of appropriate panel data estimators and robust inference procedures helps mitigate potential estimation problems and supports the validity of the empirical results (Wooldridge, 2010; Baltagi, 2021; Greene, 2018).

A potential methodological concern in the empirical analysis is endogeneity, particularly the possibility of reverse causality between income and undernourishment. While higher income levels

are expected to reduce undernourishment by improving purchasing power and access to food, widespread undernourishment may also adversely affect labor productivity, human capital accumulation, and long-term economic growth. Similar concerns may arise for other explanatory variables, as food insecurity can be both a cause and a consequence of broader socioeconomic conditions. Due to data limitations and the macro-panel structure of the dataset, this study does not employ instrumental variable techniques. Nevertheless, the inclusion of country-specific effects helps reduce omitted variable bias by controlling for unobserved time-invariant country characteristics, while time effects account for common shocks across years. Therefore, the estimated coefficients should be interpreted as conditional associations rather than strict causal effects.

Future research may extend this analysis by employing dynamic panel data models, such as the Generalized Method of Moments (GMM), or instrumental variable approaches to address potential endogeneity more explicitly. Such extensions would be particularly useful for examining lagged relationships between income, inflation, agricultural structure, and undernourishment, as food security outcomes may respond to macroeconomic and structural changes over time.

### 3.4. Diagnostic Tests and Robustness Checks

To ensure the reliability of the empirical findings, several diagnostic and robustness checks were conducted. In panel data models, potential econometric issues such as multicollinearity, heteroskedasticity, serial correlation, and cross-sectional dependence may affect the efficiency of estimates and the reliability of statistical inference. These issues are particularly relevant in macro-panel datasets, where countries may differ substantially in terms of economic structure, institutional capacity, agricultural systems, and exposure to common global shocks (Baltagi, 2021; Wooldridge, 2010).

First, the correlation structure among the variables was examined to identify potential multicollinearity concerns. Table 3 presents the pairwise correlations among the variables included in the empirical analysis. The correlation results indicate that undernourishment is negatively associated with GDP per capita and urbanization, suggesting that higher income levels and greater urbanization tend to be linked with lower levels of undernourishment. Trade openness is also negatively correlated with undernourishment, although the association is relatively weak. In contrast, agricultural value added is positively correlated with undernourishment, which may reflect the structural characteristics of developing economies where a higher agricultural share is often associated with lower income levels, weaker economic diversification, and structural dependence on agriculture. Inflation shows only a weak bivariate association with undernourishment.

Although some explanatory variables, particularly GDP per capita, agricultural value added, and urbanization, show moderate correlations, all pairwise correlation coefficients remain below the commonly used threshold of 0.80. This suggests that severe multicollinearity is unlikely. However, since pairwise correlations alone are not sufficient to assess multicollinearity, a Variance Inflation Factor (VIF) test was also conducted. The VIF results are presented in Table 3.

**Table 3.** Variance Inflation Factor Results.

Variable	R-squared	VIF
GDP_PER	0.596668	2.48
AGRI	0.678918	3.11
INFLATION	0.032749	1.03
URBAN	0.598263	2.49
TRADE	0.096039	1.11

**Note:** VIF values below 10 indicate that multicollinearity does not pose a serious problem in the model.

Table 3 shows that the VIF values range from 1.03 to 3.11, with the highest value observed for agricultural value added. Since all VIF values are well below the commonly accepted threshold of 10, the results indicate that multicollinearity does not pose a serious problem in the empirical model. Therefore, GDP per capita, agricultural value added, inflation, urbanization, and trade openness can be included in the same regression specification without generating severe multicollinearity concerns.

To address potential heteroskedasticity and improve the reliability of inference, robust standard errors were used in the fixed effects specification. Heteroskedasticity-consistent covariance estimators are widely recommended in panel data settings where the assumption of constant error variance may be violated (White, 1980; Arellano, 1987). Robust standard errors help reduce the risk of misleading statistical inference, particularly in empirical applications involving heterogeneous countries and macroeconomic variables (Stock & Watson, 2008).

The study also considers potential serial correlation and cross-sectional dependence as relevant concerns in macro-panel data. Serial correlation may arise when shocks to undernourishment persist over time, while cross-sectional dependence may occur when countries are simultaneously affected by global food price movements, international economic disruptions, or other common shocks. These issues are commonly examined using the Wooldridge test for autocorrelation in panel data and the Pesaran test for cross-sectional dependence (Wooldridge, 2002; Pesaran, 2004; Pesaran, 2006). In cases where cross-sectional and temporal dependence are jointly present, advanced covariance estimators such as Driscoll–Kraay standard errors may be considered (Driscoll & Kraay, 1998; Hoechle, 2007).

Alternative model specifications were also estimated as robustness checks. In particular, fixed effects and random effects models were compared, and model selection was evaluated using the Hausman test. This approach helps assess whether the main findings are sensitive to alternative assumptions regarding unobserved country-specific heterogeneity. Such robustness checks are important because empirical results should not depend solely on one model assumption or estimation strategy (Leamer, 1983; Sala-i-Martin, 1997).

The Hausman test results are reported in Table 4. The null hypothesis of the Hausman test states that the random effects estimator is consistent. The test statistic is 4.328169, with a probability value of 0.5032. Since the probability value is greater than 0.05, the null hypothesis cannot be rejected. This indicates that the random effects estimator is statistically acceptable for the model. Nevertheless, the two-way fixed effects model is also reported as an alternative specification because it controls for both country-specific and time-specific heterogeneity.

**Table 4.** Hausman Test Results.

Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.	Decision
Cross-section random	4.328169	5	0.5032	Random effects not rejected

**Note:** The null hypothesis of the Hausman test states that the random effects estimator is consistent. Since the probability value is greater than 0.05, the null hypothesis cannot be rejected.

The dataset was initially processed using Microsoft Excel, where missing observations were identified, variable names were standardized, and the data were structured into panel format. Data cleaning included consistency checks, the removal of invalid observations, and the alignment of the country-year structure. The econometric analysis was subsequently conducted using EViews software, which is widely used for panel data estimation and macroeconomic modeling.

The results were interpreted based on coefficient signs, statistical significance, theoretical expectations, and economic relevance. In addition to statistical significance, emphasis was placed on the substantive interpretation of coefficients in order to derive meaningful and policy-relevant conclusions (Kennedy, 2008). The diagnostic and robustness checks are summarized in Table 5.

**Table 5.** Summary of Diagnostic and Robustness Checks.

Diagnostic / Robustness Check	Purpose	Result	Interpretation
VIF test	Multicollinearity	Max VIF = 3.11	No serious multicollinearity
Hausman test	FE vs. RE selection	p = 0.5032	Random effects not rejected
White cross-section robust SE	Heteroskedasticity / cross-sectional error structure	Applied	Robust standard errors used
Fixed effects specification	Country and time heterogeneity	Included	Controls for unobserved country- and period-specific factors
Random effects specification	Alternative model	Reported	Supported by Hausman test

**Note:** VIF denotes Variance Inflation Factor. FE refers to fixed effects, and RE refers to random effects.

Overall, the diagnostic and robustness checks support the reliability of the empirical analysis. The VIF results indicate that multicollinearity is not a serious concern, while the Hausman test suggests that the random effects estimator is statistically acceptable. At the same time, the reporting of two-way fixed effects results provides an additional robustness-oriented specification by controlling for unobserved country- and period-specific heterogeneity.

## 4. Results and Discussion

### 4.1. Panel Regression Results

The empirical results of the panel data analysis are presented in Table 6. To examine the determinants of undernourishment in developing countries, both two-way fixed effects and random effects panel models were estimated. The model includes GDP per capita, agricultural value added, and inflation as the main explanatory variables, while urbanization and trade openness are included as control variables.

**Table 6.** Fixed Effects and Random Effects Panel Regression Results.

Variable	Two-Way Fixed Effects Coef.	Robust Std. Error	Random Effects Coef.	Std. Error
C	16.93836***	3.315731	15.92923***	2.000758
GDP_PER	-0.000807***	0.000079	-0.000696***	0.000127
AGRI	0.024172	0.055283	0.051931	0.045335
INFLATION	0.013424***	0.004730	0.020777***	0.006973
URBAN	-0.062104	0.064468	-0.062587**	0.029849
TRADE	-0.014913*	0.008858	-0.012722*	0.007053
Observations	976		976	
Cross-sections	72		72	
R-squared	0.924855		0.089777	

Variable	Two-Way Fixed Effects Coef.	Robust Std. Error	Random Effects Coef.	Std. Error
Adjusted R-squared	0.917306		0.085086	
Country effects	Yes		Random	
Period effects	Yes		No	

**Note:** The dependent variable is UNDERNOURISHMENT. Robust standard errors are reported for the fixed effects model using White cross-section standard errors and covariance. The random effects model was estimated using Panel EGLS with cross-section random effects. \*\*\*, \*\*, and \* indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

The results indicate that GDP per capita has a negative and statistically significant coefficient in both model specifications. In the two-way fixed effects model, the coefficient of GDP per capita is -0.000807 and significant at the 1% level. In the random effects model, the coefficient is also negative and significant, with a value of -0.000696. These findings suggest that higher income levels are associated with lower levels of undernourishment in developing countries. This result is consistent with the view that income growth improves food access by strengthening household purchasing power and enabling more stable access to sufficient and nutritious food.

Inflation has a positive and statistically significant coefficient in both specifications. The coefficient is 0.013424 in the two-way fixed effects model and 0.020777 in the random effects model, both significant at the 1% level. This finding indicates that rising prices are associated with higher undernourishment, most likely through the erosion of household purchasing power. The result is particularly relevant for developing countries, where low-income households often allocate a large share of their income to food expenditures and are therefore highly vulnerable to price increases.

Agricultural value added has a positive but statistically insignificant coefficient in both models. This result suggests that a higher agricultural share in the economy does not automatically translate into lower undernourishment. Although agricultural expansion may increase food availability, its contribution to improved nutritional outcomes depends on productivity, income distribution, rural infrastructure, market access, and the efficiency of food distribution systems. Therefore, agricultural value added should be interpreted within the broader context of food system performance rather than as a direct indicator of improved food security.

Urbanization has a negative coefficient in both specifications, but it is statistically significant only in the random effects model. This finding suggests that urbanization may be associated with lower undernourishment through improved access to infrastructure, employment opportunities, public services, health facilities, and food markets. However, the lack of statistical significance in the fixed effects model indicates that the effect of urbanization should be interpreted cautiously. The observed relationship may partly reflect cross-country structural differences rather than purely within-country changes over time.

Trade openness also has a negative coefficient in both model specifications and is weakly statistically significant at the 10% level. This suggests that greater integration into international markets may contribute to reducing undernourishment by improving food availability, supporting access to imported food products, and facilitating market integration. However, the modest level of statistical significance indicates that the effect of trade openness may depend on domestic production capacity, exposure to global price volatility, exchange rate conditions, and the ability of vulnerable households to access food.

The explanatory power of the two-way fixed effects model is high, with an R-squared value of 0.924855. This value should be interpreted in light of the model specification. Since the fixed effects model includes both country and period effects, it captures persistent country-specific heterogeneity and common time-related shocks. Therefore, the high R-squared value does not necessarily indicate overfitting; rather, it reflects the ability of the model to account for structural heterogeneity across

countries and common temporal effects. By contrast, the random effects model reports a lower R-squared value of 0.089777, which is expected because it relies on a different treatment of unobserved country-level variation and does not include period fixed effects.

Overall, the regression results show that GDP per capita and inflation are the most consistent determinants of undernourishment across the two model specifications. Agricultural value added, urbanization, and trade openness show more context-dependent effects, suggesting that food security outcomes in developing countries are shaped not only by income and prices but also by broader structural and institutional conditions.

#### 4.2. Model Comparison and Robustness of Results

The comparison between fixed effects and random effects estimates provides useful evidence on the robustness of the empirical findings. As reported in Table 6, the signs of the main coefficients are generally consistent across the two specifications. GDP per capita remains negative and statistically significant in both models, indicating that the income–undernourishment relationship is robust to alternative panel estimators. Similarly, inflation remains positive and statistically significant across both specifications, confirming the importance of price stability for food security outcomes.

Agricultural value added is positive but statistically insignificant in both specifications. This indicates that the relationship between agricultural value added and undernourishment is not direct. In developing countries, a higher agricultural share may reflect structural dependence on agriculture, low productivity, rural poverty, limited market access, and unequal distribution of agricultural gains rather than effective food system performance. Consistent with this interpretation, Dardeer and Shaheen (2025) argue that the effects of agricultural growth on food security depend strongly on country-specific structural conditions, distribution mechanisms, and institutional factors.

The results for urbanization and trade openness also require careful interpretation. Urbanization is negative in both models, but it is statistically significant only in the random effects specification. This suggests that urbanization may reduce undernourishment through improved infrastructure, public services, market access, and employment opportunities, although its effect may largely reflect cross-country structural differences. Trade openness is negative and weakly significant in both specifications, suggesting that greater integration into international markets may improve food availability and market access. However, the modest level of significance indicates that the effect of trade openness may depend on domestic production capacity, market structure, exposure to global price volatility, and the ability of vulnerable households to access food.

The Hausman test results reported in Table 4 indicate that the random effects estimator is not rejected. Therefore, the random effects model may be considered statistically acceptable. Nevertheless, the two-way fixed effects model is also reported because it controls for both country-specific and time-specific heterogeneity. This is particularly relevant in macro-panel datasets characterized by substantial structural differences across countries. As noted in the panel data literature, unobserved heterogeneity may influence the interpretation of estimated relationships, especially when countries differ in terms of income levels, agricultural structures, institutional capacity, social protection systems, market access, and food system resilience (Hausman, 1978; Wooldridge, 2010; Baltagi, 2021; Greene, 2018; Hsiao, 2014).

Overall, the model comparison suggests that the main findings, particularly the negative association between GDP per capita and undernourishment and the positive association between inflation and undernourishment, remain consistent across alternative panel specifications. This supports the reliability of the empirical results while also indicating that agricultural value added, urbanization, and trade openness should be interpreted within the broader structural context of developing countries.

#### 4.3. Discussion of Findings

The empirical findings highlight the central role of income and price stability in explaining undernourishment in developing countries. GDP per capita has a negative and statistically significant

association with undernourishment across both fixed effects and random effects specifications. This finding suggests that higher income levels improve access to food and contribute to better nutritional outcomes by strengthening household purchasing power. The result is consistent with the broader literature emphasizing income as a key determinant of food security. The Food and Agriculture Organization (2023) highlights that income growth contributes to food security by reducing poverty and expanding access to adequate and balanced diets. Similarly, the World Bank (2023) identifies insufficient purchasing power as one of the main drivers of food insecurity in low-income countries.

Inflation has a positive and statistically significant association with undernourishment in both model specifications. This finding supports the argument that rising prices worsen food access by reducing real household purchasing power. The result is consistent with the dominant view in the literature, which identifies food price increases and inflationary pressures as important drivers of food insecurity. The World Bank (2024) reports that global food inflation has generated substantial welfare losses, especially among vulnerable populations. Similarly, Headey and Ruel (2023) provide evidence that increases in food prices negatively affect nutrition outcomes.

The positive but statistically insignificant coefficient of agricultural value added indicates that agricultural expansion alone may not be sufficient to reduce undernourishment. This finding is consistent with the literature emphasizing that the relationship between agricultural production and nutrition is indirect and mediated by structural factors. The Food and Agriculture Organization (2022) states that agricultural growth contributes to food security only when supported by equitable distribution and institutional effectiveness. In addition, Headey and Ruel (2023) show that the impact of agricultural production on nutrition is conditional upon income distribution, infrastructure, and market integration. Therefore, the insignificant coefficient of agricultural value added in this study reflects the context-dependent nature of the relationship between agricultural production and food security.

Urbanization and trade openness also provide relevant but more nuanced insights. Urbanization is negatively associated with undernourishment, although its statistical significance varies across model specifications. This suggests that urbanization may contribute to lower undernourishment through improved access to infrastructure, employment opportunities, public services, health facilities, and food markets. However, the effect of urbanization should be interpreted cautiously because rapid or unequal urbanization may also create new vulnerabilities, particularly when it is accompanied by informal employment, inadequate housing, income inequality, or weak social protection.

Trade openness is also negatively associated with undernourishment, although the evidence is relatively modest. Greater integration into international markets may improve food availability by facilitating imports and diversifying food supply. However, trade openness may also expose countries to global price volatility, exchange rate fluctuations, and supply chain disruptions. Therefore, trade openness should not be interpreted as automatically beneficial for food security; rather, its effects depend on domestic production capacity, market stability, institutional quality, and the ability of vulnerable households to access food.

Overall, the results suggest that income growth plays a central role in reducing undernourishment, but it is not sufficient on its own. Sustainable improvements in food security require income growth to be complemented by price stability, inclusive agricultural policies, improved market access, effective food distribution systems, stronger institutional capacity, and resilient food systems. These findings reinforce the need for a multidimensional and context-sensitive approach to food security in developing countries.

The study has several limitations. First, although the model includes key macroeconomic and structural variables, other relevant factors such as institutional quality, education, social protection, conflict, and climate-related shocks are not directly included due to data limitations. Second, the use of aggregate country-level data may mask within-country inequalities and heterogeneity in food access. Third, potential endogeneity issues, particularly reverse causality between income and undernourishment, cannot be fully addressed within the current static panel framework. Finally, the

effects of inflation may be lagged, which is not explicitly captured in the current model. Future research may address these limitations by incorporating additional control variables, using micro-level data, and applying dynamic panel estimation techniques.

## 5. Conclusion and Policy Implications

This study examined the determinants of undernourishment in 72 developing countries over the period 2010–2023 using an unbalanced panel data framework. The analysis focused on GDP per capita, agricultural value added, and inflation as the main explanatory variables, while urbanization and trade openness were included as control variables. Both fixed effects and random effects models were estimated to assess the robustness of the empirical relationships. Based on the Hausman test results, the random effects estimator was not rejected and may be considered statistically acceptable. Nevertheless, the two-way fixed effects model was also reported as an alternative specification to account for country-specific and time-specific heterogeneity.

The findings indicate that GDP per capita is negatively and significantly associated with undernourishment across both model specifications. This result confirms the importance of income growth for improving food access and reducing undernourishment in developing countries. Higher income levels can strengthen household purchasing power and improve access to sufficient, safe, and nutritious food. This finding is consistent with the Food and Agriculture Organization (2023), the World Bank (2023), and Smith and Haddad (2015), which emphasize the central role of income and purchasing power in improving food security and nutritional outcomes.

Inflation is found to be positively and significantly associated with undernourishment. This finding suggests that price instability is a major risk factor for food security, particularly in countries where vulnerable households allocate a large share of their income to food expenditures. Inflationary pressures may reduce real purchasing power, restrict access to affordable and nutritious food, and increase the risk of undernourishment. This result is consistent with Ivanic and Martin (2008), Headey and Ruel (2023), and the World Bank (2024), which highlight the adverse effects of rising food prices on poverty, food access, and nutrition.

Agricultural value added has a positive but statistically insignificant coefficient, suggesting that agricultural expansion alone may not be sufficient to reduce undernourishment. This finding indicates that the contribution of agriculture to food security depends on complementary structural conditions, including productivity, infrastructure, market access, equitable distribution, and institutional effectiveness. Without appropriate policy and institutional mechanisms, increases in agricultural value added may not translate into improved food access or better nutritional outcomes. This result is consistent with FAO (2022), Fan and Brzeska (2014), and Headey and Ruel (2023).

Urbanization and trade openness are negatively associated with undernourishment, although their statistical significance is weaker and more dependent on model specification. Urbanization may reduce undernourishment when it improves access to infrastructure, employment opportunities, public services, health facilities, and food markets. However, rapid urbanization may also generate vulnerabilities if it is accompanied by inequality, informal employment, inadequate housing, or weak social protection. Similarly, trade openness may improve food availability and diversify food supply, but its benefits depend on domestic production capacity, market stability, exposure to global price volatility, and households' ability to access food.

The findings provide several policy implications. First, income-enhancing policies should remain central to food security strategies. Poverty reduction, employment creation, rural income support, and targeted social protection programs can improve households' access to food and reduce undernourishment. Second, price stability should be treated as a core component of food security policy. Targeted subsidies, food price stabilization mechanisms, and well-designed social safety nets may help protect vulnerable households from inflationary shocks. Third, agricultural policies should move beyond a narrow focus on production expansion and instead promote inclusive, productive, and accessible food systems. Supporting smallholder farmers, strengthening agricultural value chains, improving rural infrastructure, and expanding market access can help ensure that agricultural

growth translates into improved nutritional outcomes. Fourth, urbanization and trade policies should be managed in ways that improve food access while reducing vulnerability to inequality, informality, external price shocks, and supply disruptions.

In conclusion, this study shows that income growth and price stability are the most consistent determinants of undernourishment in developing countries, while agricultural value added, urbanization, and trade openness operate through more context-dependent channels. Sustainable improvements in nutritional outcomes require a comprehensive policy approach that integrates income growth, inclusive agricultural transformation, price stability, social protection, responsible urban development, trade resilience, and sustainable food systems. The findings contribute to the literature by providing recent panel-based evidence on the macroeconomic and structural determinants of undernourishment and offer policy-relevant insights for designing more inclusive and resilient food security strategies in developing countries.

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