Impact of retail food loss on undernourishment in developing countries

Andrii Dankevych[1], Meherun Nesa Mitu[2], Nurul Mohammad Zayed[3], Vitalii Nitsenko[4], Keisha LaRaine Ingram[5]

1 – National University of Food Technologies, Kyiv, Ukraine
2 – Daffodil International University, Dhaka, Bangladesh
3 – INTI International University, Nilai, Malaysia
4 – Kauno kolegija Higher Education Institution, Kaunas, Lithuania
5 – Mykolas Romeris University, Vilnius, Lithuania

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Corresponding author:

Andrii Dankevych
E-mail: dankevichie@nuft.edu.ua

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Abstract

Introduction. This study aims to examine the relationship between caloric losses at the retail distribution level and the prevalence of undernourishment in developing countries, while accounting for key agricultural and macroeconomic factors.

Materials and methods. The effect of caloric losses at the retail distribution level (ICLRD) on the prevalence of undernourishment (POU) was examined using a balanced panel of 30 developing countries from 2010 to 2022. Data were obtained from United Nations databases and the World Development Indicators. The food price index (FPI), inflation, agricultural value added, and gross domestic product per capita were included as control variables. Pooled ordinary least squares, fixed effects, random effects, and the Hausman test were applied.

Results and discussion. The empirical findings reveal a positive relationship between retail food losses and undernourishment. The coefficient of caloric losses at the retail distribution stage (ICLRD) is 1.6469 ($p < 0.01$) in the Fixed Effects model and 1.3742 ($p < 0.05$) in the Random Effects model. These results indicate that greater caloric losses at the retail distribution stage are associated with higher undernourishment. The positive and statistically significant coefficient in the preferred model suggests that food losses before reaching consumers may reduce food availability and contribute to food insecurity in developing countries. However, Pooled OLS shows an inverse relationship between ICLRD and the prevalence of undernourishment, highlighting the importance of accounting for country-specific factors. Among the control variables, GDP per capita has a statistically significant negative effect on undernourishment, indicating that higher economic development is associated with better access to food and lower vulnerability to undernourishment. Inflation, the FPI, and agricultural value added do not have statistically significant effects in the selected specification. Overall, the findings highlight the importance of minimizing food losses during retail distribution as part of broader food security strategies. Retail food losses represent not only resource waste but also a food security concern in developing countries. Improving retail distribution efficiency could help preserve food availability and reduce unnecessary caloric losses.

Conclusions. Reducing retail food losses through efficient supply chains, cold-chain management, and food redistribution may improve food security and contribute to Sustainable Development Goals 2 (Zero Hunger) and 12 (Responsible Consumption and Production).

Introduction

Food shortages have never been the only reason for food insecurity around the world. Despite there being enough food production globally to fulfill the nutritional needs of the entire population of the planet, hundreds of millions of people have still remained deprived of adequate nourishment. This has been among the greatest enigmas in the discourse on food security: how is it possible that hunger is rampant amid the wastage of almost a third of the total amount of food production worldwide? The majority of the academic literature sees the disparity between developing and developed nations' economies as a sharp, almost geographical law. According to Gustavsson et al. (2011) food losses occur upstream, at the farm and post-harvest stage in poor countries due to ineffective cold chains and storage systems, whereas in rich countries, they do not happen during the production stage and take place at retailers and consumers due to their habits and purchasing behaviors. Moreover, Sheahan and Barrett (2017) and Aragie et al. (2018) summarize the evidence and conclude that food losses in sub-Saharan Africa and at the level of ten agrarian nations (Benin, Chad, Ethiopia, Kenya, Madagascar, Malawi, Mali, Mozambique, Niger, and Rwanda) account for about 28 percent of calories per capita per day, respectively. It was also established that the countries in question lose approximately 38 percent of produce at the pre-harvest stage and 34 percent at the post-harvest stage. Indeed, in the countries mentioned, fruit losses resulting from improper storage and a lack of necessary skills in handling refrigeration technologies range from 30% to 80% (James & Zikankuba, 2017). Kumar and Kalita (2017) add that grain losses in developing countries due to inefficient storage technologies can reach 50-60%. Thus, poor postharvest handling and storage can lead to the loss of one-third of the produce and, in extreme cases involving cereal storage, even more than half of the harvest.

Despite substantial research on food loss, food waste, and food security, the direct link between retail-stage food loss and the prevalence of undernourishment in developing countries has received scant attention (Shynkaruk et al., 2025). The existing literature covers various aspects of food loss and waste, including cost analysis (Nahman & De Lange, 2013), nutritional analysis (Khan et al., 2024), country-specific studies (Mirzoieva et al., 2024), econometric analysis of factors influencing undernourishment (Kramer & Allen, 2015), and circular economy approaches, including the conversion of waste into value-added products (Stabnikova et al., 2023). However, these research areas have not adequately addressed the direct relationship between retail-stage food loss and undernourishment in developing countries. Existing studies either aggregate food losses and waste across the supply chain without considering the specific role of retail-stage losses (Alexander et al., 2013), focus on retail losses in developed economies, where infrastructure, consumer behaviour, and policy environments differ from those in developing countries (Joardder & Masud, 2019), or model undernourishment using macroeconomic and institutional indicators without incorporating supply-chain losses disaggregated by stage (Hodges et al., 2011).

Furthermore, the broad variation in the magnitude of global food losses from 1.3 to 1.6 billion tons of food (Ishangulyyev et al., 2019) and 263 billion to 2.6 trillion US dollars (Wang et al., 2023) in value across different studies clearly emphasizes the uncertain empirical base of this field, necessitating a need for a targeted examination of this issue at each individual stage of the food cycle. The novelty of the current research lies in the fact that it considers the food losses at the retail stage as an independent variable, as compared to considering them as an essential component of food loss and waste in general, with respect to tackling undernourishment in developing countries. Whereas earlier works (James & Zikankuba, 2017; Kumar & Kalita, 2017) have concentrated on food losses and waste in general, this paper will look into retail-stage calorie losses and their effect on undernourishment in developing nations using panel data methods. The significance of this methodology derives from it directly, and this is because retail stage is the point in the food chain at which the nutritious food gets disposed of the nearest to the consumer,

meaning that the food would have been available to be consumed by the hungry ones before the food was taken out of the system; something which cannot be said about food loss at the farm level which happens earlier in the process. In order to systematically analyze such empirical irregularities, the present paper aims to achieve three specific objectives as follows: firstly, to empirically investigate the degree to which retail food losses impact on hunger in developing nations; secondly, to compare the relative importance of this link versus other major macroeconomic and agricultural factors determining undernourishment, such as income, food production, inflation, and agriculture's contribution to value added; and Thirdly, to ascertain whether this link still exists when controlling for any potential unobserved heterogeneity in each country using diagnostic tests for panel data.

To realize these objectives, the study uses a cross-country panel dataset of 30 developing economies from Sub-Saharan Africa, Latin America and the Caribbean (LAC), Southeast Asia, Middle East and North Africa (MENA), and South Asia, covering 2010–2022. In this context, the empirical strategy adopted is focused on isolating the impact of the prevalence of calorie losses at the retail distribution level on the level of undernourishment while holding constant some shifting variables at the macroeconomic and sector levels, which include: Food Production Index, Agriculture, Forestry and Fishing Value Added, Inflation Rate, and Per Capita GDP.

Materials and Methods

Materials

The research utilizes the quantitative method to conduct an analysis on the link between food loss and undernourishment within different nations. The quantitative method is ideal for conducting this research since the use of numeric values in this research will help in examining the correlation between food loss, economy, agriculture, and its impact on food security. The use of numeric values will help in measuring, estimating, and empirically testing the effect of food loss. This paper uses secondary data analysis since all data used in the research come from international databases instead of being gathered by the researcher. Secondary data are data that have already been collected, compiled, and published by certain institutions for statistical and research purposes. The data were gathered using two major sources of secondary data: the United Nations database and the World Bank's World Development Indicators database.

Sample selection

The dataset comprises a balanced panel of 30 countries from Southeast Asia, South Asia, the Middle East and North Africa (MENA), Latin America and the Caribbean (LAC), and Sub-Saharan Africa over the period 2010–2022. The countries included in the analysis are Bolivia, Nicaragua, Malaysia, Peru, Paraguay, Thailand, Ecuador, Cameroon, Sri Lanka, Egypt, Nepal, Cambodia, Ghana, Indonesia, Senegal, the Philippines, Jordan, Benin, India, Honduras, Pakistan, Bangladesh, Malawi, Ethiopia, Togo, Kenya, Uganda, Mozambique, Rwanda, and Zambia. The countries were selected based on the availability of complete data for all variables included in the study. These regions were chosen because they continue to face significant food security challenges, including food insecurity, food losses, agricultural constraints, and economic vulnerability. Panel data are suitable for this study because they combine cross-sectional and time-series dimensions, increasing the number of observations and potentially improving the efficiency of econometric estimates. Furthermore, panel data methods allow researchers to account for unobserved country-specific characteristics and time effects, thereby helping to control for heterogeneity across countries and changes over time (Table 1).

Table 1

Definition, measurement, classification and data sources of variables

Type	Variables	Abbreviation	Definition and measurement	Source
Dependent	Prevalence of undernourishment	POU	% of population	World Bank
Control	Inflation	INF	Annual, %	
Independent	Incidence of caloric losses at retail distribution level	ICLRD	Caloric losses at the retail distribution stage	UN Database
Control	GDP per capita	GDPPC	Constant 2015, US$	World Bank
Control	Food production index	FPI	Index (2014–2016 = 100)	
Control	Agriculture, forestry and fishing value	AFV	% of GDP	

Source: compiled by the authors based on (World Bank Group, 2025)

Conceptual structure

Figure 1 provides the conceptual framework for this study.

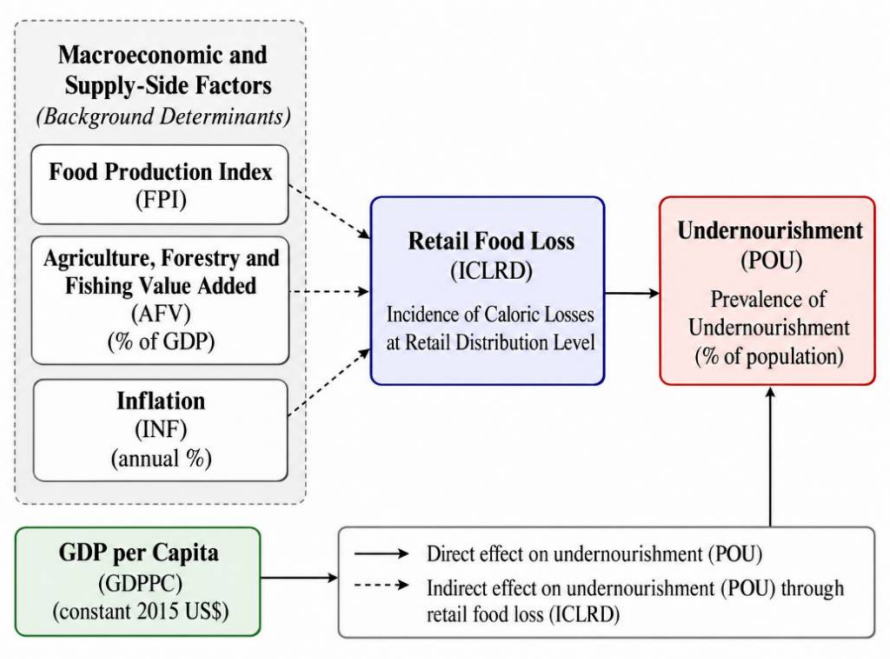


Figure 1. Conceptual structure

Source: Developed by the authors based on the literature review and study framework

The conceptual framework highlights Retail Food Loss, measured in terms of the Incidence of Caloric Losses at the Retail Distribution Level (ICLRD), as the major independent variable affecting the Prevalence of Undernourishment (POU). The Food Production Index (FPI), Agriculture, Forestry and Fishing Value Added (AFV), and Inflation (INF) have been included as macroeconomic and supply-side factors that could potentially affect undernourishment indirectly through their impact on retail food loss. On the other hand, GDP per Capita (GDPPC) has been shown to have a direct relationship with undernourishment, which is in line with the empirical results obtained in this study, wherein GDPPC had a statistically significant negative effect on POU. The framework reflects the study's empirical model while emphasizing ICLRD as the central mechanism linking food system conditions to undernourishment.

To reduce the calorie deficit in the population, it is necessary to consider the traditional food security indicator POU together with calorie losses at the retail distribution level (ICLRD). These indicators can help identify the need for measures to increase food production, as reflected by the FPI indicator. The relationship between ICLRD and FPI reflects the need to maintain a balance between the population's food requirements and the efficiency of the food production and distribution system. For example, if FPI increases without a corresponding improvement in the population's food security and access to sufficient calories, retailers may be unable to sell the additional food products, which, in turn, may increase ICLRD.

The loss of calories at the retail stage results in a loss of the corresponding food value. Thus, the AFV indicator, without accounting for calorie losses at the retail stage, may not fully reflect the actual state of food security. The relationships between AFV, ICLRD, and POU may also help characterize the strength of the regional food system. Inflation (INF) changes food prices, which may affect the supply and availability of food products at the retail stage. These changes may contribute to an increase in POU.

The relationships between FPI, ICLRD, and POU; AFV, ICLRD, and POU; and INF, ICLRD, and POU reflect the functioning of the national food system. As mentioned above, GDP per capita and POU are directly related, although the relationship is inverse. In countries with higher GDP per capita, the proportion of people who may experience a calorie deficit is generally lower than in countries with lower GDP per capita.

At the same time, as shown in Fig. 1, the FPI, AFV, and INF indicators are assumed to affect POU indirectly through ICLRD rather than directly. The POU indicator is estimated on the basis of the availability of dietary energy for the population. Changes in food production and inflation may affect food prices and consumer purchasing behaviour. As food prices increase, consumers may buy less food or switch to cheaper products. This may also change the composition of their diets, including the proportions of protein, fat, fruit, and vegetables consumed. Since these food groups differ in their energy content, changes in dietary composition may affect total calorie intake. For example, potatoes have an energy content of approximately 0.77 kcal/g. Changes in the demand for perishable products, such as fruit and vegetables, may also increase retail food losses if storage and distribution infrastructure is insufficient. This may, in turn, increase ICLRD. These considerations support the proposed mediating role of ICLRD in the relationships between FPI, AFV, INF, and POU.

This led to the development of Equation (2), which mathematically formalizes the proposed mediation of the relationships between POU and FPI, AFV, and INF. The significance of retail-stage calorie losses for POU is further formalized in Equations (3)–(5).

Model specification and estimation procedure

To investigate the relationship between food loss and undernourishment, the following panel-data regression model is estimated:

Basic model:

$$e_{it}=a_0+a_1v_1+a_2v_2+a_3v_3+a_4v_4+a_5v_5+\mu_{it} \quad (1)$$

In this linear regression model, e_{it} represents the outcome of the dependent variable at time t and country i, a_0 intercept, which is constant, a_1 to a_5 are the coefficients, independent variables v_1 to v_5 and μ_{it} are the error terms.

Overall model (Based on selective variables):

$$POU_{it}=a_0+a_1ICLRD_{it}+a_2FPI_{it}+a_3AFV_{it}+a_4INF_{it}+a_5GDPPC_{it}+\mu_t \quad (2)$$

where:

POU_{it} represents the Prevalence of Undernourishment in the country i during the year t,

$ICLRD_{it}$ represents the Incidence of Caloric Losses at Retail Distribution Level in the country i during the year t,

FPI_{it} represents the Food Production Index in the country i during the year t,

AFV_{it} represents Agriculture, Forestry and Fishing Value Added as a percentage of GDP in the country i during the year t,

INF_{it} represents Inflation measured by Consumer Prices in the country i during the year t,

$GDPPC_{it}$ represents GDP per Capita in the country i during the year t,

Firstly, descriptive statistics along with the Jarque-Bera normality test will be used to analyze the distribution properties of the variables. After that, a correlation analysis will be performed to analyze the connection between the factors and identify any potential issues with multicollinearity. Data organization and preparation will be done using Microsoft Excel software, whereas statistical analysis will be carried out using EViews. Next, Levin-Lin-Chu (LLC), Im–Pesaran–Shin (IPS), and Fisher-ADF panel unit root tests will be used to ensure that the variables are stationary. The empirical model will be estimated using Pooled Ordinary Least Squares (OLS), Fixed Effects (FE), and Random Effects (RE) estimators. Additionally, the Hausman specification test will be done to find out which estimation technique is the best suited one for panel data. Finally, heteroskedasticity and cross-sectional dependence tests are conducted to check the assumptions of the model.

Potential food-energy recovery from retail loss reduction equation

The calculation begins with the annual food-energy availability of each country. For country (i) in year (t), total annual food calories available are calculated as:

$$TFC_{it}=FS_{it} \times POP_{it} \times 365 \quad (3)$$

where:

FS_{it} is Per-capita daily food supply in kcal/person/day

POP_{it} is Country's population

Retail-stage calorie losses are then estimated from the ICLRD measure:

$$CL_{it}=TFC_{it} \times \frac{ICLRD_{it}}{365} \quad (4)$$

where CL_{it} is Calories lost at the retail distribution stage

To reflect the reviewer's observation that natural and operational losses cannot realistically be reduced to zero, the analysis assumes a 50% reduction in the observed retail calorie loss:

$$RC_{it}=CL_{it} \times 50\% \quad (5)$$

where RC_{it} is potentially recoverable calories under the 50% reduction scenario

Therefore, the counterfactual does not assume that all food losses are completely replaceable. Rather, the counterfactual poses the more conservative policy question of what the food/energy equivalents would be if one-half of existing retail losses were to be eliminated?

The recovered energy is transformed into a feeding-equivalent measure using a reference requirement of 2,000 kcal per person per day, according to Dietary Guidelines for Americans (2020-2025), for cross-national and cross-year comparison (U.S. Department of Agriculture, 2020). Accordingly, the annual reference requirement is:

$$ARC=2{,}000\times365=730{,}000 \text{ (kcal/person/year)}$$

where ACR ıii Annual Calorie Requirement

And the number of annual person-equivalents associated with the recoverable calories is:

$$PE_{it}=\frac{RC_{it}}{730{,}000} \quad (6)$$

This 2,000 kcal/day figure is used only as a standard reference energy requirement but not as a claim that all people have identical physiological energy requirement. Energy requirement differs depending on age, gender, body mass, and level of physical activity. Therefore, the use of the standard figure is intended to provide a point of comparison for the magnitude of the loss of food energy between different nations and years.

Bangladesh had a total annual food-calorie availability of 1.58829×10^4 kcal in 2021 and 1.61966×10^{14} kcal in 2022. With an ICLRD of 2.64%, the corresponding retail-stage calorie losses were:

$$CL_{2021}=1.58829\times10^{14}\times\frac{2.64}{100}=4.19309\times10^{12} \text{ kcal}$$

$$CL_{2022}=1.61966\times10^{14}\times\frac{2.64}{100}=4.27590\times10^{12} \text{ kcal}$$

Under the 50% reduction scenario:

$$RC_{2021}=4.19309\times10^{12} \text{ kcal}\times50\%=2.09654\times10^{12} \text{ kcal}$$

$$RC_{2022}=4.27590\times10^{12} \text{ kcal}\times50\%=2.13795\times10^{12} \text{ kcal}$$

Thus, the corresponding annual person-equivalents are:

$$PE_{2021}=\frac{2.09654\times10^{12} \text{ kcal}}{730{,}000}\approx2.87 \text{ millions}$$

$$PE_{2021}=\frac{2.13795\times10^{12} \text{ kcal}}{730{,}000}\approx2.93 \text{ millions}$$

So, in the case where one-half of the retail-calorie loss recorded in Bangladesh is prevented, then the resulting amount of energy saved in 2022 will be equal to the yearly calorie needs of 2.93 million people.

For the broader study, the same calculation is performed separately for each country and year. The country-specific estimates can then be summed for a given year:

$$PE_{total,t}=\sum_{i=1}^{28}PE_{it} \quad (7)$$

$PE_{total,2022}=57.62$ millions

The corresponding average across the 28 countries is:

$$\frac{57.62}{28}=2.06 \text{ million annual person-equivalents per country}$$

Results and discussion

Descriptive statistics of study variables

Descriptive statistics provide a preliminary analysis of the distribution of the variables in question across countries and over time before conducting any panel estimates (Baltagi, 2021;

Wooldridge, 2021). Undernourishment (POU) is 13.6 percent on average, varying between 2.5 and 43.9 percent with a standard deviation of 9.1, thus showing true cross-country heterogeneity rather than being driven by outliers. Inflation (INF) is the most volatile variable, varying between -1.1 and 49.7 percent with a skewness of 2.73 and kurtosis of 14.64, which is much higher than normal.

The core independent variable in the study, ICLRD, shows the least variability (mean 2.50, skewness -0.50, kurtosis 3.42). GDP per capita varies between USD 421 and USD 11,192, with an average of USD 2,615, which is significantly below the range median, showing that most of the countries in the panel belong to the low-income group. Variables of FPI and AFV display similar right-skewed distributions, while AFV shows the distribution closest to a normal one with kurtosis of 3.19. None of the six variables follows a normal distribution, confirming the heterogeneous nature of the panel (Table 2).

Table 2

Descriptive statistics

Variable	Mean	Max	Min	SD	Skew	Kurt
POU	13.616	43.900	2.500	9.105	1.249	4.054
INF	6.001	49.721	-1.139	5.869	2.728	14.641
ICLRD	2.505	3.750	0.026	0.636	-0.501	3.417
GDPPC	2615.010	11191.650	421.899	2193.644	1.510	5.067
FPI	104.401	183.450	62.400	15.526	1.405	7.597
AFV	16.356	44.331	2.861	7.880	0.637	3.186

Note: POU – Prevalence of Undernourishment; INF – Inflation; ICLRD – Incidence of Caloric Losses at Retail Distribution Level; GDPPC – GDP per Capita; FPI – Food Production Index; AFV – Agriculture, Forestry and Fishing, Value Added. SD – standard deviation; Max – maximum; Min – minimum; Skew – skewness; Kurt – kurtosis.
Source: estimated by the authors

Cross-country and regional patterns of food security and economic development

Malnutrition is unevenly distributed across the developing countries in the world. There are certain countries where malnutrition is more prevalent than others, and it is imperative to note some of the underlying factors for this trend before making sense out of the data presented below. Malnutrition is highly prevalent in Zambia, Rwanda, Mozambique, and Uganda, with more than 27% undernourishment, and there are also Kenya, Ethiopia, Malawi, Bolivia, and Nicaragua that have undernourishment rates ranging from 16% to 24%. Bolivia and Nicaragua should be highlighted as countries that belong to the same level of malnutrition prevalence as several other East African countries despite being part of a completely different geographical region, in line with Aragie et al. (2018), who reported that ten sub-Saharan countries lose up to 28% of per capita calorie intake in the production and post-harvest stages alone.

This paper aims to show that this specific level of malnutrition is a structural problem, not a Sub-Saharan one, and this assertion holds true in line with Ishangulyyev et al. (2019), who pointed out that developing countries lose more food during the production, handling, and storage stages than at the consumption stage regardless of the region they are located in (Figure 2). For this purpose, the methodology for calculating the ICLRD indicator proposed by Thayyil and Manogna (2026) was used. This indicator measures the loss of food energy content (as a percentage) within the retail sector relative to its total value.

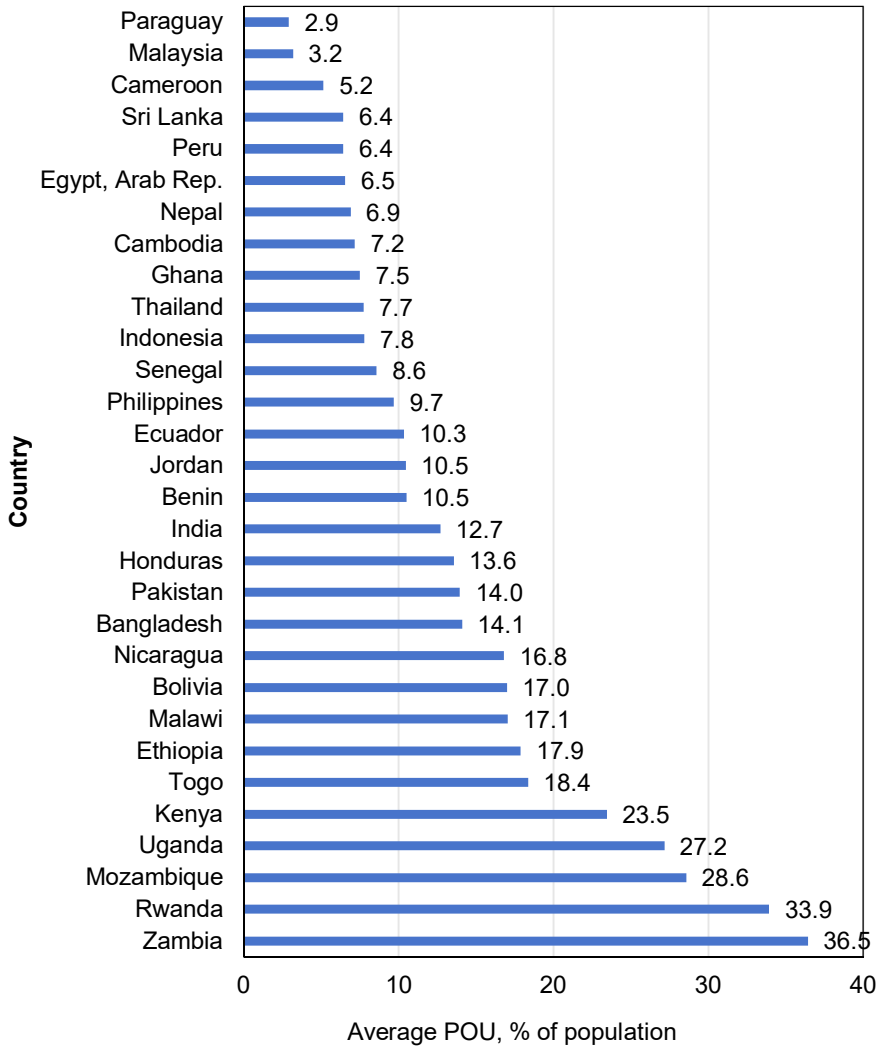


Figure 2. Country-level average prevalence of undernourishment across 30 developing countries (2010–2022)
Source: Authors' calculations based on (World Bank Group, 2025)

GDP per capita offers a second dimension instead of merely repeating that income inequality creates food inequality. The near $9,700 average for Malaysia is nearly twice that of the following bracket (Peru, Paraguay, Thailand, Ecuador, near $5,800-$6,200), but it also marks a prelude to how Malaysia will turn out to be one of the least undernourished nations in the data set. As noted by Baykoca and Yılmaz (2025), using a typology of 105 nations based on their GDP, there is an identical trend where richer nations have their food lost later in the line, i.e., at consumption, whereas poorer nations have theirs lost much earlier in the process, at the harvest/production stage – and it is precisely that separation between Malaysia

and Bolivia/Nicaragua. But income cannot offer the full explanation on its own, as Bolivia and Nicaragua remain as lower middle-income nations and yet record undernourishment rates more consistent with East Africa than with their income counterparts (Figure 3).

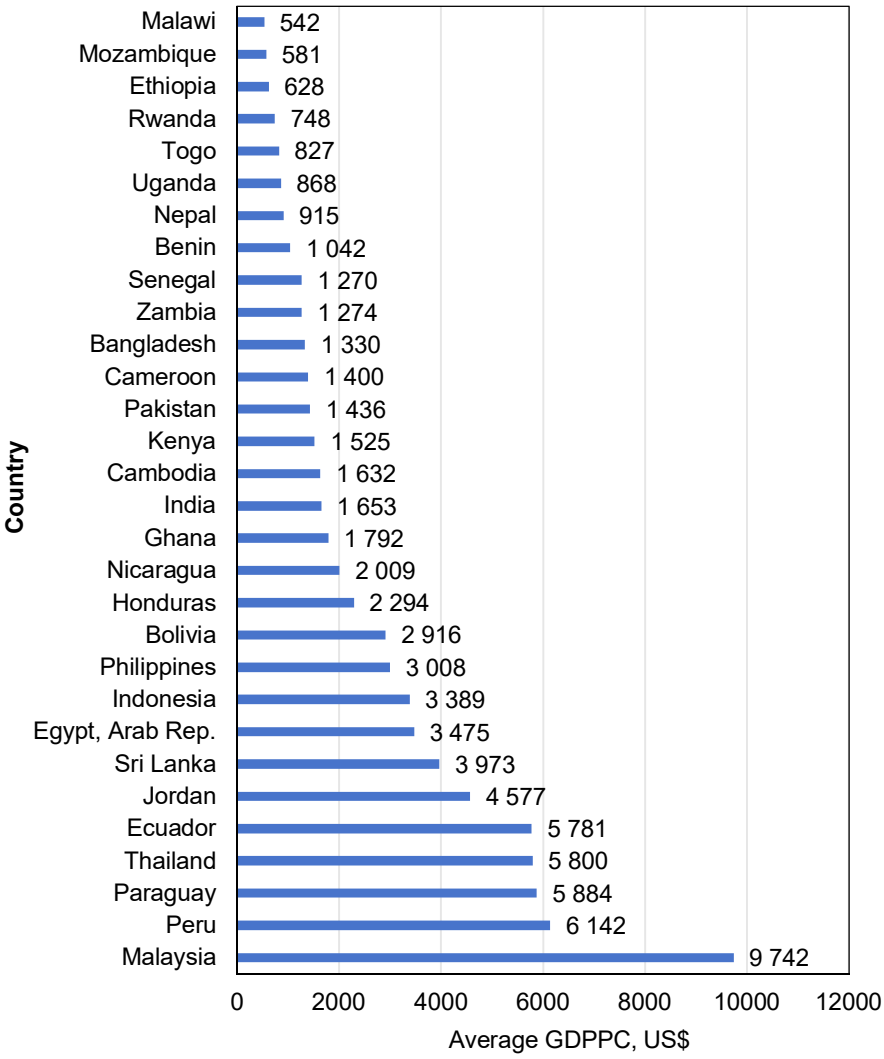


Figure 3. Average GDP per capita across sample countries
Source: Authors' calculations based on based on (World Bank Group, 2025)

It is here that the ICLRD comparison makes its mark as the most innovative contribution of the paper, since neither of the above rankings is followed. Ecuador, Jordan, Indonesia, Rwanda and Cameroon show up with the largest numbers of calorie losses, above 3.2, while Zambia and Malawi, burdened with the highest rate of undernourishment in the entire sample, and score the lowest (Figure 4).

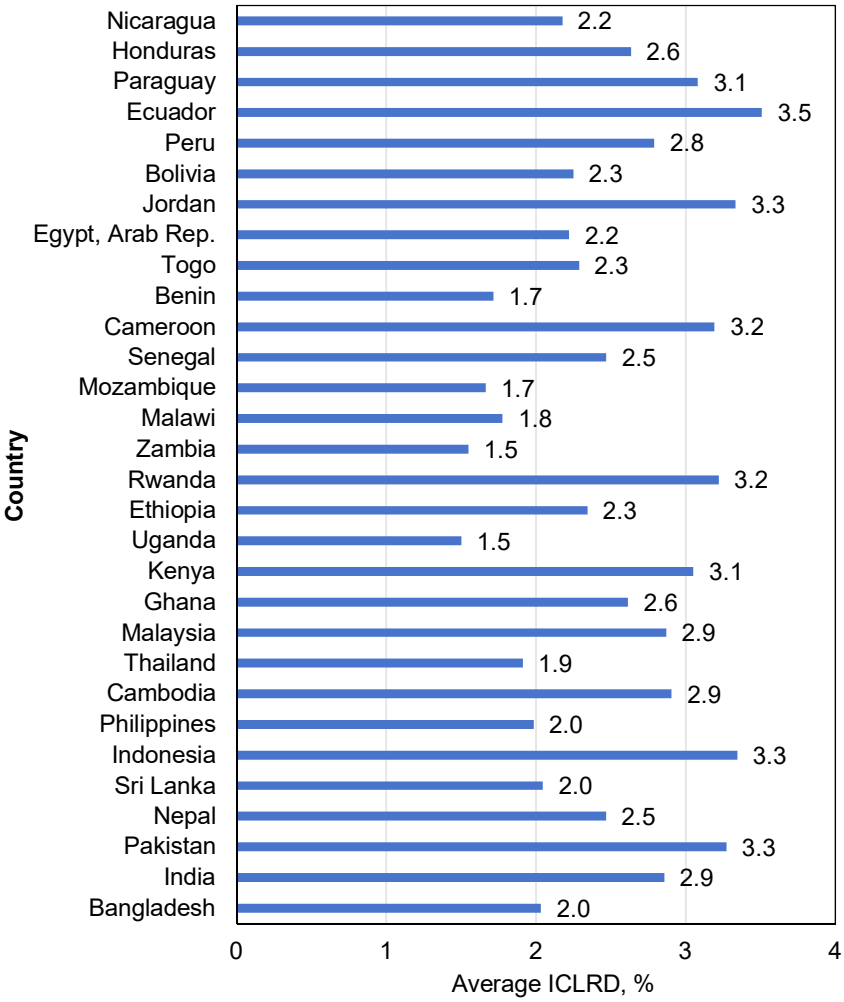


Figure 4. Average level of calorie losses at the retail stage in the countries included in the sample

Source: Authors' calculations based on (UNEP, 2024)

Pakistan's relatively favourable position on this particular indicator is not an anomaly. Khalid et al. (2019) estimated that Pakistani households lost approximately 2.6% of their daily calorie requirements due to food losses, even before wider retail-stage losses were taken into account. Abbade (2020) demonstrated that annual global food losses contained sufficient calories to feed more people than the number of undernourished people worldwide in that year. Thus, the caloric content of food losses, rather than their total volume alone, may be relevant to understanding their relationship with undernourishment. Furthermore, Porat et al. (2018) linked fruit and vegetable losses at the retail stage to cold-chain and inventory management problems rather than to a country's poverty level alone. This may help explain why Ecuador, a middle-income country, also has a high ICLRD value (Figure 4).

This comparison highlights an aspect of the problem that has received limited attention in the existing literature. Both Sub-Saharan Africa and the MENA region experience similar levels of undernourishment, approximately 19–20%. This similarity may be overlooked because the two regions are not frequently compared in the literature. Abiad and Meho (2018) examined the problem of food waste in the Arab world but considered it separately, focusing on the extensive import of food from other countries rather than comparing it with food losses at the production stage in Africa. As the comparison of these regions shows, similar levels of undernourishment may result from different underlying processes. Therefore, solutions should be adapted to the specific conditions and causes of undernourishment in each region (Figure 5).

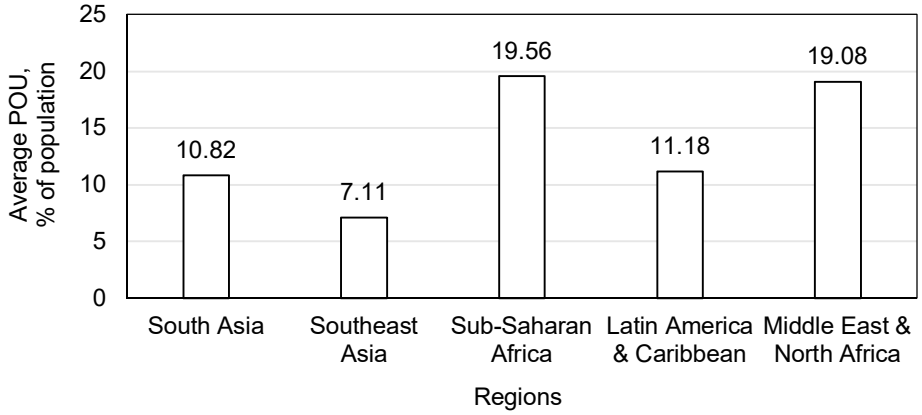


Figure 5. Average prevalence of malnutrition by region
Source: **Authors' calculations based on (World Bank Group, 2025)**

The relationship between GDP per capita and undernourishment can be seen clearly in the scatterplot. Countries having more than 25% undernourishment have GDP per capita below $2,000, and countries having GDP above $5,000 have undernourishment below 11%, making it a threshold rather than a smooth trend. Malaysia is the outlier in terms of being both wealthy and low-undernourished, while Zambia, Rwanda, and Mozambique represent the other extreme of the spectrum. Bolivia and Nicaragua stand out as outliers in this regard, and their importance cannot be understated because according to Kuiper & Cui (2021), food waste reduction produces the most significant food security gains when performed in poor nations where the loss of food is a structural issue rather than a coincidence – in other words, the positioning of Bolivia and Nicaragua on the graph is not an anomaly, but rather represents the only clear message that the income does not explain undernourishment when the loss of food in the retail sector is ignored (Figure 6).

Assessment of data normality

The Jarque-Bera test (Table 3) validates non-normality based on the skewness and kurtosis results in Table 2. All six variables prove not to be normally distributed at $p<0.01$, with INF exhibiting the largest lack of normality (JB = 2685.96), consistent with its extremely high kurtosis, due to its sporadic inflationary peaks in the data set. The lack of normality detected here calls for care in future analyses based on distributional assumptions.

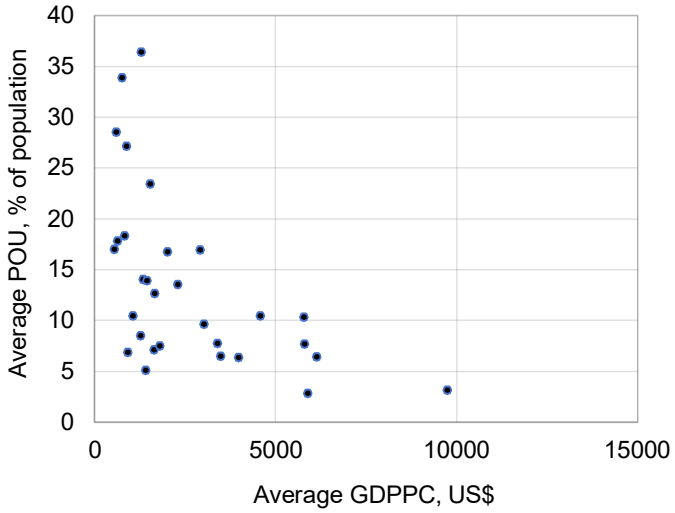


Figure 6. Scatter Plot of GDP per Capita and Prevalence of Undernourishment
Source: Authors' calculations based on (UNEP, 2024; World Bank Group, 2025)

Table 3

Jarque-Bera Normality Test

Variable	Jarque Bera Statistics	Probability
POU	119.5147	0.00000
INF	2685.955	0.00000
ICLRD	19.74016	0.000052
GDPPC	217.5667	0.00000
FPI	471.7217	0.00000
AFV	26.93107	0.000001

Note: POU - Prevalence of Undernourishment; INF - Inflation; ICLRD - Incidence of Caloric Losses at Retail Distribution Level; GDPPC - GDP per Capita; FPI - Food Production Index; AFV - Agriculture, Forestry and Fishing, Value Added.
Source: estimated by the authors

Correlation analysis

As shown in Table 4, none of the correlations between the independent variables exceeds 0.80, suggesting that multicollinearity is not a serious concern (Gujarati & Porter, 2009). The strongest correlation is observed between GDPPC and AFV ($r = -0.6696$), which is below the commonly used threshold.

Panel unit root tests (LLC, IPS, and Fisher-ADF) were performed before estimation to assess the stationarity of the variables and avoid spurious regression (Choi, 2001; Im et al., 2003; Levin et al., 2002). The variables POU, ICLRD, INF, and AFV are stationary at level [I(0)], whereas FPI and GDPPC are stationary at first difference [I(1)]. Since none of the variables is integrated of order two, the results satisfy a condition commonly considered when selecting appropriate methods for panel data analysis. The estimation was therefore conducted using Pooled OLS, Fixed Effects, and Random Effects models (Table 5).

Table 4

Correlation matrix

Correlation	POU	INF	ICLRD	GDPPC	FPI	AFV
POU	1.0000					
INF	0.1821	1.0000				
ICLRD	-0.2849	-0.1874	1.0000			
GDPPC	-0.5227	-0.2470	-0.2947	1.0000		
FPI	0.1343	0.0188	-0.1359	-0.1693	1.0000	
AFV	0.2903	0.3112	-0.1600	-0.6696	0.0810	1.0000

Note: POU - Prevalence of Undernourishment; INF - Inflation; ICLRD - Incidence of Caloric Losses at Retail Distribution Level; GDPPC - GDP per Capita; FPI - Food Production Index; AFV - Agriculture, Forestry and Fishing, Value Added.
Source: estimated by the authors

Table 5

Unit Root Test

Variable	LLC	IPS	Fisher-ADF	Decision
POU	I(0)	I(0)	I(0)	I(0)
FPI	I(1)	I(1)	I(1)	I(1)
GDPPC	I(1)	I(1)	I(1)	I(1)
ICLRD	I(0)	I(0)	I(0)	I(0)
INF	I(0)	I(0)	I(0)	I(0)
AFV	I(0)	I(0)	I(0)	I(0)

Note: POU - Prevalence of Undernourishment; INF - Inflation; ICLRD - Incidence of Caloric Losses at Retail Distribution Level; GDPPC - GDP per Capita; FPI - Food Production Index; AFV - Agriculture, Forestry and Fishing, Value Added.
Source: estimated by the authors

Baseline Pooled OLS regression

Pooled OLS regression (Table 6) reveals that ICLRD and GDP per capita are the major determinants of undernourishment. GDP per capita is statistically significant (β=-0.0022, p<0.01), but ICLRD, while being statistically significant, has a negative sign (β=-1.873, p<0.01), a finding which should be considered with caution due to the fact that pooled OLS does not account for unobserved country-specific heterogeneity. The model is statistically significant (F=32.89, p<0.01) and accounts for about 30 percent of the variance.

Estimated Fixed Effects Equation:

$$POU_{it}=23.7467-1.8730ICLRD_{it}+0.0195FPI_{it}-0.1239AFV_{it}+0.0662INF_{it}-0.0022GDPPC_{it}+\mu_t$$

Fixed effects model

Table 7 demonstrates how the Fixed Effects regression directly addresses cross-country heterogeneity.

Estimated Fixed Effects Equation:

$$POU_{it}=23.7467-1.8730ICLRD_{it}+0.0195FPI_{it}-0.1239AFV_{it}+0.0662INF_{it}-0.0022GDPPC_{it}+\mu_t$$

Fixed effects model

Table 7 demonstrates how the Fixed Effects regression directly addresses cross-country heterogeneity.

Table 6

Baseline Pooled OLS regression results

Variable	Coefficient	Std. Error	t-Statistic	Probability
C	23.74669	3.670719	6.469220	0.0000
INF	0.066244	0.070620	0.938026	0.3488
ICLRD	-1.873007	0.648720	-2.887233	0.0041
GDPPC	-0.002235	0.000249	-8.963139	0.0000
FPI	0.019488	0.025549	0.762846	0.4460
AFV	-0.123859	0.067739	-1.828480	0.0683

R-squared	0.299861	Mean dependent var	13.61615
Adjusted R-squared	0.290745	S.D. dependent var	9.104516
S.E. of regression	7.667576	Akaike info criterion	6.927143
Sum squared resid	22576.02	Durbin-Watson stat	0.039386
Log likelihood	-1344.793	Schwarz criterion	6.988161
F-statistic	32.89255	Hannan-Quinn criter.	6.951331
Prob(F-statistic)	0.000000		

Note: INF - Inflation; ICLRD - Incidence of Caloric Losses at Retail Distribution Level; GDPPC - GDP per Capita; FPI - Food Production Index; AFV - Agriculture, Forestry and Fishing, Value Added.
Source: estimated by the authors

Table 7

Fixed Effects (FE) Model

Variable	Coefficient	Std. Error	t-Statistic	Probability
C	12.44546	2.878314	4.323873	0.0000
INF	-0.006742	0.034754	-0.193999	0.8463
ICLRD	1.646918	0.605402	2.720370	0.0068
GDPPC	-0.001483	0.000551	-2.689395	0.0075
FPI	-0.017866	0.011386	-1.569154	0.1175
AFV	0.172905	0.088899	1.944958	0.0526

R-squared	0.908098	Mean dependent var	13.61615
Adjusted R-squared	0.899296	S.D. dependent var	9.104516
S.E. of regression	2.889215	Akaike info criterion	5.045305
Sum squared resid	2963.385	Durbin-Watson stat	0.264221
Log likelihood	-948.8345	Schwarz criterion	5.401241
F-statistic	103.17	Hannan-Quinn criter.	5.186400
Prob(F-statistic)	0.000000		

Note: INF - Inflation; ICLRD - Incidence of Caloric Losses at Retail Distribution Level; GDPPC - GDP per Capita; FPI - Food Production Index; AFV - Agriculture, Forestry and Fishing, Value Added.
Source: estimated by the authors

Random effects model

The Random Effects model (Table 8) reveals that ICLRD is a substantial driver of undernourishment (β=1.3742, p<0.05), similar to Aragie et al. (2018) and Gatto and Chepeliev (2024). GDP per capita is still negative and extremely significant (β=-0.0017, p<0.01). Inflation and FPI are not statistically significant, although AFV has a weak positive correlation at the 10% level.

Table 8

Random effects (RE) model

Variable	Coefficient	Std. Error	t-Statistic	Probability
C	14.13689	3.038406	4.652732	0.0000
INF	-0.004406	0.034612	-0.127283	0.8988
ICLRD	1.374184	0.583693	2.354295	0.0191
GDPPC	-0.001744	0.000439	-3.968425	0.0001
FPI	-0.015901	0.010906	-1.457944	0.1457
AFV	0.139660	0.083620	1.670169	0.0957

R-squared	0.106999	Mean dependent var	1.436114
Adjusted R-squared	0.095372	*S.D.* dependent var	3.043675
S.E. of regression	2.894898	Durbin-Watson stat	0.241418
Sum squared resid	3218.087	Prob(F-statistic)	0.000000
F-statistic	9.202175		

Effects Specification	*S.D*	Rho
Cross-Section random	7.555175	0.8724
Idiosyncratic random	2.889215	0.1276

Note: INF - Inflation; ICLRD - Incidence of Caloric Losses at Retail Distribution Level; GDPPC - GDP per Capita; FPI - Food Production Index; AFV - Agriculture, Forestry and Fishing, Value Added.
Source: estimated by the authors

Estimated Random Effects Equation:

$$POU_{it} = 14.1369 + 1.3742ICLRD_{it} - 0.0159FPI_{it} + 0.1397AFV_{it} - 0.0044INF_{it} - 0.001744GDPPC_{it} + \mu_t$$

Both FE and RE models show that ICLRD is significantly positive, which means that the pooled OLS model suffers from omitted country-specific heterogeneity. In case such heterogeneity is considered, the actual positive impact of food waste at the retail level on undernourishment becomes apparent. The lack of statistical significance in the coefficients of the Food Production Index (FPI), Agriculture, Forestry, and Fishing Value Added (AFV), and Inflation (INF) imply that these macroeconomic and agricultural variables do not have any direct effect on undernourishment once food loss is taken into consideration. They might actually have an indirect effect on undernourishment via the availability of food and purchasing power among others. The decision to choose either the FE or RE model depends on the result of the Hausman test below.

However, this neat distinction is not applicable to all datasets. For instance, Laso et al. (2021), and Campoy-Muñoz et al. (2021), analyzing the supply chain of Spain, discovered that 53.3 percent of food losses caused by economic and nutritional factors took place at the stage of agricultural production, rather than at the retail and domestic stages, thus challenging the idea that food waste in developed countries takes place downstream. According to Karwowska et al. (2021), another important nuance related to meat industry should be taken into consideration: while in the industrialized regions, 64 percent of losses take place during the consumption of meat, in the developing regions, the same product is lost mainly at the production and storage stages; hence, this distinction between developed and developing countries can be applied to meat products despite the fact that it does not hold for some other products. Finally, Gatto and Chepeliev (2024) offer another perspective, arguing that in low-income regions, food exports lead to farm-level food loss. Among the numerous stages of the food supply chain, the retail sector merits special attention because it is the point at which food is closest to being consumed.

According to Gustavsson et al. (2011), the amount is equal to 1.3 billion tonnes per year, and this figure was later repeated almost verbatim by Alexander et al. (2013), Vilariño et al. (2017), Wunderlich and Martinez (2018), and Shafiee-Jood and Cai (2016), which may imply that a considerable part of the field relies on one FAO estimate without re-measuring the phenomenon in an independent way. On the other hand, Ishangulyyev et al. (2019) state the amount to be 1.6 billion tonnes, while Durán-Sandoval et al. (2023) reached 1,498 million tonnes using the top-down mass-balance method, and Paraschivu et al. (2022) decided on one billion tonnes. Even the economic value attached to this loss varies by an order of magnitude depending on who is counting and what they include: Ishangulyyev et al. (2019), and Eastham and Creedon (2023) cite figures near 750 and 936 billion dollars respectively, Spang et al. (2019), Vilariño et al. (2017) and Kechagias et al. (2024) converge on roughly one trillion dollars, and Mokrane et al. (2023) with Berjan et al. (2018) push the number to 2.6 trillion once hidden environmental and social costs are folded in. None of this disagreement is trivial; it tells a reader, before a single policy recommendation is offered, that while these estimates emphasize the worldwide extent of food loss, they offer little insight into how losses at various levels of the food supply chain affect food security and nutritional outcomes.

Retail itself, the stage most relevant to the present study, has attracted a smaller and more geographically lopsided body of work than either farm-level or household-level loss. Nahman and de Lange (2013) costed the entire South African food value chain at roughly 7.7 billion US dollars, or 2.1 percent of national GDP, tracing the bulk of that cost to processing, distribution and agricultural production rather than the retail shelf, a finding at odds with the developed-country retail-dominance narrative given that South Africa is a middle-income economy. Moraes et al. (2020), synthesising 54 studies on retail food waste, catalogued 34 distinct causes and 32 mitigation practices, from forecasting errors to inadequate inventory management, yet almost all their underlying studies were conducted in Europe or North America. Busetti and Pace (2023), and Todd and Faour(2024), offer one of the few frameworks built specifically around the retail supply chain, reporting that 13 percent of food is lost before reaching retail and a further 17 percent wasted domestically and in food services, yet their analysis, like Chalak et al. (2018) study of hospitality, restaurant and retail waste across 33 developed countries, is again anchored in wealthy-economy data. However, Porat et al. (2018) discussed post-harvest losses for fruits and vegetables at retail level as well as at household levels; yet again, this study is based on limited evidence from industrialized retail settings. Collectively, this group of papers reveals one thing that is not commonly mentioned in the literature regarding the underdeveloped countries: Retail losses have been studied mostly in cases where the retail system is modernized. Retail food loss has significant nutritional repercussions that may directly affect undernourishment and food security outcomes in addition to its economic ramifications.

A number of studies step back from measuring loss altogether and instead model the broader determinants of undernourishment, and it is here that a genuine gap in the literature becomes visible. Nugroho et al. (2022), using system GMM estimation across 57 developing countries, found that corruption control, institutional quality and food-system factors jointly shape the number of undernourished people, while Baykoca and Yılmaz (2025) built a typology of 105 countries by GDP, growth and health expenditure and confirmed that developing countries lose food earlier in the chain while developed countries lose it later, and Jayadevan (2022) found across 165 countries that food wastage depresses economic growth while raising poverty. None of these econometric studies, however, isolates retail-stage loss as a distinct explanatory variable; they either treat food loss and waste as a single undifferentiated aggregate or examine wastage alongside unrelated macroeconomic controls.

Smith (1998) adds an important qualification from an earlier era of this literature, arguing that hunger can persist in cities even where aggregate food supply is adequate, because access and distribution, not production volume, determine who actually eats, a point Gómez and Ricketts (2013) extend by showing that modern and traditional food value chains affect undernourishment, micronutrient deficiency and over-nutrition in genuinely opposite directions depending on which population is served. Popkin et al. (2020) and Schmidhuber and Shetty (2005), writing fifteen years apart, both describe a "double burden" in which undernutrition and rising obesity coexist within the same developing populations, a phenomenon that plain calorie-loss accounting cannot explain and that Kramer and Allen (2015) and Pollard and Booth (2019) show is not confined to poor countries alone, since food insecurity affects 8 to 20 percent of populations even in some of the wealthiest nations on earth. To address these difficulties, a growing body of literature has recommended different legislative and administrative measures aimed at minimizing food loss and boosting food-system efficiency.

The nutritional consequences of loss, as distinct from its economic cost, form a third strand of evidence smaller in size but arguably more directly relevant to undernourishment. Wang et al. (2023) calculated that China's annual per-capita food loss and waste contain enough nutrients to sustain a person for 66.2 days, with losses of vitamin K, copper, and vitamin C exceeding 74 percent of the dietary reference intake, a demonstration that nutrient loss and calorie loss do not move together.

Eastham and Creedon (2023) push this further, insisting that counting tonnes lost tells us little unless nutrient density at each stage of degradation is also tracked, since storage, processing and temperature exposure erode micronutrient content even when bulk mass is preserved. Abbade (2020), who introduced the Nutritional Loss and Waste and Feeding Potential indicators, calculated that in 2017 food loss could have fed up to 940 million adults on the planet, surpassing almost all contemporary estimates of undernourishment in the world, while Chen et al. (2020), studying 151 countries, concluded that on average annually food waste per capita would be sufficient for maintaining a healthy nutrition regime for about 18 days, and losses of vitamin C, vitamin K, zinc, copper, manganese and selenium were equal or exceeded one quarter of daily recommended intake.

In the context of household level losses Khalid et al. (2019), who studied Pakistan, and Chalak et al. (2019), who studied Lebanon, calculated daily caloric and micronutrient losses from kitchen waste and came to quite similar figures of daily energy and protein losses reaching several hundred kilocalories and tens of grams respectively, proving that the issue of nutritional loss occurs not only at the household level but through the whole chain. The question of micronutrient malnutrition and insufficient protein quality in developing regions was considered by Miller and Welch (2013) and Schönfeldt and Hall (2012).

This last point brings the discussion to its central weakness. Chaboud and Daviron (2017), Xue et al. (2017), Shalash et al. (2025), and Imran et al. (2025) independently diagnose the same underlying problem from different angles: the former shows that inconsistent definitions of loss and waste undermine cross-study comparison, and the latter demonstrates empirically that global data on food loss remain narrow in temporal, geographic, and supply-chain coverage, concentrated overwhelmingly in a handful of industrialized countries such as the United Kingdom and the United States. Van der Werf and Gilliland (2017), compiling 55 estimates from prior research, directly confirm this bias, since their entire sample is drawn from developed-country studies. The consequence of this concentration is that the retail segment specifically, as opposed to food loss and waste in general, has been measured almost exclusively in contexts where retail systems are already efficient, formalized and data-rich, while the developing-country literature has instead

concentrated its attention on farm-level and post-harvest losses, treating retail as a secondary or even negligible stage simply because that is where losses happen to be smaller in absolute terms.

This asymmetry matters because retail systems in developing countries are neither absent nor uniform: informal markets, inconsistent cold-chain access, and rapidly urbanizing consumer bases mean that retail-level loss in these settings may behave very differently from either the mature retail systems of Europe and North America or the on-farm losses that dominate existing developing-country research. Thi et al. (2015) come closest to acknowledging this blind spot, noting that urbanization and rising incomes are reshaping food waste generation in developing economies in ways the existing farm-centric literature was not designed to capture, yet even their review stops short of isolating retail loss as a distinct variable and testing its relationship to undernourishment directly.

A distinct but related body of economic modelling asks not how much is lost but what would happen if losses were reduced, and here the literature disagrees quite openly about where intervention would do the best. Okawa (2015), using the OECD-FAO Aglink-Cosimo model, found that demand-side reductions in consumer waste in wealthy countries exert far greater downward pressure on international prices than supply-side gains from reduced producer losses, generating cumulative consumer savings of 2.52 trillion US dollars over a decade alongside 421 billion dollars in producer revenue losses concentrated in China's pigmeat sector.

Munesue et al. (2015) and Munesue and Masui (2019) obtained a complementary conclusion from a different perspective, which estimated that a reduction in food loss and waste by half in developed areas would decrease the number of undernourished people in developing nations by about 63 million people, thereby showing that there is a spill-over effect of policies from rich nations on poor nations. Kuiper and Cui (2021), on the other hand, using a global economy-wide modeling approach, showed that reducing losses during the initial production stage will yield the maximum benefit in terms of increased availability and access to food in low-income regions. Lopez Barrera and Hertel (2021) complicate matters further with evidence of a non-linear relationship between income and food waste across 158 countries, projecting that household waste will rise sharply in emerging economies such as China and South Asia as incomes grow, which suggests that today's low-waste developing countries may not remain low-waste for long.

Rutten (2013) offers perhaps the most sobering caution among this group, showing through supply-and-demand theory that reducing losses does not automatically produce uniform welfare gains at all, since producers can suffer short-run losses even as consumers benefit, a nuance that much of the more descriptive literature overlooks entirely. Xia et al. (2026), applying multi-regional input-output modelling, add a distributive-justice dimension by showing that production-based accounting understates the responsibility of import-dependent nations for global food loss and waste, shifting an average of 31 percent of responsibility back onto importing countries. While global modelling studies provide useful insights, country-specific research is still crucial since the causes and consequences of food loss vary across economic and institutional contexts.

Country-based case studies present valuable insight into the diverse manifestations of food losses and food insecurity in developing nations. Research from countries such as China, South Africa, Pakistan, India, Turkey, Lebanon, and others reveals that food loss impacts food availability, nutrition, and food security through inefficient supply chains, poor infrastructure for storage, post-harvest food losses, and food access issues.

The negative consequences of armed conflicts have a significant impact on food security (Dankevych et al., 2024). While the extent and causes of food losses differ in different

countries, most research studies suggest that food losses have been shown to help improve food availability and nutrition and make food security more attainable. In essence, the findings emphasize the need to understand the impact of losses in particular parts of the food supply chain that cause undernutrition in developing countries (Wang et al., 2023). Although country-level studies provide comprehensive contextual evidence, they do not fully explain why undernutrition occurs in nations with diverse economic and food-system situations.

A further cluster of work addresses solutions rather than causes, and even here consensus is partial. Garrone et al. (2014) proposed an availability–surplus–recoverability–waste model, Vilariño et al. (2017) and de Oliveira et al. (2021) frame circular-economy principles as the organising solution, and Tchonkouang et al. (2023) with Aschemann-Witzel et al. (2023) argue for valorisation and upcycling of food that would otherwise be discarded. Yet Dudziak et al. (2022), examining gendered and regional patterns in self-reported food waste, expose a methodological weakness running through much of this literature: self-declared waste behaviour is vulnerable to social desirability bias, so the demographic differences circular-economy interventions target may not hold under objective, diary-based measurement. Manzoor et al. (2024), Chauhan et al. (2021), reviewing hundreds of studies between them, converge on the observation that stakeholder coordination and standardised measurement are repeatedly recommended but rarely implemented at scale, while Akkerman and Cruijssen (2024), Zayed et al. (2026), argue that even the underlying convention of counting loss by weight or volume is flawed, since it ignores how nutrient density differs across food types. Horák et al. (2023) emphasize the importance of efficient agricultural resource use for sustainable development and food security. Nitsenko et al. (2024) emphasize the need for ethical and social incentives when analyzing approaches. Von Braun et al. (2023) frame the coexistence of loss and hunger as a fundamental failure of contemporary food systems, a framing broad enough to be difficult to disagree with but also too broad to say where, within the supply chain, action should begin. Despite these essential advances, there are considerable conceptual and empirical gaps in understanding the precise role of retail-stage food losses in influencing undernutrition outcomes in developing countries.

Model selection: the Gausman specification test

The Hausman specification test has been carried out in Table 9 so as to identify the optimal approach to estimate the panel data model. The chi-squared value was 6.512, with a p-value of 0.2595. It indicates that we cannot reject the null hypothesis. It can be seen from the results that the Random Effects model is superior to the Fixed Effects model since there is no systematic relationship between the unobserved country effects and the explanatory variables. The opposite sign of the coefficients in pooled OLS vs. panel estimates indicates that there is country-specific heterogeneity omitted. Those countries that have better economic and institutional performance might at the same time experience higher retail loss while having low levels of undernourishment. Having controlled for this hidden heterogeneity using Fixed and Random Effects estimations, the actual positive relationship becomes clear. This conclusion emphasizes the need to take into account cross-country heterogeneity in the analysis of the food security problem of food losses at the retail stage.

Table 9

Hausman test result

Test	Chi-Sq. Statistics	Chi-Sq. *d.f*	Probability
Cross Section Random	6.512157	5	0.2595

Source: estimated by the authors

Diagnostic tests

Panel heteroskedasticity LR test rejects the null hypothesis of homoskedasticity (statistic=467.772, p<0.01), thus verifying the use of robust standard errors (Table 10).

Table 10

Panel Cross-Section Heteroskedasticity LR Test

Test	Statistics	*d.f.*	P-value	Decision
Panel Cross-Section Heteroskedasticity LR Test	467.772	30	0.0000	Reject H_0

Source: estimated by the authors

Panel cross-sectional dependence test results in Table 11 exhibit highly significant Breusch-Pagan LM and Pesaran Scaled LM statistics (p<0.01), although the Pesaran *CD* test is insignificant (p=0.1474). There seems to be little cross-sectional correlation on an average basis.

Table 11

Cross-sectional dependence test

Test	Statistics	*d.f.*	*P*-value
Breusch-Pagan LM	2133.243	435	0.0000
Pesaran Scaled LM	57.576	-	0.0000
Pesaran CD	-1.449	-	0.1474

Source: estimated by the authors

Potential food-energy recovery from retail loss reduction

Econometrics confirms the existence of a statistically significant association between calorie losses at the retail stage and undernutrition; yet, the scale of this relationship becomes more comprehensible in light of its translation into the possible consequences for food security. To answer the question of how much food would actually be recovered, this research conducts a counterfactual calorie recovery analysis. It does not aim to assume that all food losses can be eliminated but to consider a more realistic case scenario when half of retail-stage calorie losses are saved.

Based on the findings, there is a positive impact of reducing the retail stage calories losses on food security. Under the 50 percent reduction assumption, the recoverable calories were equal to 57.62-million-person equivalents per year in 2022 for 28 countries, averaging 2.06-million-person equivalents for each country. It means that the reduction of retail stage losses will have the positive impact on the volume of food energy available for human consumption, thereby contributing to food security improvement. These findings are supported by the literature review where it is stated that food loss and waste reduction can lead to food availability increase and, therefore, to food security improvement. Nevertheless, these person equivalents are the potential food energy but not the number of people who will become free from undernutrition.

Summary of novelty and contribution

Overall, the findings presented in this paper differ from the food loss literature in three aspects. First, whereas previous studies (Aragie et al., 2018; Ishangulyyev et al., 2019) reveal

very significant upstream losses in one specific region, this paper reveals the same degree of losses in geographically different regions (East Africa and the Bolivia-Nicaragua Cluster). In doing so, undernourishment ceases to be a geographically determined problem and becomes a structural one. Second, the adoption of the retail-level calorie loss index (ICLRD) as the key explanatory variable addresses another issue with the data.

Namely, the correlation between ICLRD and undernourishment is clear only when controlling for heterogeneity through the Random Effects model; otherwise, it appears that the countries with high ICLRD values are not necessarily the most undernourished. Third, direct comparison of Sub-Saharan Africa with the Middle East and North Africa rather than region-siloed comparison, which is typical of the literature (Abiad & Meho, 2018), demonstrates that despite structurally different reasons for food loss, they can result in the same outcomes of undernourishment. In summary, the findings clearly show that food loss continues to play an important role in causing under-nutrition, even after accounting for the effects of income, prices, and cross-country variation.

Policy implications

With retail-level loss and income being separate, balancing factors of undernourishment, policies to reduce hunger should focus specifically on improving retail efficiency without relying on the automatic result of income generation or agricultural output, especially considering that the SDG Target 12.3 aims to reduce retail and consumer food losses by half by 2030. Since undernourishment prevalence has more of a structural than a regional pattern, retail and cold chain policies known to be successful in one country, for instance, East African nations, can be adopted in similarly structured nations, like Bolivia and Nicaragua, without having to create a new policy for each region. Nevertheless, the similar level of undernourishment found in Sub-Saharan Africa and MENA is due to different causes, namely production-stage inefficiency in one and dependence on imports in the other, thus requiring the development of policies for each path separately. Digital retail monitoring systems, enhanced inventory management, cold-chain development, and food donation initiatives are examples of practical approaches.

Limitations

The primary drawbacks of this study are associated with the availability of data and research scope. The choice of the ICLRD as the main explanatory variable is justified due to the lack of similar cross-country data on previous stages of the food supply chain: production, harvesting, post-harvesting, storage, and transportation of food products. Hence, the results of the study present the correlation between the caloric losses during the retail stage and the level of undernourishment, but not the overall impact of the losses throughout the food supply chain. The lack of data also prevents the inclusion of institutional variables that would allow assessing their possible moderating role in the examined relationship. Despite the geographical diversity of the panel of 30 countries, the differences in food supply systems, infrastructure, and retail structure can influence the applicability of the study's results. Lastly, only 28 countries have data for the assessment of the food energy recovery and person-equivalent; therefore, this measure is estimated only within this subsample.

Future research directions

Based on the limitations highlighted above, Future research should focus on the comparison between the Food Loss Index (FLI) and Food Waste Index (FWI), as well as the retail food loss index, in order to determine the stage that has the biggest effect on

malnutrition. The reason is that such studies would provide much more information in support of the development of specific food security policy measures, especially in developing nations. Lastly, using dummy variables or interaction of ICLRD and regions would turn the current regional descriptive comparison into a more rigorous testing process. Extending the panel data to years beyond 2022 and including a larger number of countries would validate the pattern observed in the current study. Future research should also use more extensive and harmonized food-supply data to expand the food-energy recovery evaluation to the entire study sample and increase the precision of person-equivalent estimations.

Conclusions

This paper analyzes the effect of retail food waste on undernutrition in 30 developing countries from Sub-Saharan Africa, MENA, South Asia, Southeast Asia, and Latin America and the Caribbean over the period of 2010–2022 using Pooled OLS, Fixed Effects, and Random Effects panel data models. The empirical results suggest that allowing for unobservable differences between countries significantly alters the relationship between retail food waste and undernutrition. According to the Pooled OLS, the relationship is negative, while both Fixed Effects ($\beta = 1.6469$, $p < 0.01$) and Random Effects ($\beta = 1.3742$, $p < 0.05$) models indicate a positive and statistically significant relationship, implying that omission of unobserved country heterogeneity results in biased results. In line with the results of the Hausman test, the Random Effects model is chosen as the preferred estimator.

On the control variables, the variable GDP per capita is seen to be highly significant in having a negative impact on undernourishment. Although Food Production Index (FPI), Agriculture, Forestry and Fishing Value Added (AFV), and Inflation (INF) were not statistically significant in the estimated models, these variables remain important background determinants of food security. Their influence is likely to be indirect, operating through production capacity, agricultural productivity, food prices, purchasing power, and supply-chain conditions rather than exerting an immediate direct effect on undernourishment.

The results of the descriptive comparison show that undernourishment is not only affected by the geographic position of the country. Different countries in various regions can have an equal degree of undernourishment despite having various economic and institutional conditions, while different countries in the same region can reach the same outcome due to various mechanisms. It means that reduction of retail food loss by the optimization of logistics, cold chain infrastructure, stock management, and redistribution of the food can be considered together with economic development measures. Such a combination of policy measures will help to accomplish SDG2 (zero hunger) and SDG12.3 on food loss reduction.

References

Abbade, E. B. (2020). Estimating the nutritional loss and the feeding potential derived from food losses worldwide. *World Development, 134*, 105038. https://doi.org/10.1016/j.worlddev.2020.105038

Abiad, M. G., & Meho, L. I. (2018). Food loss and food waste research in the Arab world: A systematic review. *Food Security, 10*, 311–322. https://doi.org/10.1007/s12571-018-0782-7

Akkerman, R., & Cruijssen, F. (2024). Food loss, food waste, and sustainability in food supply chains. In *Sustainable supply chains: A research-based textbook on operations and strategy* (pp. 219–239). Springer. https://doi.org/10.1007/978-3-031-45565-0_9

Alexander, C., Gregson, N., & Gille, Z. (2013). Food waste. In A. Murcott, W. Belasco, & P. Jackson (Eds.), *The handbook of food research* (pp. 471–484). Bloomsbury Academic. https://doi.org/10.5040/9781350042261-ch-0028

Aragie, E., Balié, J., & Morales-Opazo, C. (2018). Does reducing food losses and wastes in sub-Saharan Africa make economic sense? *Waste Management & Research, 36*(6), 483–494. https://doi.org/10.1177/0734242X18770247

Aschemann-Witzel, J., Asioli, D., Banovic, M., Perito, M. A., Peschel, A. O., & Stancu, V. (2023). Defining upcycled food: The dual role of upcycling in reducing food loss and waste. *Trends in Food Science & Technology, 132*, 132–137. https://doi.org/10.1016/j.tifs.2023.01.001

Baltagi, B. H. (2021). *Econometric analysis of panel data* (6th ed.). Springer, Cham, Switzerland. https://doi.org/10.1007/978-3-030-53953-5

Baykoca, B., & Yılmaz, S. (2025). Understanding food loss patterns across developed and developing countries using a GDP, growth rate, and health expenditure-based typology. *Scientific Reports, 15*, 27597. https://doi.org/10.1038/s41598-025-13156-3

Berjan, S., Capone, R., Debs, P., & El Bilali, H. (2018). Food losses and waste: A global overview with a focus on Near East and North Africa region. *International Journal of Agricultural Management and Development, 8*(1), 1–16. https://doi.org/10.22004/ag.econ.292516

Busetti, S., & Pace, N. (Eds.). (2023). *Food loss and waste policy: From theory to practice*. Routledge, London. https://doi.org/10.4324/9781003226932

Campoy-Muñoz, P., Cardenete, M. A., Delgado, M. C., & Sancho, F. (2021). Food losses and waste: A needed assessment for future policies. *International Journal of Environmental Research and Public Health, 18*(21), 11586. https://doi.org/10.3390/ijerph182111586

Chaboud, G., & Daviron, B. (2017). Food losses and waste: Navigating the inconsistencies. *Global Food Security, 12*, 1–7. https://doi.org/10.1016/j.gfs.2016.11.004

Chalak, A., Abiad, M. G., Diab, M., & Nasreddine, L. (2019). The determinants of household food waste generation and its associated caloric and nutrient losses: The case of Lebanon. *PLOS ONE, 14*(12), e0225789. https://doi.org/10.1371/journal.pone.0225789

Chalak, A., Abou-Daher, C., & Abiad, M. G. (2018). Generation of food waste in the hospitality and food retail and wholesale sectors: Lessons from developed economies. *Food Security, 10*, 1279–1290. https://doi.org/10.1007/s12571-018-0841-0

Chauhan, C., Dhir, A., Akram, M. U., & Salo, J. (2021). Food loss and waste in food supply chains: A systematic literature review and framework development approach. *Journal of Cleaner Production, 295*, 126438. https://doi.org/10.1016/j.jclepro.2021.126438

Chen, C., Chaudhary, A., & Mathys, A. (2020). Nutritional and environmental losses embedded in global food waste. *Resources, Conservation and Recycling, 160*, 104912. https://doi.org/10.1016/j.resconrec.2020.104912

Choi, I. (2001). Unit root tests for panel data. *Journal of International Money and Finance, 20*(2), 249–272. https://doi.org/10.1016/S0261-5606(00)00048-6

Dankevych, A., Stoyanova-Koval, S., Polova, O., Los, Z., Burdeina, N., & Kazak, O. (2024). State of economic security and directions of restoration socio-economic development and food security in the conditions of war. *Financial and Credit Activity Problems of Theory and Practice, 2*(55), 441–460. https://doi.org/10.55643/fcaptp.2.55.2024.4170

de Oliveira, M. M., Lago, A., & Dal' Magro, G. P. (2021). Food loss and waste in the context of the circular economy: A systematic review. *Journal of Cleaner Production, 294*, 126284. https://doi.org/10.1016/j.jclepro.2021.126284

Dudziak, A., Stoma, M., & Derkacz, A. J. (2022). Circular economy in the context of food losses and waste. *Sustainability, 14*(16), 10116. https://doi.org/10.3390/su141610116

Durán-Sandoval, D., Durán-Romero, G., & Uleri, F. (2023). How much food loss and waste do countries with problems with food security generate? *Agriculture, 13*(5), 966. https://doi.org/10.3390/agriculture13050966

Eastham, J., & Creedon, A. (2023). Food losses, food waste, and beyond in food supply chains: Retaining optimum nutrient density. *Food Frontiers, 4*, 971–979. https://doi.org/10.1002/fft2.271

Garrone, P., Melacini, M., & Perego, A. (2014). Opening the black box of food waste reduction. *Food Policy, 46*, 129–139. https://doi.org/10.1016/j.foodpol.2014.03.014

Gatto, A., & Chepeliev, M. (2024). Global food loss and waste estimates show increasing nutritional and environmental pressures. *Nature Food, 5*, 136–147. https://doi.org/10.1038/s43016-023-00915-6

Gómez, M. I., & Ricketts, K. D. (2013). Food value chain transformations in developing countries: Selected hypotheses on nutritional implications. *Food Policy, 42*, 139–150. https://doi.org/10.1016/j.foodpol.2013.06.010

Gustavsson, J., Cederberg, C., Sonesson, U., van Otterdijk, R., & Meybeck, A. (2011). *Global food losses and food waste: Extent, causes and prevention*. Food and Agriculture Organization of the United Nations, Rome. https://www.fao.org/4/mb060e/mb060e00.pdf

Hodges, R. J., Buzby, J. C., & Bennett, B. (2011). Postharvest losses and waste in developed and less developed countries: Opportunities to improve resource use. *The Journal of Agricultural Science, 149*(S1), 37–45. https://doi.org/10.1017/S0021859610000936

Horák, J., Bilan, Y., Dankevych, A., Nitsenko, V., Kucher, A., & Streimikiene, D. (2023). Bioenergy production from sunflower husk in Ukraine: Potential and necessary investments. *Journal of Business Economics and Management, 24*(1), 1–19. https://doi.org/10.3846/jbem.2023.17756

Imran, M., Tufail, M., Mo, C., Wahab, S., Khan, M. K., Chee Hoo, W., & Ling, Z. (2025). From resources to resilience: Understanding the impact of standard of living and energy consumption on natural resource rent in Asia. *Energy Strategy Reviews, 57*, 101590. https://doi.org/10.1016/j.esr.2024.101590

Ishangulyyev, R., Kim, S., & Lee, S. H. (2019). Understanding food loss and waste: Why are we losing and wasting food? *Foods, 8*(8), 297. https://doi.org/10.3390/foods8080297

James, A., & Zikankuba, V. (2017). Postharvest management of fruits and vegetables: A potential for reducing poverty, hidden hunger and malnutrition in sub-Sahara Africa. *Cogent Food & Agriculture, 3*(1), 1312052. https://doi.org/10.1080/23311932.2017.1312052

Joardder, M. U. H., & Masud, M. H. (2019). *Food preservation in developing countries: Challenges and solutions*. Springer, Cham, Switzerland. https://doi.org/10.1007/978-3-030-11530-2

Karwowska, M., Łaba, S., & Szczepański, K. (2021). Food loss and waste in meat sector: Why the consumption stage generates the most losses? *Sustainability, 13*(11), 6227. https://doi.org/10.3390/su13116227

Kechagias, E. P., Gayialis, S. P., Panayiotou, N., & Papadopoulos, G. A. (2024). A holistic framework for evaluating food loss and waste due to marketing standards across the entire food supply chain. *Foods, 13*(20), 3273. https://doi.org/10.3390/foods13203273

Khalid, S., Naseer, A., Shahid, M., Shah, G. M., Ullah, M. I., Waqar, A., Abbas, T., Imran, M., & Rehman, F. (2019). Assessment of nutritional loss with food waste and factors governing this waste at household level in Pakistan. *Journal of Cleaner Production, 206*, 1015–1024. https://doi.org/10.1016/j.jclepro.2018.09.138

Khan, A. A., Siddiqui, Y., Siddique, K. H. M., Bobo, J. A., & Ali, A. (2024). Minimizing postharvest food losses: A vital strategy to alleviate food insecurity and malnutrition in developing nations: A review. *Discover Food, 4*, 145. https://doi.org/10.1007/s44187-024-00129-0

Kramer, C. V., & Allen, S. (2015). Malnutrition in developing countries. *Paediatrics and Child Health, 25*(9), 422–427. https://doi.org/10.1016/j.paed.2015.04.002

Kuiper, M., & Cui, H. D. (2021). Using food loss reduction to reach food security and environmental objectives: A search for promising leverage points. *Food Policy, 98*, 101915. https://doi.org/10.1016/j.foodpol.2020.101915

Kumar, D., & Kalita, P. (2017). Reducing postharvest losses during storage of grain crops to strengthen food security in developing countries. *Foods, 6*(1), 8. https://doi.org/10.3390/foods6010008

Levin, A., Lin, C.-F., & Chu, C.-S. J. (2002). Unit root tests in panel data: Asymptotic and finite-sample properties. *Journal of Econometrics, 108*(1), 1–24. https://doi.org/10.1016/S0304-4076(01)00098-7

Lopez Barrera, E., & Hertel, T. (2021). Global food waste across the income spectrum: Implications for food prices, production and resource use. *Food Policy, 98*, 101874. https://doi.org/10.1016/j.foodpol.2020.101874

Manzoor, S., Fayaz, U., Dar, A. H., Dash, K. K., Shams, R., Bashir, I., Pandey, V. K., & Abdi, G. (2024). Sustainable development goals through reducing food loss and food waste: A comprehensive review. *Future Foods, 9*, 100362. https://doi.org/10.1016/j.fufo.2024.100362

Miller, D. D., & Welch, R. M. (2013). Food system strategies for preventing micronutrient malnutrition. *Food Policy, 42*, 115–128. https://doi.org/10.1016/j.foodpol.2013.06.008

Mokrane, S., Buonocore, E., Capone, R., & Franzese, P. P. (2023). Exploring the global scientific literature on food waste and loss. *Sustainability, 15*(6), 4757. https://doi.org/10.3390/su15064757

Moraes, C. C. D., Costa, F. H. D. O., Pereira, C. R., Silva, A. L. D., & Delai, I. (2020). Retail food waste: Mapping causes and reduction practices. *Journal of Cleaner Production, 256*, 120124. https://doi.org/10.1016/j.jclepro.2020.120124

Munesue, Y., & Masui, T. (2019). The impacts of Japanese food losses and food waste on global natural resources and greenhouse gas emissions. *Journal of Industrial Ecology, 23*(5), 1196–1210. https://doi.org/10.1111/jiec.12863

Munesue, Y., Masui, T., & Fushima, T. (2015). The effects of reducing food losses and food waste on global food insecurity, natural resources, and greenhouse gas emissions. *Environmental Economics and Policy Studies, 17*, 43–77. https://doi.org/10.1007/s10018-014-0083-0

Nahman, A., & De Lange, W. (2013). Costs of food waste along the value chain: Evidence from South Africa. *Waste Management, 33*(11), 2493–2500. https://doi.org/10.1016/j.wasman.2013.07.012

Nitsenko, V., Dankevych, A., Dzoba, O., Ustenko, A., Bashynska, Yu. (2024). Ethical and social incentives for the transformation of the business model of enterprise management in conditions of sustainable development. *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu*, 4, 172-179. https://doi.org/10.33271/nvngu/2024-4/172.

Nugroho, A. D., Cubillos Tovar, J. P., Bopushev, S. T., Bozsik, N., Fehér, I., & Lakner, Z. (2022). Effects of corruption control on the number of undernourished people in developing countries. *Foods, 11*(7), 924. https://doi.org/10.3390/foods11070924

Okawa, K. (2015). *Market and trade impacts of food loss and waste reduction* (OECD Food, Agriculture and Fisheries Papers No. 75). OECD Publishing, Paris. https://doi.org/10.1787/5js4w29h0wr2-en

Paraschivu, M., Cotuna, O., Matei, G., & Sărățeanu, V. (2022). Are food waste and food loss a real threat for food security? *Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 22*(1), 479–484. https://managementjournal.usamv.ro/pdf/vol.22_1/Art56.pdf

Pollard, C. M., & Booth, S. (2019). Food insecurity and hunger in rich countries: It is time for action against inequality. *International Journal of Environmental Research and Public Health, 16*(10), 1804. https://doi.org/10.3390/ijerph16101804

Popkin, B. M., Corvalan, C., & Grummer-Strawn, L. M. (2020). Dynamics of the double burden of malnutrition and the changing nutrition reality. *The Lancet, 395*(10217), 65–74. https://doi.org/10.1016/S0140-6736(19)32497-3

Porat, R., Lichter, A., Terry, L. A., Harker, R., & Buzby, J. C. (2018). Postharvest losses of fruit and vegetables during retail and in consumers' homes: Quantifications, causes, and means of prevention. *Postharvest Biology and Technology, 139*, 135–149. https://doi.org/10.1016/j.postharvbio.2017.11.019

Rutten, M. M. (2013). What economic theory tells us about the impacts of reducing food losses and/or waste: Implications for research, policy and practice. *Agriculture & Food Security, 2*, 13. https://doi.org/10.1186/2048-7010-2-13

Schmidhuber, J., & Shetty, P. (2005). The nutrition transition to 2030: Why developing countries are likely to bear the major burden. *Acta Agriculturae Scandinavica, Section C—Food Economics, 2*(3–4), 150–166. https://doi.org/10.1080/16507540500534812

Schönfeldt, H. C., & Gibson Hall, N. (2012). Dietary protein quality and malnutrition in Africa. *British Journal of Nutrition, 108*(S2), S69–S76. https://doi.org/10.1017/S0007114512002553

Shafiee-Jood, M., & Cai, X. (2016). Reducing food loss and waste to enhance food security and environmental sustainability. *Environmental Science & Technology, 50*(16), 8432–8443. https://doi.org/10.1021/acs.est.6b01993

Sheahan, M., & Barrett, C. B. (2017). Review: Food loss and waste in Sub-Saharan Africa. *Food Policy, 70*, 1–12. https://doi.org/10.1016/j.foodpol.2017.03.012

Shlash, A. A. M., Al-Ramadan, A. M., Ibrahim Mohammad, S., Al Oraini, B., Vasudevan, A., Turki Alshurideh, M., Chen, Q., & Ali, I. (2025). Enhancing metadata management and data-driven decision-making in sustainable food supply chains using blockchain and AI technologies. *Data and Metadata, 4*, 683. https://doi.org/10.56294/dm2025683

Shynkaruk, L., Dielini, M., Vlasenko, T., Svyrydenko, D., Nitsenko, V., Kondratyev, Y., & Salii, I. (2025). Food security and the agri-food sector of Ukraine: An inclusive approach. *Rocznik Ochrona Środowiska, 27*, 553–570. https://doi.org/10.54740/ros.2025.045

Smith, D. W. (1998). Urban food systems and the poor in developing countries. *Transactions of the Institute of British Geographers, 23*(2), 207–219. https://doi.org/10.1111/j.0020-2754.1998.00207.x

Spang, E. S., Moreno, L. C., Pace, S. A., Achmon, Y., Donis-Gonzalez, I., Gosliner, W. A., Jablonski-Sheffield, M. P., Momin, M. A., Quested, T. E., Winans, K. S., & Tomich, T. P. (2019). Food loss and waste: Measurement, drivers, and solutions. *Annual Review of Environment and Resources, 44*, 117–156. https://doi.org/10.1146/annurev-environ-101718-033228

Stabnikova, O., Shevchenko, O., Stabnikov, V., & Paredes-López, O. (Eds.). (2023). *Bioconversion of waste to value-added products*. CRC Press. https://doi.org/10.1201/9781003329671

Tchonkouang, R. D., Onyeaka, H., & Miri, T. (2023). From waste to plate: Exploring the impact of food waste valorisation on achieving zero hunger. *Sustainability, 15*(13), 10571. https://doi.org/10.3390/su151310571

Thayyil, A., & Manogna, R. L. (2026). Impact of climate change mitigation finance on food security in emerging and developing economies of Global South. *Discover Food*. https://doi.org/10.1007/s44187-026-01202-6

Thi, N. B. D., Kumar, G., & Lin, C.-Y. (2015). An overview of food waste management in developing countries: Current status and future perspective. *Journal of Environmental Management, 157*, 220–229. https://doi.org/10.1016/j.jenvman.2015.04.022

Todd, E. C. D., & Faour-Klingbeil, D. (2024). Impact of food waste on society, specifically at retail and foodservice levels in developed and developing countries. *Foods, 13*(13), 2098. https://doi.org/10.3390/foods13132098

U.S. Department of Agriculture, & U.S. Department of Health and Human Services. (2020). *Dietary guidelines for Americans, 2020–2025* (9th ed.). U.S. Department of Agriculture; U.S. Department of Health and Human Services, Washington, DC. https://www.dietaryguidelines.gov/

United Nations Environment Programme. (2024). *Food waste index report 2024*. https://www.unep.org/resources/publication/food-waste-index-report-2024

van der Werf, P., & Gilliland, J. A. (2017). A systematic review of food losses and food waste generation in developed countries. *Proceedings of the Institution of Civil Engineers—Waste and Resource Management, 170*(2), 66–77. https://doi.org/10.1680/jwarm.16.00026

Vilariño, M. V., Franco, C., & Quarrington, C. (2017). Food loss and waste reduction as an integral part of a circular economy. *Frontiers in Environmental Science, 5*, 21. https://doi.org/10.3389/fenvs.2017.00021

von Braun, J., Sánchez Sorondo, M., & Steiner, R. (2023). Reduction of food loss and waste: The challenges and conclusions for actions. In J. von Braun, M. Sánchez Sorondo, & R. Steiner (Eds.), *Science and innovations for food systems transformation* (pp. 569–578). Springer, Cham, Switzerland. https://doi.org/10.1007/978-3-031-15703-5_31

Wang, R., Lu, S., Zhou, L., Yang, Z., Tang, Z., Zhao, M., & Cheng, G. (2023). Assessing nutritional and economic aspects of food loss and waste in China. *Sustainable Production and Consumption, 42*, 95–105. https://doi.org/10.1016/j.spc.2023.09.010

Wooldridge, J. M. (2021). *Introductory econometrics: A modern approach* (7th ed.). Cengage Learning, Boston, MA.

World Bank Group. (2025). *World development indicators*. https://databank.worldbank.org/source/world-development-indicators

Wunderlich, S. M., & Martinez, N. M. (2018). Conserving natural resources through food loss reduction: Production and consumption stages of the food supply chain. *International Soil and Water Conservation Research, 6*(4), 331–339. https://doi.org/10.1016/j.iswcr.2018.06.002

Xue, L., Liu, G., Parfitt, J., Liu, X., Van Herpen, E., Stenmarck, Å., O'Connor, C., Östergren, K., & Cheng, S. (2017). Missing food, missing data? A critical review of global food losses and food waste data. *Environmental Science & Technology, 51*(12), 6618–6633. https://doi.org/10.1021/acs.est.7b00401

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Dankevych, A., Mitu, M. N., Zayed, N. M., Nitsenko, V., & Ingram, K. L. (2026). Impact of retail food loss on undernourishment in developing countries. *Ukrainian Food Journal, 15*(3), 949–976. https://doi.org/10.24263/2304-974X-2026-15-3-19