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Research Article

Addressing Under-Nourishment in India: Insights from Factor Analysis and Regression Analysis

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Abstract: Malnutrition is a situation where an individual intakes insufficient energy and nutrients to meet the requirement of maintaining good health. India, despite its economic growth and advancements in agricultural productivity, continues to face significant challenges in combating malnutrition. Rising inflation, fluctuating food prices, and climate change-induced agricultural instability exacerbate undernourishment, particularly among rural and marginalized communities. This study investigates the determinants of under-nutrition in India using factor analysis and regression modelling. Three key factors were identified: Economic Development and Inequality, Price Dynamics and Consumption Patterns, and Environmental and Institutional Factors. Regression analysis revealed that Price Dynamics and Consumption Patterns significantly exacerbate under-nutrition (B=0.604, p=0.014), highlighting the critical role of food prices and inflation in worsening food insecurity. In contrast, Economic Development and Inequality and Environmental and Institutional Factors did not show statistically significant effects. The findings align with economic theories such as the Demand-Supply Theory, Kuznets Curve, and Malthusian Theory, emphasizing the importance of stabilizing food prices, reducing income inequality, and promoting environmental sustainability. Policy implications include implementing price controls, subsidies, and investments in agricultural productivity to mitigate food price volatility, alongside addressing income inequality and strengthening institutional frameworks.

Keywords: Under-nutrition, Food security, Economic development, Price dynamics, Environmental sustainability, Factor analysis, Regression analysis, India

JEL Classification: I15, Q18, O15, Q54

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1. Introduction

Malnutrition constitutes a condition in which an individual fails to consume adequate energy and essential nutrients necessary for the maintenance of optimal health. This phenomenon encompasses three overarching categories of conditions, specifically under- nutrition, micronutrient deficiencies, and overweight, obesity, and diet-related non- communicable diseases (WHO, 2024). Various metrics exist for assessing nutritional status, including physical functionality, clinical manifestations of deficiencies, biochemical markers, and dietary consumption patterns. Malnutrition predominantly affects dependent and vulnerable populations who rely on external support, adversely impacting appetite, digestion, nutrient absorption, and overall utilization (Golden, Weatherall, Ledingham, & Warrel, 1996). This public health issue persists as a significant global crisis, undermining individual health, productivity, and broader economic development (WHO, 2024). Factors such as unemployment, gender inequity, income inequality, and lifestyle choices—including alcohol consumption—create systemic obstacles to achieving adequate nutrition, particularly in developing nations like India.

Despite notable economic progress and advancements in agricultural efficiency, India continues to grapple with formidable challenges in its efforts to mitigate malnutrition. The impacts of rising inflation, volatile food prices, and agricultural instability attributable to climate change intensify undernourishment, especially among rural and marginalized populations. According to the National Family Health Survey (NFHS-5, 2019-21), 35.5 percent of children under five years of age exhibit stunting, while the prevalence of wasting has decreased from 21 percent to 19.3 percent, and the rate of underweight children has declined from 35.8 percent to 32.1 percent.

A variety of theoretical frameworks provide essential insights for comprehending the complex economic factors that influence under-nutrition. These theoretical constructs elucidate the interplay between economic circumstances, environmental sustainability, and food security. A pertinent example is the Demand-Supply theory articulated by Adam Smith and Alfred Marshall, which posits that fluctuations in price lead to supply constraints and demand surges, ultimately influencing food affordability. In a similar vein, Simon Kuznets' Kuznets curve elucidates how initial phases of economic development may exacerbate inequality, thereby constraining access to food and essential resources. Moreover, Amartya Sen's Capability approach postulates that poverty is not solely a function of low income, but also reflects a deficiency in the capabilities required to fulfil basic needs, thereby influencing food and nutrition security.

2. Objectives of the study

(i) To determine the key factors influencing under-nourishment in India

(ii) To assess the impact of social, economic and environmental factors on under-nutrition.

3. Methodology

Research Design

This study uses a quantitative research design to examine the determinants of under-nourishment with the help of factor analysis and regression analysis. It is structured into two main stages namely Factor Analysis and regression analysis. Factor analysis is done in order to identify the underlying dimensions of the dataset. Regression analysis is applied to assess the impact of the extracted factors on under-nutrition.

Table 2(a): Variables used in the model and their explanation

Sl.	Variable	Explanation	Source
1	Malnutrition	Refers to deficiencies, excesses, or imbalances in a person's intake of energy and/or nutrients. It includes undernutrition (wasting, stunting, underweight), micronutrient deficiencies, and overnutrition (obesity).	Food and Agriculture Organization of the United Nations (FAO)
2	GDP Per Capita	Gross Domestic Product (GDP) divided by the population, indicating the average economic output per person. It measures a country's economic performance and standard of living.	Ministry of Statistics and Programme Implementation (MOSPI); Population data from Census of India
3	Per Capita Private Consumption Expenditure (PCPCE)	The average amount spent by individuals on goods and services for personal use. It reflects the standard of living and consumer spending patterns.	National Accounts Statistics, MOSPI
4	Global Food Price Index	International prices of food commodities, which can impact domestic food prices and affordability.	FAO
5	Inflation Rate	The rate at which the general level of prices for goods and services rises, eroding purchasing power. It is calculated using the Consumer Price Index (CPI) or Wholesale Price Index (WPI).	Reserve Bank of India (RBI); MOSPI
6	Exchange Rate	The value of the Indian Rupee compared to other currencies, affecting imports, exports, and foreign investment.	Reserve Bank of India (RBI)
7	Rainfall	The amount of precipitation, crucial for agriculture, water resources, and food production.	India Meteorological Department (IMD), Ministry of Earth Sciences
8	Economic Freedom	An index measuring the degree of economic freedom in a country, including factors like Property rights, government integrity, and business freedom.	The Heritage Foundation and The Wall Street Journal
9	Inequality- Adjusted Human Development Index (IHDI)	A composite index measuring a country's average achievements in health, education, and income.	UNDP
10	Consumer Price Index (CPI)	Measures changes in the price level of a basket of consumer goods and services, used to calculate inflation.	MOSPI
11	Food Expenditure	The amount spent on food by households, Indicating food security and consumption patterns.	National Sample Survey Office (NSSO), MOSPI

Sl.	Variable	Explanation	Source
12	Unemployment	The percentage of the labour force without work but available for and seeking employment.	Periodic Labour Force Survey (PLFS), MOSPI
13	Agricultural Production	The output of crops, livestock, and other Agricultural products, essential for food security and rural livelihoods.	Ministry of Agriculture and Farmers Welfare
14	Income Inequality Index	Measures the disparity in income distribution within a population, often using the Gini coefficient.	MOSPI
15	Alcohol Consumption	The amount of alcohol consumed per capita, which can impact health, nutrition, and social issues.	National Sample Survey (NSS), NFHS
16	Gender Inequality Index	Measures disparities between males and females in health, education, and economic participation.	UNDP
17	Food Availability Index	Measures food supply or accessibility, indicating how much food is available to the population.	Global Food Security Index (GFSI)
18	Food Affordability Index	Measures the cost of food relative to income, indicating how affordable food is for the population.	Global Food Security Index (GFSI)

The descriptive statistics of the above variables for India for the period of 2010 to 2024 can be found in the table 2. The table presents descriptive statistics for 17 variables potentially linked to under-nutrition and food security dynamics over a 14-year period (2010–2024). These variables include economic, nutritional, agricultural, and social indicators, with measures such as mean, median, mode, standard deviation, variance, skewness, kurtosis, and range providing insights into their central tendencies, dispersion, and distributional properties

Table 2(b): Descriptive Statistics of various factors influencing under-nutrition

Variables	Mean	Median	Mode	Std. Deviation	Variance	Skewness	Kurtosis	Range
Global Food Price	112.22	115	91.9	16.4587	270.889	0.328	-0.945	52.8
Inflation Rate	6.67	7	7	2.498	6.238	0.597	-0.106	9
GDP Per Capita	1884.47	1916	1351	429.386	184372.6	0.531	-0.753	1380
Exchange Rate	65	67	46	11.892	141.429	-0.294	-0.811	37
Rainfall	1202.2	1099	1099	217.565	47334.6	2.578	8.109	894
Economic Freedom	54.67	55	55	1.113	1.238	-0.306	-1.157	3
IHDI	0.41693	0.428	0.444	0.025833	0.001	-0.679	-1.071	0.075
CPI-Food and Beverages	133.73	133	90	31.118	968.352	0.187	-0.838	100
Undernourishme nt	15.5133	15.8	16.3	1.23049	1.514	-0.298	-0.993	4.1
Food Expenditure	42.68	42	38.20	3.27178	10.705	0.556	-0.791	10.4
Unemployment	6.2133	5.8	5.50	0.78819	0.621	0.751	-1.15	2.2
Agricultural Production	285.507	284.83	244.49	30.62455	937.863	0.257	-1.454	87.81
Income Inequality	34.4133	34.4	34.4	0.6435	0.414	-0.606	2.692	2.9
Alcohol Consumption	5.1387	4.96	4.87	0.44264	0.196	1.491	1.469	1.59
Gender inequality Index	0.5221	0.524	.44	0.06279	0.004	0.138	-0.892	0.19

Food Availability	63.78	63.8	63.10	0.90406	0.817	0.637	1.841	3.4
Food Affordability	57.06	58.35	50.20a	4.97018	24.703	-0.14	-1.274	14.1

Source: Author's Calculation based on data provided based on various government sources.

The descriptive statistics for 2010–2024 reveal key variables impacting under-nutrition in India, with economic theories providing context. Global Food Price (Mean=112.22, SD= 16.4587) shows moderate volatility, aligning with supply and demand dynamics, affecting food affordability per Engel's Law. Inflation Rate (Mean=6.67%, SD=2.498) and CPI-Food and Beverages (Mean = 133.73, SD = 31.118) reflect persistent price pressures, consistent with monetarist views on inflation eroding purchasing power. GDP Per Capita (Mean = 1884.47, SD = 429.386) indicates economic growth, supporting trickle-down theory, yet its variability suggests unequal benefits. Undernourishment (Mean = 15.5133%, SD = 1.23049) remains stable but high, challenging Kuznets' hypothesis of inequality-driven development reducing malnutrition. Rainfall (Mean = 1202.2 mm, SD = 217.565, Skewness = 2.578) exhibits extreme variability, critical for agricultural supply per Ricardo's land productivity theory. Income Inequality (Mean=34.4133, SD=0.6435) is stable, hinting at entrenched disparities per Piketty's capital accumulation framework. These patterns underscore economic volatility and structural inequities influencing food security, warranting deeper econometric analysis.

Data Collection

SecondarydatawerecollectedfromvariousgovernmentsourcessuchasGlobalHunger Index, NSSO Data, NFHS, NITI Aayog various reports, WHO, UNDP, RBI and Economic surveys of India. Data were collected from the year 2010 to 2024. Data were also collected from FAO, Agricultural statistics of India and PDS data to understand and poverty and hunger index. The data collected included 17 standardized (Z-scored variables) which are divided into three categories namely Economic Variable, Environmental Variables and Social Variables. The dependent variable Undernourishment, was derived from Food and Agriculture Organization of the United Nations (FAO).

Principal Component Analysis (PCA)

PCA with Varimax rotation was used to reduced imensionally and multi-collinearity to extract three key components (Eigenvalues>1) explaining the substantial variance. Factors with factor loadings ≥0.5 were considered significant. The three factors were interpreted as a) Economic Development and Inequality, b) Price Dynamics and Consumption Patterns and c) Environmental and Institutional Factors.

Multiple Regression Analysis

Secondly, multiple regression model was constructed to assess the impact of the identified principal components on undernourishment, measured using a standardized Z-score as well test for interaction effects.

Model Specification

The regression model is specified as follows:

$$Malnutrition=\beta 0+\beta 1(FactorScore1)+\beta 2(FactorScore2)+\beta 3(FactorScore3)+\beta 4(InteractionTerm)+\varepsilon$$

Where:

Factor Score1: Economic Development and Inequality.

Factor Score2: Price Dynamics and Consumption Patterns.

Factor Score3: Environmental and Institutional Factors.

Interaction Term: Interaction between Factor Score2 and Factor Score3.

β0: Constant term, β1, β2, β3, β4: Coefficients for the respective factors and interaction term, and ϵ: Error term.

Results and Discussion

Factor Analysis Results

This table shows the proportion of variance in each variable explained by the extracted components.

Table 3(a): Communalities

Variables	Initial	Extraction	Variables	Initial	Extraction
Zscore: GDP Per Capita	1.000	.980	Zscore: Inflation Rate	1.000	.879
Zscore: CPI-Food and Beverages	1.000	.937	Zscore: Food Expenditure	1.000	.981
Zscore: Unemployment	1.000	.856	Zscore: Alcohol Consumption	1.000	.876
Zscore: Gender inequality Index	1.000	.920	Zscore: Economic Freedom	1.000	.502
Zscore: Agricultural Production	1.000	.951	Zscore: Rainfall	1.000	.749
Zscore: PCPCE	1.000	.947	Zscore: Food Availability	1.000	.827
Zscore: Global Food Price	1.000	.900	Zscore: Food Affordability	1.000	.778
Extraction Method: Principal Component Analysis.					

Source: Authors' Calculation

The communalities table shows the proportion of variance in each variable explained by the extracted components. Most variables had high extraction communalities (≥ 0.8), indicating

that the components effectively capture their underlying structure. For example, GDP Per Capita (0.980), Agricultural Production (0.951), and Food Expenditure (0.981) are very well-explained by the components. However, Economic Freedom had a relatively low communality (0.502), suggesting that it may not fit well within the factor structure.

The factor analysis extracted three components with eigen values greater than 1, collectively explaining 86.3% of the total variance in the dataset. Component1 accounted for 49.1% of the variance, Component 2 explained an additional 21.3%, and Component 3 contributed 15.9%. The remaining components had eigen values less than 1 and were excluded from further analysis.

Table 3(b): Total Variance Explained

Component	Initial Eigen values	Extraction Sums of Squared Loadings	Rotation Sums of Squared Loadings				
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	6.878	49.125	49.125	6.878	49.125	49.125	6.835
2	2.985	21.319	70.444	2.985	21.319	70.444	2.903
3	2.221	15.862	86.306	2.221	15.862	86.306	2.749
4	0.800	5.714	92.020	-	-	-	-
5	0.588	4.200	96.220	-	-	-	-

Notes: Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

Source: Authors' Calculation

Component1: Economic Development and Inequality (explains 49.1% of variance)

This factor includes GDP per capita, CPI-Food, unemployment, agricultural production. The result shows positively correlated factors among GDP per capita (0.981), CPI-Food and Beverages (0.966), Agricultural Production (0.963), PCPCE (0.957), and Unemployment (0.873). Only Gender Inequality Index showed a negative correlation (-0.932). This means that while economic growth and agricultural production improve food security, higher unemployment rates suggest labour market challenges.

Component 2: Price Dynamics and Consumption Patterns (explains 21.3% of variance)

The significant variables include Global Food Price (0.853), Inflation Rate (0.792), Food Expenditure (0.681), and Alcohol Consumption (0.726). From the data we can interpret that Rising food prices and inflation increase food expenditure, making food less affordable. Alcohol consumption patterns may be linked to inflation-induced stress spending. Thus, Inflation and global food prices significantly predict undernourishment, necessitating policy measures to stabilize food costs.

Component3: Environmental and Institutional Factors (explains15.9% of the variance)

Under this factor, the significant variables include Economic Freedom (0.633), Rainfall (0.751), Food Availability (0.627). Food Affordability however shows a negatively correlated factor (-0.872). This shows that although rainfall and economic freedom improve food availability, they do not ensure affordability. Market accessibility alone is insufficient to combat food insecurity. Thus, economic growth does not guarantee food security as affordability becomes a major concern. Food affordability is inversely related to economic and environmental factors, requiring direct government intervention.

Table 3(c): Component Matrix

Variable	Component1	Component2	Component3
Zscore: GDP Per Capita	0.988	-0.023	-0.058
Zscore: CPI-Food and Beverages	0.968	-0.020	0.017
Zscore: Unemployment	0.852	0.176	0.315
Zscore: Gender Inequality Index	-0.944	-0.104	0.129
Zscore: Agricultural Production	0.950	0.055	0.214
Zscore: PCPCE	0.965	-0.108	-0.066
Zscore: Global Food Price	0.407	0.843	0.153
Zscore: Inflation Rate	-0.320	0.773	0.422
Zscore: Food Expenditure	-0.681	0.696	-0.180
Zscore: Alcohol Consumption	0.596	0.721	0.018
Zscore: Economic Freedom	-0.218	-0.054	0.672
Zscore: Rainfall	0.430	0.296	0.690
Zscore: Food Availability	0.263	-0.619	0.612
Zscore: Food Affordability	-0.074	-0.148	-0.867

Notes: Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
Source: Authors' Calculation

The rotated component matrix reveals the factor loadings of each variable on the three extracted components. Component 1 (Economic Development and Inequality) is strongly associated with variables such as GDP per capita (0.988), agricultural production (0.950), and gender inequality (-0.944). Component2 (Price Dynamics and Consumption Patterns) captures variables like global food prices (0.843) and inflation (0.773). Component 3 (Environmental and Institutional Factors) includes rainfall (0.690) and food affordability (-0.867). The rotation simplified the interpretation of the components, making them more distinct and meaningful."

The structure matrix, which accounts for correlations between components, shows similar patterns to the rotated component matrix. Component 1 remains strongly correlated with economic variables, Component 2 with price dynamics, and Component 3 with

environmental and institutional factors. The high correlations confirm the robustness of the factor structure.

Table 3(d): Structure Matrix

Variable	Component1	Component2	Component3
Zscore: GDP Per Capita	0.981	-0.018	0.080
Zscore: CPI-Food and Beverages	0.966	-0.015	0.152
Zscore: Unemployment	0.873	0.199	0.436
Zscore: Gender Inequality Index	-0.932	-0.104	-0.007
Zscore: Agricultural Production	0.963	0.073	0.347
Zscore: PCPCE	0.957	-0.104	0.067
Zscore: Global Food Price	0.416	0.853	0.230
Zscore: Inflation Rate	-0.289	0.792	0.392
Zscore: Food Expenditure	-0.694	0.681	-0.257
Zscore: Alcohol Consumption	0.595	0.726	0.119
Zscore: Economic Freedom	-0.167	-0.021	0.633
Zscore: Rainfall	0.480	0.334	0.751
Zscore: Food Availability	0.309	-0.585	0.627
Zscore: Food Affordability	-0.138	-0.193	-0.872

Notes: Extraction Method: Principal Component Analysis.
Rotation Method: Promax with Kaiser Normalization.
Source: Authors' Calculation

Multiple Regression Analysis Results

The regression analysis was conducted to examine the impact of the extracted factors (Economic Development and Inequality, Price Dynamics and Consumption Patterns, and Environmental and Institutional Factors) on under-nutrition. The results are presented in Tables 1, 2, and 3, followed by a detailed interpretation.

Table 3.2(a): Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.857	.735	.602	.52976906

Source: Authors' Calculation

The regression model explains 73.5% of the variance in under-nutrition (R Square = 0.735), indicating strong fit. After adjusting for the number of predictors, the model explains 60.2% of the variance (Adjusted R Square=0.602). The standard error of the estimate (0.53) suggests that the model's predictions are relatively close to the actual values.

Table 3.2(b): ANOVA

Model	Sum of Squares	Df	Mean Square	F	Sig.
Regression	4.667	3	1.556	5.543	0.036
Residual	1.684	6	0.281		
Total	6.351	9			

Source: Authors' Calculation

The above ANOVA results confirm the statistical significance of the extracted components in predicting undernourishment. The F(3,6) = 5.543, p =0.036, indicates that the principal components significantly contribute to variations in undernourishment. A strong model fit suggests targeted interventions in economic, price stability, and environmental factors can effectively reduce food insecurity.

The regression analysis reveals that Component 2 (Price Dynamics and Consumption Patterns) has a statistically significant positive effect on under-nutrition (B=0.604,p=0.014). A one-unit increase in Factor Score 2 is associated with a 0.604 increase in under-nutrition, highlighting the critical role of food prices and inflation in exacerbating food insecurity. In contrast, Factor Score 1 (Economic Development and Inequality) and Factor Score 3 (Environmental and Institutional Factors) do not have statistically significant effects on under-nutrition ($p > 0.05$). These findings underscore the importance of addressing price volatility and inflation as key strategies to reduce under-nutrition, while also considering the indirect effects of economic development and environmental sustainability.

Table 3.2(c): Coefficient of the Predictors

Predictor	B (Coefficient)	Beta	t-value	p-value	Significance
(Constant)	-0.482	0.168	-2.878	0.028	
Component 1: Economic Development and Inequality	0.143	0.170	0.789	0.460	Not Significant
Component2: Price Dynamics and Consumption Patterns	0.604	0.719	3.412	0.014	Significant
Component3: Environmental and Institutional Factors	0.294	0.349	1.619	0.159	Not Significant

Source: Author's Calculation

Policy Implications

The results of this investigation underscore multiple significant policy ramifications for the alleviation of under-nutrition. Initially, the stabilization of food prices is paramount for alleviating food insecurity, as posited by the Demand-Supply Theory articulated by Marshall. Implementing policies such as price controls, subsidies, and strategic investments in agricultural productivity may contribute to controlling inflation and ensuring the affordability of food, particularly for populations deemed vulnerable. Secondly, although economic development and inequality did not exhibit a statistically significant correlation, the Kuznets curve and Malthusian theory may possess a prospective influence in determining the outcomes of under-nutrition. This model may directly affect under-nutrition, thereby emphasizing the necessity of addressing income inequality and enhancing access to resources as vital components for sustainable food security. Mitigating disparities in wealth and resource allocation through progressive taxation and the establishment of social safety nets

can fortify resilience against food insecurity. Thirdly, the enhancement of environmental and institutional frameworks is essential for advancing food security. Policies that aim to foster environmental sustainability, including climate adaptation and sustainable agricultural practices, coupled with initiatives to improve institutional quality, can bolster resilience to food insecurity, even if their direct influence on under-nutrition does not reach statistical significance in this evaluation.

Limitations and Future Research

Despite the strong explanatory power of the model, which explains 73.5% of the variance in under-nutrition, 26.5% of the variance remains unexplained. This suggests that other factors not included in the model, such as healthcare access, education levels, and conflict, may also play a significant role in influencing under-nutrition. Future research should explore these additional variables to improve the model's explanatory power. Additionally, this study did not test for interaction effects between the factors. Future studies should investigate whether the impact of one factor on under-nutrition depends on the level of another factor, as this could provide deeper insights into the complex dynamics of food insecurity. Finally, the use of cross-sectional data limits the ability to establish causal relationships. Longitudinal studies are needed to examine how changes in economic, environmental, and institutional factors over time affect under-nutrition, providing a more comprehensive understanding of the determinants of food security.

Conclusion

This study underscores the critical role of food affordability in combating undernourishment in India. While economic growth and climatic conditions contribute, inflationary pressures remain the dominant factor. Future research should explore micro-level interventions and regional disparities to formulate more effective policies.

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