



Robustness and Sensitivity Analysis of the India State Hunger Index (ISHI): A Comparative Evaluation of Weighting and Standardization Approaches

¹Arshi T. Khan

¹Assistant Professor

¹Department of Statistics,

¹Shri Shivaji College Of Arts science & Commerce Akola, Maharashtra, India

Abstract : Hunger and malnutrition remain significant development challenges in India despite sustained economic growth and improvements in food production. Accurate measurement of hunger at the sub-national level is essential for identifying regional disparities and guiding effective policy interventions. This study evaluates the robustness and methodological stability of the India State Hunger Index (ISHI) using alternative weighting and standardization approaches. Four versions of the index were constructed: ISHI(1) based on Principal Component Analysis (PCA) weights with non-standardized components, ISHI(2) using PCA weights with standardized components, ISHI(3) using International Food Policy Research Institute (IFPRI) weights with non-standardized components, and ISHI(4) using IFPRI weights with standardized components. The study employs state-level data for 35 Indian states and union territories and applies statistical techniques including Spearman rank correlation, paired sample t-tests, rank shift analysis, Pearson correlation, and coefficient of variation to assess the sensitivity of the index to methodological choices. The results indicate extremely high rank correlations between PCA-based and IFPRI-based indices ($\rho > 0.98$), suggesting strong consistency in state rankings across different weighting schemes. Rank shift analysis reveals only minor positional changes among states, while the standardization impact analysis shows near-perfect correlations between standardized and non-standardized versions of the index ($r > 0.99$). Among the four formulations, ISHI(1) demonstrates strong statistical robustness and balanced variability, making it the most suitable specification for empirical analysis. The study highlights the usefulness of composite indices in monitoring food security and provides evidence-based insights that can support policy formulation aimed at reducing hunger and improving nutritional outcomes across Indian states.

IndexTerms- India State Hunger Index; Composite Index; PCA Weights; IFPRI Weights; Sensitivity Analysis; Robustness Testing; Standardization Effects; Sub-national Inequality; Hunger Measurement;

I. INTRODUCTION

Hunger and malnutrition remain central development challenges in emerging economies despite sustained economic growth. India, as one of the world's largest and fastest-growing economies, continues to face significant disparities in nutritional outcomes across its states and union territories. Sub-national heterogeneity in hunger reflects variations in poverty, infrastructure, public health systems, literacy, sanitation, and governance effectiveness.

Composite indices have emerged as essential tools for measuring multidimensional deprivation. The India State Hunger Index (ISHI) adapts the conceptual framework of global hunger measurement to capture inter-state disparities within India. By aggregating indicators related to undernourishment, child wasting, stunting, and mortality, ISHI provides a multidimensional perspective on hunger beyond income poverty measures.

This research rigorously interrogates the structural stability of the index by examining how variations in methodological assumptions specifically regarding variable aggregation and scaling protocols propagate uncertainty through the resulting state-level rankings (Ibok et al., 2019). By contrasting the weighting schemes derived from principal component analysis against fixed global standards, this study identifies the degree to which domestic subnational disparities are masked or amplified by disparate normalization frameworks (Khan, 2021). The highest weight (0.29) for the percentage of stunted children in India followed by percentage of population undernourished (0.25), child mortality (0.24) and percentage of wasted children (0.22) (Khan & Ubale, 2022). Furthermore, we evaluate the impact of survey-weighted aggregation techniques in mitigating sampling biases inherent in complex survey data, which otherwise jeopardize the reliability of nutritional estimates (Singh et al., 2023). To address these methodological ambiguities, we systematically assess how the transition from global normalization denominators to context-specific benchmarks alters the sensitivity of the index to extreme outliers in child morbidity. This analytical framework facilitates a comprehensive decomposition of variance, enabling the quantification of how sensitive the final composite scores are to

individual parameter perturbations. By applying both first-order and total-order sensitivity indices, we effectively partition the output variance to isolate the contributions of specific input assumptions and their higher-order interactions (Sterrantino et al., 2022). Such an evaluation is critical, as recent evidence suggests that the main sources of output variability including variable selection and data imputation exert a hierarchical influence on overall index stability (Caccavale & Giuffrida, 2019). The discourse surrounding multidimensional index construction consistently highlights the tension between simple arithmetic aggregation and more complex axiomatic approaches designed to capture subnational nutritional shortfalls (Jain & Agnihotri, 2020). Specifically, scholars emphasize that the absence of prior standardization can inadvertently permit components with high variance to dominate the index, thereby distorting the composite representation of regional hunger. Such "unintentional weighting" necessitates a careful re-evaluation of normalization procedures to ensure that the mathematical influence of indicators remains proportional to their conceptual contribution (Wiesmann et al., 2015). Furthermore, while equal weighting remains a common convention for its intuitive transparency, empirical evidence suggests that alternative weighting strategies often yield minimal variance in overall rankings, underscoring the index's relative resilience to moderate shifts in parameterization ("The World's Most Deprived: Characteristics and Causes of Extreme Poverty and Hunger," 2007). Nevertheless, the selection of an appropriate transformation technique whether through Z-score normalization or mapping indicators to a common percentile range remains critical to preserving the empirical distribution of subnational data (Santeramo, 2014). Beyond these standard approaches, the application of multivariate statistical techniques such as principal component analysis allows for weight derivation based on the empirical variance and inherent covariance structures of the underlying indicators (Diana & Putri, 2022). However, adopting such data-driven weighting necessitates caution regarding potential multicollinearity, which may artificially inflate the contribution of correlated nutritional outcomes. Consequently, this study explores the utility of shortfall sensitivity and hiatus-related axiomatic conditions to improve upon traditional linear aggregation models (Jain & Agnihotri, 2020). By rigorously testing these methodological variations, we assess whether specific normalization protocols such as min-max rescaling against global versus state-specific thresholds induce significant volatility in subnational rankings (Amin & Guddattu, 2025).

II. RESEARCH METHODOLOGY

The present study adopts a quantitative and comparative research design to evaluate the robustness and methodological stability of the India State Hunger Index (ISHI). The analysis focuses on examining how different weighting schemes and standardization procedures influence the construction and interpretation of the composite hunger index. To achieve this objective, four alternative versions of the ISHI were constructed and statistically compared using sensitivity and variability analysis.

The study uses cross-sectional data for 35 Indian states and union territories. The analysis is primarily based on statistical techniques such as correlation analysis, paired mean comparison tests, rank shift analysis, and dispersion measures. These methods help assess whether variations in methodological assumptions significantly alter the measurement of hunger disparities across states.

- 1. Construction of India State Hunger Index (ISHI):** The India State Hunger Index is a composite indicator designed to measure hunger and undernutrition across states. The index aggregates multiple hunger-related indicators into a single numerical value that reflects the overall severity of hunger in a region. To examine the effect of methodological choices on index construction, four alternative versions of ISHI were developed:

Index Version	Weighting Method	Standardization
ISHI(1)	PCA Weights	Non-standardized components
ISHI(2)	PCA Weights	Standardized components
ISHI(3)	IFPRI Weights	Non-standardized components
ISHI(4)	IFPRI Weights	Standardized components

The composite index was calculated as a weighted aggregation of the selected indicators using the general composite index formula:

$$ISHI_i = \sum_{j=1}^n w_j X_j, \quad i = 1, 2, 3, 4$$

Where

- $ISHI_i$ = the i -th version of the India State Hunger Index
- $i=1,2,3,4$ represents the four index formulations
- X_j = value of the j -th hunger indicator
- w_j = weight assigned to the j -th indicator
- n = number of hunger indicators used in the index

Weighting Methods

Principal Component Analysis (PCA)

Principal Component Analysis was used as a data-driven statistical technique to determine the weights of the indicators. PCA transforms correlated variables into a smaller number of uncorrelated components that capture the maximum variance in the dataset. The weights for each indicator were derived from the factor loadings of the first principal component, which represents the largest share of variation among hunger indicators.

The advantage of PCA weighting is that it reduces subjectivity and accounts for multicollinearity among indicators, ensuring that each variable contributes to the composite index according to its statistical importance. (Khan et al., 2021)

IFPRI Weighting Scheme

The second approach used the normative weighting system adopted by the International Food Policy Research Institute (IFPRI) in constructing global hunger indices. In this approach, predetermined weights are assigned to each indicator based on conceptual importance rather than statistical variation.

While this method ensures consistency with internationally recognized frameworks, it may introduce some degree of subjectivity because the weights are not derived directly from the observed data. (Klaus et al., 2015)

Standardization of Indicators: Since the hunger indicators are measured in different units and scales, standardization is often used to make them comparable before aggregation. In this study, standardized versions of the indices were generated using the ratio of the value of the state j (X_j) to an estimated maximum value for variable X . (Klaus et al., 2015)

$$\text{Standardize value of } X_j = X_j / X_{\max(\text{est})}$$

Where, $X_{\max(\text{est})}$ is the estimated maximum value for variable X .

The formulated India state hunger index were subject to sensitivity analysis, standardization impact analysis and variability analysis for testing the variability amongst the indices.

1. Sensitivity Analysis:

To evaluate whether the choice of weighting scheme affects the resulting hunger index, a sensitivity analysis was performed. The analysis compared PCA-based indices with IFPRI-based indices using the following statistical tools:

1. Spearman Rank Correlation (ρ)

This non-parametric statistic measures the degree of similarity in state rankings between alternative index formulations. A high correlation indicates strong ranking consistency across weighting methods.

2. Paired Sample t-test

The paired t-test was used to determine whether the mean difference between alternative index values is statistically significant. While rankings may remain similar, differences in mean values indicate variations in the magnitude of hunger scores.

3. Rank Shift Analysis

Rank shift analysis measures the extent to which individual states change positions when different weighting schemes are applied. Two summary statistics were calculated:

- Mean rank shift
- Maximum rank shift

These measures help assess the practical impact of methodological changes on state-level hunger rankings.

2. Standardization Impact Analysis

To determine whether scaling transformations affect the composite index, the standardized and non-standardized versions of the ISHI were compared using Pearson correlation analysis. A correlation coefficient close to one indicates that standardization does not substantially alter the relative distribution of index values across states. This analysis helps verify whether the index results are sensitive to the normalization procedure applied during index construction.

3. Variability Analysis

The dispersion of hunger scores across states was evaluated using the **Coefficient of Variation (CV)**, which measures the relative variability of index values.

$$CV = \frac{\sigma}{\mu} \times 100\%$$

Where:

σ represents the standard deviation and

μ represents the mean of the index values.

The coefficient of variation allows comparison of variability across different index versions and helps determine which formulation provides a balanced representation of inter-state disparities.

Analytical Tools

All statistical analyses were performed using Python-based statistical computing techniques. These tools enabled accurate computation of sensitivity measures and ensured reproducibility of results.

III. Results

To examine the robustness of the India State Hunger Index (ISHI), a sensitivity analysis was conducted by comparing indices constructed using Principal Component Analysis (PCA) weights and International Food Policy Research Institute (IFPRI) weights. The results are presented in Table 1.

Table 1: Sensitivity Analysis (PCA vs IFPRI Weighting Schemes)

Comparison	Spearman ρ	p-value (ρ)	Paired t-statistic	p-value (t)
ISHI(1) vs ISHI(3)	0.980	0.000	15.856	0.000
ISHI(2) vs ISHI(4)	0.984	0.000	10.066	0.000

The Spearman rank correlation coefficient between ISHI(1) and ISHI(3) is 0.980, while the correlation between ISHI(2) and ISHI(4) is 0.984, both statistically significant at the 1% level ($p < 0.001$). These extremely high correlations indicate that the overall ranking of states remains largely consistent regardless of the weighting method used. In other words, states identified as having high or low levels of hunger tend to remain in similar positions even when the weighting scheme changes.

However, the paired t-test results show statistically significant differences between the index values derived from PCA and IFPRI methods. The t-statistic values of 15.856 for ISHI(1) vs ISHI(3) and 10.066 for ISHI(2) vs ISHI(4) indicate that although the rankings are highly correlated, the absolute magnitude of the index values differs significantly between the two weighting approaches.

These result suggests that while IFPRI weights produce broadly similar patterns of hunger across states, the PCA-based approach provides a statistically distinct representation of hunger intensity. Since PCA weights are derived from the empirical variance structure of the data, they capture the relative importance of indicators based on observed variability rather than predetermined normative weights. Consequently, the PCA-based index (ISHI(1)) may better reflect the underlying statistical relationships among hunger indicators.

2. Rank Shift Analysis

Table 2: Rank Shift Analysis between PCA and IFPRI Weighted ISHI

Statistic	Value
Mean Rank Shift	1.49
Maximum Rank Shift	5

To further evaluate the impact of alternative weighting methods on state rankings, a rank shift analysis was performed. The results indicate a mean rank shift of 1.49 positions, with a maximum shift of 5 positions across all states.

The relatively small average rank change suggests that the overall spatial distribution of hunger across Indian states remains stable under different methodological frameworks. In practical terms, this means that the classification of states into relatively better or worse performing groups is largely unaffected by the choice of weighting scheme.

Nevertheless, the existence of rank shifts up to five positions indicates that some states are moderately sensitive to methodological assumptions. Such shifts can occur because PCA assigns weights based on statistical variance, whereas IFPRI uses fixed theoretical weights for each indicator. As a result, states with unusual indicator combinations may experience minor adjustments in their rankings.

Despite these variations, the magnitude of rank shifts remains relatively small, reinforcing the robustness and reliability of the composite hunger index. From a policy perspective, this finding implies that general policy priorities would remain consistent regardless of the weighting methodology used, although slight adjustments in state rankings may occur.

3. Impact of Standardization

Another important methodological issue in composite index construction is whether the component indicators should be standardized prior to aggregation. To assess this, correlations were computed between the non-standardized and standardized versions of both PCA and IFPRI indices.

The Pearson correlation between ISHI(1) and ISHI(2) is 0.996, while the correlation between ISHI(3) and ISHI(4) is 0.994, both statistically significant at the 1% level. These near-perfect correlations indicate that standardization has minimal impact on the final index values and state rankings.

This finding suggests that the relative variation among states is sufficiently consistent across indicators such that scaling transformations do not substantially alter the structure of the composite index. In other words, the hunger indicators already exhibit comparable patterns of variation across states, making the index construction relatively insensitive to standardization.

The result is particularly important from a methodological standpoint, as it demonstrates that the robustness of the hunger index is not dependent on specific data transformations. Consequently, both standardized and non-standardized versions produce nearly identical outcomes, confirming the stability of the index structure.

4. Variability in Index Versions

Table 2: Variation amongst Indices

ISHI Version	Coefficient of Variation
ISHI(1)	0.241
ISHI(2)	0.241
ISHI(3)	0.293
ISHI(4)	0.286

To examine the dispersion of index values across states, the Coefficient of Variation (CV) was calculated for each ISHI version. The CV values are 0.241 for ISHI(1), 0.241 for ISHI(2), 0.293 for ISHI(3), and 0.286 for ISHI(4).

These results indicate that indices constructed using IFPRI weights exhibit higher variability across states compared to those based on PCA weights. A higher coefficient of variation implies greater dispersion in index values, which may exaggerate differences between states.

In contrast, the PCA-based indices display relatively lower variability, suggesting that they provide a more balanced representation of hunger disparities across states. Since PCA weights are derived from the statistical structure of the data, they distribute influence across indicators in a way that reflects actual variability rather than predetermined assumptions.

The relatively moderate dispersion observed in ISHI(1) indicates that the PCA-based index captures meaningful differences among states without artificially inflating disparities. This property enhances the interpretability and statistical stability of the index, making it more suitable for comparative analysis.

Conclusion

Taken together, the empirical results demonstrate that the India State Hunger Index is highly robust across alternative methodological specifications. Both PCA and IFPRI weighting schemes produce broadly similar rankings of states, and the impact of standardization on the index is negligible.

However, the PCA-based formulation, particularly ISHI(1), offers several methodological advantages. First, it derives weights directly from the statistical characteristics of the data, ensuring that indicators contribute to the composite index in proportion to their observed variability. Second, PCA effectively addresses issues of multicollinearity among hunger indicators, preventing redundancy and improving statistical efficiency. Third, the moderate dispersion of PCA-based indices provides a balanced representation of interstate disparities, avoiding the excessive variability observed in IFPRI-weighted indices.

These findings suggest that ISHI(1) represents a statistically robust and empirically grounded measure of hunger across Indian states. By integrating multiple indicators using a data-driven weighting framework, the index offers a reliable tool for identifying regional disparities and guiding evidence-based policy interventions aimed at reducing hunger and improving nutritional outcomes.

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