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Market integration of animal-sourced food products in India: An analysis using recursive principal components

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Abstract
A well-integrated food market is essential for ensuring food security. An integrated food market leads to lower volatility thereby dampening the impacts of regional and temporary shocks in the demand and supply of the food products, potentially leading to decreased episodes of periodic food insecurity. In this study, we analyze the integration of major animal-source food product markets in India. Wholesale price indices of seven animal-source food products are analyzed using the principal component analysis in a recursive rolling-window framework to obtain a time-varying measure of market integration. Results show that there is potential to improve the integration of animal-source food product markets in India especially the poultry product markets. This article discusses the implications of the findings with respect to food security in India.

Keywords: India, market integration, principal component analysis, animal proteins, food security

Introduction
India has been on an impressive trajectory of economic growth over the last two decades or so. Data from the World Bank show that India's GDP grew at a rate of 6.07 percent in the 2000-2022 period. Obviously, such a steady economic growth is expected to result in overall upliftment in the society [1]. Shows that 24.82 crore Indians have escaped the poverty trap in the last nine years alone as measured by the multidimensional poverty index. Poorer states have achieved better results in terms of poverty alleviation. Uttar Pradesh, Bihar, and Madhya Pradesh recorded the largest decline in the number of poor people between 2013-14 and 2022-23.

With improved economy, people become more aspirational as their purchasing power increases. They aspire for improved quality of life. For example, the Bennett's law posits that the share of a household's expenditure on "starchy staple" food items declines with increasing income and the expenditure share on foods of higher nutritive value such as the animal proteins increases [2]. Research elsewhere in Asia, for example [3], shows a westernization of dietary preferences following globalization with substantial increase in consumption of meat and other animal products. In addition, improved quality of life also implies people can access technologies such as refrigeration, resulting in wider distribution and increased shelf-life of perishable commodities such as the animal-sourced foods [4].

Typical Indian diet is high on carbohydrates due to the dominance of rice and other starchy foods. In addition, there are myriad factors such as demography, economic status, religion, customs, prices, and regional factors that shape food consumption preferences in India. Nevertheless, given consistent economic growth, globalization, information revolution, and rising aspirations, it is likely that a dietary transformation is taking place in India characterized by greater inclusion of animal-sourced proteins. Such a change towards animal proteins in India could help in tackling rampant problems of food and nutritional insecurity such as malnutrition and child stunting.

Therefore, animal-sourced food products are of immense policy relevance for food and nutrition security in India. Poorer households tend to spend relatively more on food items as per the well-known Engel's law of consumption, and hence a volatile and less integrated market for animal-sourced foods can be detrimental especially to the welfare of poorer households. A large section of the population could benefit from improved integration of the animal product markets. Elimination of trade barriers in the domestic market, for example through the implementation of the common Goods and Services Tax system in India in July 2017 in India, can facilitate easier flow of goods across different parts of the country thereby making the markets more integrated.

In this study, the term *market integration* is used to denote the degree of co-movement in the prices of the major animal-source food products in India over time. This follows the assertion that while much of the literature on market integration focuses on the definition of market based on identical goods separated by distance, it is also possible to define a market in the product space such that the price of similar goods tend to uniformity, after allowing for differences in quality [5]. The co-movement of product prices is driven by the type of demand relationships among the products, i.e., substitutability and complementarity. Moreover, the price co-movements reflect interactions among the product markets and are driven by common macroeconomic factors [6].

Given this premise, the hypothesis of our study is that animal-based food product markets in India would show greater integration over time. That is, the prices of animal-source food products in India would move closer together over time. This hypothesis is derived from the notion that with improvement in the country's overall economic health, reduction in distortive regulations, improvements in connectivity and technology, their joint influence on the product markets of India would pull them closer together. For the empirical analysis, we measure the co-movement in the monthly wholesale price index (WPI) of major animal-source food products. These products are: eggs; chicken; fish (inland/freshwater fish as well as marine fish); buff meat; mutton (goat meat); and pork[1].

In the next section we review the literature on market integration, food security, and animal-source food products to throw light on the research gap and then describe the objective of the study. In the ensuing methodology section, we describe the index of integration that we develop through the empirical analysis. Specifically, we use the Principal Component Analysis (PCA) to measure the co-movement of prices. A detailed description of the suitability of the PCA method in measuring the integration of markets is provided in the Methodology and Data section. This is followed by a description of the findings and finally we conclude with discussions on implications of the findings of the study.

Review of literature and Research gap

India's situation vis-à-vis food security is often described as the "hidden hunger" problem wherein much of the population of the country is not facing calory deficiency but suffers from poor dietary quality and deficiency of essential nutrients [7]. The nutritional adequacy of typical Indian diet is debated. Studies have found insufficient dietary improvement over time in India leading to prevalence of micronutrient deficiencies [8]. In such a situation, research has shown that animal-sourced foods can help improve dietary quality thereby advancing the country's performance in terms of overall human development index (HDI). [9] Notes that these foods are the best available sources of nutrient-rich food for children aged 6-23 months. [10] Provide a detailed account of the benefits of animal-source foods and the potential role they can play in achieving food security. Animal foods of marine origin such as fish and shellfish are rich sources of essential fatty acids, vitamin D, and iodine-nutrients that are difficult to obtain in sufficient quantities from other sources [11]. Hence, the hidden hunger prevalent in India can be tackled by increased consumption of animal-source foods.

While the nutrition aspect of food security as discussed above is important, another equally important aspect from an economics lens is the market. Market can be thought of as one of the most important pathways for obtaining nutritious foods, whether it is a rural area or urban. It becomes easier for households to access food items of their choice when there is smoother flow of goods and information across geographic markets and over time. Hence, one of the strategies suggested for improved food security in India is the enhanced market integration to help households access diverse food items [12]. In a country with estimated 200 million malnourished people, market integration therefore assumes critical importance in combating food insecurity.

Market integration as an economic concept has commonly been analyzed empirically through the interrelationships among market prices of related goods. This is because of the importance of price in defining a market. For example, [13] defines a market as "the area within which the price of a commodity tends to uniformity, allowance being made for transportation costs". The popularity of price analysis in evaluating market integration also stems from the fact that often only the price data are available but not the data on quantities [14]. While the definition of a market as noted above has been used in the analysis of price relationships across geographic space, the underlying concept can also be extended to describe price relationships across the product space. In the product space, a market can be defined as the area within which prices of goods tend to be uniform, after allowing for quality differences [5].

With increased per capita income, it is quite likely that India's food consumption preferences are changing, with greater inclusion of animal products in the diet. Therefore, it is necessary to understand the extent of integration of animal-source food markets in India. This analysis can throw light on the evolution of market integration over time and can identify product markets that show lower integration. While there have been several studies in India that have analyzed the integration of markets for agricultural and food products, there are not many studies on animal-source foods. Moreover, there is very little research on the food security implications of market integration. Our analysis is an attempt to fill this gap in research. Given this background, the objective of this study is to measure the degree of integration of markets for non-dairy animal-source foods in India. The study provides quantitative measures of static as well as time-varying degree of integration for these product markets.

Methodology and Data

Data

Secondary data on WPI of major animal-source foods was obtained from the [15]. These are monthly observations starting from April 2012 and ending at December 2023 giving a total of 141 observations. It is worthwhile to note the various major events that occurred during this period that are of great significance to the Indian economy including the demonetization, implementation of the GST, the novel

[1] We do not include milk or other dairy products among the products because in India governments have a substantial role in determining their prices unlike other animal proteins whose prices are determined by market forces of supply and demand. Moreover, in the Indian context, preferences for milk among consumers may be different to (i.e., separable from) preference for meat, fish, and eggs. Therefore, it is worthwhile to consider non-milk animal proteins as a separate basket of goods.

Coronavirus pandemic (COVID19), bank privatization, and the Ukraine war. Corresponding data on prices at the farm level or the retail level could not be found, and hence we restrict the analysis to the wholesale prices.

Statistical modeling

The economic concept of market integration can be traced back to the French mathematician Cournot who defined an integrated market as "an entire territory of which the parts are so united by the relations of unrestricted commerce that prices take the same level throughout with ease and rapidity" [16], cross-referenced from) [17]. Therefore, in an integrated market, (i) the law of one price holds, that is, the level of equilibrium prices at different parts are equal; (ii) after any shock in the market, prices return to equilibrium quickly and easily [16].

Market integration in the product space can be described as co-movements of prices, and, more generally, to the smooth transmission of price signals and information across product markets. Integration of product markets is often carried out by evaluating the relationship among the prices of related products over time using appropriate statistical analysis such as correlation coefficients, cointegration tests, causality tests, and centrality tests. The PCA is used as a technique to measure market integration with common applications in the analysis of integration of financial and commodity markets (for example) [18-21].

The PCA is used in dimensionality reduction and in describing the common features among a set of variables. Outputs of the PCA are the "principal components" (PC) that explain as much of the variance in the original variables as possible. The common features of a group of variables, i.e., the PCs, can be used to measure the co-movement of the variables. The PCs are useful in the context of measuring market integration: the higher the degree of co-movement in the original variables, the fewer the number of PCs needed to explain a large portion of the variance of the original series. In addition, if the proportion of variation in the data explained by the first PC is substantial, then it is an indication to the underlying variables being deeply interconnected. When the PCA is applied over subsamples of the data in a recursive rolling-window estimation, we can use the proportion of total variations explained by the first PC from each time-window as a measure of time-varying market integration.

The main outputs of PCA are the PCs, which are linear combinations of the prices at the individual markets that explain as much of the variations in prices across the product market as possible. Thus, the first PC is the linear combination of prices at individual spatial markets with the largest variance, subject to the constraint that the squares of the coefficients sum to 1. Specifically, let X be a matrix of n observed variables (representing market prices of n animal protein products) whose dimensionality needs to be reduced while retaining as much information in it as possible. PCA is one of the techniques to do this. Mathematically, the first PC (PC_1) can be written as in equation (1).

$$PC_1 = a_1^T X = \alpha_{11}\chi_1 + \alpha_{12}\chi_2 + \cdots + \alpha_{1n}\chi_n \quad (1)$$

Where the component PC_1 is the linear combination defined by the weight coefficients α_{1i} (called scoring coefficients or factor loadings) on χ_i which are the original individual price vectors contained in X. The coefficients are calculated such that PC_1 retains maximum variance possible in the sample subject to the constraint that $a_1^T a_1 = \sum_{i=1}^{N} a_{1j}^2 = 1$.

Similarly, the second PC (PC_2) explains maximum of the residual variation after PC_1 is removed from the data; PC_2 is the linear combination of prices at individual spatial markets with the largest variance such that the combination is uncorrelated with the first PC and the squares of the coefficients sum to 1. The PCs are thus ranked by their variance, with the higher order PCs explaining most of the residual variation in the data not captured by the preceding lower-order PCs.

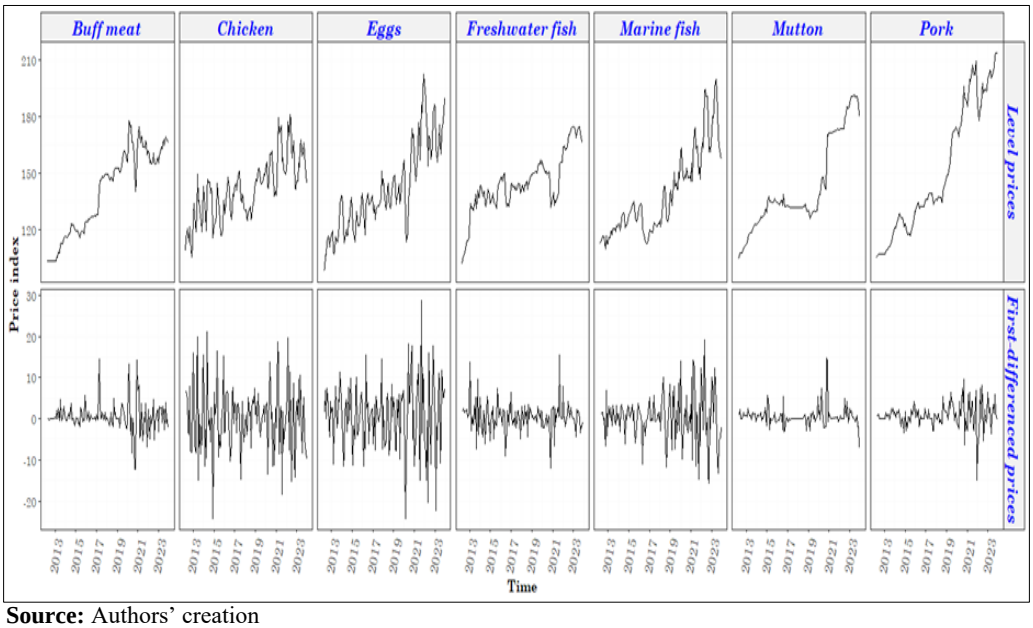
Econometrically, PCA has merits over other measurements of market integration as it is robust to outliers and distributional assumptions [18, 20]. More importantly, PCA can overcome measurement errors in the data [22] and problems associated with collinearity. We estimate PCs in recursively rolling (i.e., moving) windows and interpret the proportion of the total variation in the level of WPI explained by PC_1 as a dynamic measure of integration of markets for the selected animal-source food products. In essence, PC_1 indicates the extent to which a common factor can explain the price movements. The size of the window is set at 96 months (8 years) to allow enough data in each subsample/window to capture market dynamics as well as the influence of exogenous variables such as macroeconomic shocks. We perform PCA in a rolling-windows framework for the WPI of all animal-source foods together, as well as for distinct product groupings, i.e., poultry products (encompassing chicken and eggs), fish products (inland fish and marine fish), and meat (buff meat, mutton, and pork). This helps us in gaining a better understanding of the dynamics of market integration for different product groupings.

Results and Discussion

The first row in Figure 1 presents the graph of the WPI of the selected animal-source food products, and the second row of the plot shows the corresponding first-differences. The WPI of all products have trended upwards over time, but there are subtle differences. For example, the mutton WPI does not change much over the 2013-2019 period but shows a steady increase in other periods. In addition, WPIs of chicken, eggs, and to a lesser extent that of marine fish show considerable intra-year seasonality whereas there appears to be negligible seasonality in the WPI of buff meat, mutton, and pork.

Figure 1 also shows the first-difference of the WPI series. The first-differenced prices represent the monthly price change and therefore can provide a basic indication about the price volatility. Abrupt changes in prices over a short period of time can be termed high volatility. Therefore, we use the plots of the first-differences to understand the volatility behavior. Figure 1 shows that first-differences of WPIs of buff meat, freshwater fish, mutton, and pork display lower volatility as their plots move too far from the mean value of the series over the time period. The graph also shows that there is some indication to the increased volatility in the buff meat prices and pork prices at the end of the sample period. Chicken prices and Egg prices show higher volatility among all the products. There is some volatility clustering such that periods with higher (lower) volatility are followed by periods of higher (lower) volatility. Such a clustering can be seen in the 2016-2019 period for chicken prices and 2013-2019 period for egg prices. Higher volatility is seen for chicken WPI in the 2012-2015 period and in the 2020-2023 period of the sample. For the WPI of eggs, higher volatility is seen in the 2020-2023 period.

The issue of price volatility is of great importance with respect to food security. Maintaining low volatility of important food items is vital in making those food items affordable to the poorer sections of the society. Sudden increase or decrease in the prices of staple food items can throw the poorer households into food insecure status especially if a substantial proportion of their income is spent on food purchases. In India's context, contrary to popular misconception, 71 percent of the population identifies itself as non-vegetarian and consumes meat at least occasionally [23]. Annual per capita availability of various animal-source proteins for human consumption in 2020 in the country are as



Source: Authors' creation

Fig 1: Time path of the levels and first-differences of WPI of the selected animal-source food products

Table 1: Descriptive statistics of the market integration index

Product	Minimum value of the integration index	Maximum value of the integration index	Average value of the integration index
All animal products	75.7	79.5	77.7
Poultry products	68.3	80.8	76.3
Fish products	82.9	91.4	86.9
Meat products	86.5	92.4	88.4

Source: Authors' creation

Follows: 2.57 kg poultry/person/year; 91 eggs/person/year; 1.13 kg beef/ person/year; 0.59 kg sheep and goat/person/year; 0.24 kg pork/person/year; and 7.89 kg seafood/person/year [24][2]. Therefore, sharp increases in the prices of animal-source food would make these essential protein sources unaffordable to a large section of the population.

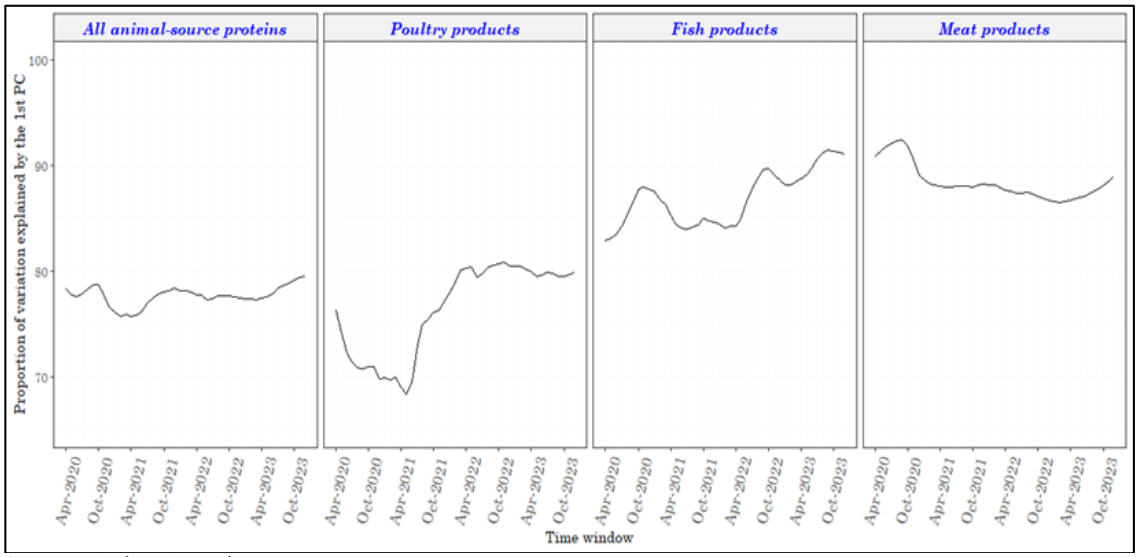
Figure 2 shows the time-window (i.e., 96-month rolling windows) on the x-axis[3] and the index of market integration on the y-axis. The actual range of the integration index is 0 to 100 but we have truncated the range for better visualization. The index of market integration is the proportion of variation in the WPIs explained by the first Principal Component. Figure 2 shows the market integration index for four product groupings, one for all the seven selected animal-source proteins together, followed by those for poultry products, fish products, and meat products. A higher value of the integration index indicates greater product market integration.

As evident from Figure 2, the integration index is relatively lower for all animal-source proteins together and for the poultry products, whereas it is higher for the fish products and the meat products. This is supported by the minimum, maximum, and average values of the integration index for the four product groupings shown in Table 1. These can be considered as static measures of market integration. The lower integration of the poultry products could be in part due to the high intra-year seasonality of prices reflecting supply and demand factors in play.

Figure 2 shows the evolution of the integration index over time. These are time-varying measures, i.e., dynamic, measures of market integration. For the All animal-source proteins grouping, there is a slight decrease in integration index around the 2020 window and there is also slight increase in integration index in the later half of 2023. For poultry products, the extent of integration decreases in the initial half of the period followed by a rapid increase and then a stagnant period from mid-2022 onwards. Fish products show a relatively decreased integration in 2021 to mid-2022, and then a positive trend. For meat products, there is a slight increase in the initial period followed by a secular decrease until mid-2023 and then a slight increase. Thus, there is a dip in the integration index for all the products in the initial time periods, which perhaps reflects the impacts of major disruptions in the market such as the COVID19. The products tend to show better integration after the initial dip which perhaps indicates the recovery of the markets from the shocks. In general, agricultural and livestock products are characterized by inelastic supply and demand with respect to change in prices particularly in the short-run. There is a longer gestation period in livestock production. Unfavorable weather conditions exert negative pressure on supply. Given the inelastic demand, even a small change in supply can result in large change in prices, leading to extreme movements or volatility in the prices. For products with substantial seasonal fluctuations, prices rise sharply in the peak season and then decrease during the off-season. A general governmental response in developing countries in the case of food crisis is to directly intervene in the market process, for example by imposing ban on exports or placing a cap on the prices. Such measures may discourage private players from making investments to the full extent. Alternatively, governments may also invest in creating better connectivity across regional markets for easier flow of products and information. Therefore, a key question is the mechanism of government interventions in the food market.

[2] These are "apparent consumption" quantities arrived at using production, supply, uses, and wastage quantities.

[3] Given the 96-month window, the first window pertains to the period beginning at April 2012 and ending at March 2020. The last window corresponds to the period January 2016 to December 2023. We also analyzed the sensitivity of the integration index for different window sizes (60, 72, 84, and 96), and found no substantial change in the overall behavior of the index.



Source: Authors' creation.

Fig 2: Evolution of the first principal component as the measure of market integration for the different groups of animal-sourced proteins

Post-COVID19, the Government of India increased the capital expenditure substantially by 35% to ₹ 7.5 lakh crore focusing on investments in infrastructure on critical connectivity projects [25]. Such efforts in infrastructure development could prove critical in improving flow of goods across the country thereby creating a more integrated nationwide market.

It is essential to understand market integration and its determinants as it can help in price stabilization. Insufficient post-harvest logistics and processing facilities are some of the major sources of variability in the prices of animal-source food products in India [26]. Post-harvest losses in the supply chain of eggs, meat, and poultry in India is estimated to be 10 to 25 percent [27]. In marine fisheries, the extent of loss depends on the type of fishing. For example, the losses can be about 19 percent for fish harvested by large mechanized fishing vessels and the ensuing post-harvest operations, whereas it is only about 1.14 percent for traditional fishing activities [27]. Therefore, there is an urgent need to develop value chains for animal-source products that can more efficiently utilize the harvests to prevent excessive loss. Collectives of farmers and fishers, for example Producer Enterprises, can be set up that can leverage facilities available from various governmental and financial institutions in setting up capital intensive post-harvest facilities. Alternatively, traditional processing technologies such as fish curing and drying can be encouraged that can produce shelf-stable nutrient-dense products. Such measures can immensely improve the contribution of animal-source products in food security while also leading to stable and integrated markets.

Summary and Conclusions

Non-dairy animal source foods such as meat and fish are vital sources of essential nutrients for a large section of the Indian society. Prices of major food items should not exhibit high volatility so that the poorer sections of the society can afford to purchase them. An integrated market can help achieve low volatility. The purpose of this study was to understand the extent of market integration of these non-dairy animal-source foods by analyzing their wholesale price indices and the co-movement patterns. We also provide a descriptive analysis of the price volatility using the first-differences of the wholesale price index.

We find higher intra-year seasonality in the prices of poultry products (chicken and eggs) and to a lesser extent in marine fish, compared to the other products. These three products also show higher volatility as indicated by the graphs of the first-differences of the respective price indices. These prices also show some clustering in volatility where lower volatility values are clustered together over time. In terms of market integration, the PC_1 integration index is relatively lower for all animal-source proteins together and for the poultry products, whereas it is higher for the fish products and the meat products. Thus, the poultry products show lower integration compared to fish products and meat products. There is a dip in the integration index for all the products in the initial time periods, and the prices tend to show better integration after the initial dip which perhaps indicates the recovery of the markets from the shocks.

Government has a vital role in ensuring food and nutrition security to the mammoth population of India by improving market integration. If the public policies are able to prevent sudden spikes in the prices of important food items, the food and nutrition security status of a large section of the society can improve. Therefore, policymakers must prioritize creating an environment conducive for easier flow of animal-source foods across markets as well as the flow of market information so as to achieve improved market integration.

This study has elucidated the patterns in the integration of animal-source food products at the national level in India, and proceeded to discuss the implications. What this study has not achieved is the analysis at regional levels. Regional trade, or in India's case inter-state and intra-state trade, is a critical driver of market integration. The physical distance can induce frictions in regional trade in the form of perishability and transportation costs. Therefore, when very long-distance trade cannot be undertaken due to physical hindrances such as lack of infrastructure, it could be pertinent to facilitate trade between smaller and closer geographic markets. Growth of megacities can lead to transformation in regional trade aimed at provisioning of animal-source food. Such transformation can reflect changing consumer demographics, westernization etc. when provisioning urban centers.

Moreover, macro-level observations made on a complex phenomenon such as food security are not sufficient to draw a complete picture especially in a large and diverse country like India. Food security has a strong regional component: For example, region-specific vulnerabilities, provisioning, self-sufficiency, deficiency cannot be captured with a macro or national level analysis. Additionally, governance takes place at the regional level in India, and there are even more diverse stakeholder groups and other actors at the regional level who are involved in the decision-making process. Efforts to achieve food security are linked with social and cultural preferences, institutional structures, and laws and regulations.

These factors can be more effectively captured through regional analysis.

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