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ORIGINAL RESEARCH

Vulnerability to Food Insecurity: A Decomposition Exercise for Rural India using the Expected Utility Approach

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Abstract

Devising multi-pronged strategies for those highly prone to food insecurity in the future remains a challenge for food policymakers. This set of food-insecure households faces different kinds of shocks (economic, political, environmental, pandemic, personal, etc.), which render them vulnerable to food insecurity. This study identifies those who are vulnerable to food insecurity, and will be useful for policymakers to resolve food insecurity related challenges in crisis or no crisis periods on an ex-ante basis. This paper decomposes the total welfare loss resulting from vulnerability to food insecurity into components due to 'food poverty' (expected consumption of the current food secure falling below the food poverty line), and risk (variability of food consumption over time). The last term can be further decomposed into the aggregate (region or community-specific), and idiosyncratic (household or individual-specific) risks. The paper identifies the key determinants of the different components of vulnerability to food insecurity based on household consumption expenditure surveys conducted in rural India in 2004–05, 2009–10, and 2011–12. Expected utility-based measures, and pseudo-panel regression techniques were used to identify risk-prone households. The key findings are: idiosyncratic risk is the largest driver (a loss in the utility of almost 51%) as compared to the poverty and covariate shocks; states with poor Public Distribution System (PDS) performance are more susceptible, a rise in the price of staple food items increases the chances of food insecurity, gendered disparity persists over time, forward social and religious groups are more vulnerable, and finally a higher level of

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urbanization increases the exposure and sensitivity to shocks (like the spread of contagious diseases), disrupts the supply of food commodities from rural markets, loss in income, and increase in rural vulnerability to food insecurity. Our key policy suggestion is a mix of cash versus in-kind transfers to resolve rural food insecurity related issues, tend towards resiliency, and simultaneously tackle the triple burden of malnutrition and SDG-2 related goals.

Keywords Vulnerability · Expected utility approach · Risk decomposition · Quality-adjusted unit values · Food policy · India

1 Motivation

Poverty and food insecurity remain to be globally eradicated. Methodologies have evolved to identify who the poor and who the food insecure is. With changing times the necessity for measures evolved to identify the present non-poor who may become poor in the future. Similarly, to identify those who have enough food or nutrient intake this period but may remain food insecure in the future. This paper contributes to the literature on identifying those who may remain food insecure in the future. The objective is to demonstrate the application of a general utility-based measure that can be used for any kind of food environment. In the poverty literature households/individuals whose income lies below a particular level were initially identified as poor (Comité Information Sahel 1974; Sen 1981). With changing times the definition evolved to include those who lacked access to elements of basic well-being like clean drinking water, sanitation, health services, etc. (World Bank 2001,2018). Therefore, the present definition of poverty encompasses both the monetary and non-monetary elements. Along with measuring the poor was introduced the concept of vulnerability (Sen 1981; Ravallion 1988; Chambers 1989, 2006). Those who were non-poor in the present period suddenly plunged into poverty the next period due to shocks, disasters, etc., and were called the vulnerable to poverty (World Bank 2001; León and Carlos 2006; UNDP 2014). World Bank (2001) observed that poverty is no longer only about the deficit in levels of consumption, education, and health-related outcomes. It is increasingly about the risk that the poor fear perpetuates further destitution. The index proposed by Chakravarty (1983) lays down the foundation for the measure of vulnerability in general. Sophisticated methods evolved to measure poverty and inequality. Additionally, such measures were further modified to estimate vulnerability to poverty (Chakravarty 1983; Baulch and Hoddinott 2000; Pritchett et al. 2000; Chaudhuri et al. 2002; Kamanou and Morduch 2002,2005; Ligon and Schechter 2003; Bourguignon et al. 2004; Subbarao and Christiaensen 2004; Calvo and Dercon 2005,2007,2013; Günther and Maier 2008; Kakwani and Silber 2008; Imai et al. 2011; Jha et al. 2011). Similarly, the literature on measuring vulnerability to poverty enriched over time (Glewwe and Hall 1998; Pritchett et al. 2000; Mansuri and Healy 2001; Kühl 2003; Kakwani and Silber 2008; Fujii 2016; Calvo 2018; Gallardo 2018). Ravallion (1988) is one of the pioneer studies to provide an empirical estimate of how risk contributes to poverty. Using a long panel dataset for selected villages in India the author finds a positive impact of income and consumption variability on different measures of poverty. Without the usage of the term vulnerability, the study ushered future exploration of theoretical and empirical measures of vulnerability to poverty. Zhang and Wan (2009) and Celidoni (2013) provide the latest comprehensive overview of the literature. The family of measures of individual vulnerability to poverty (Kakwani and Silber 2008) when aggregated, is nothing but expected poverty (Chaudhuri et al. 2002;

Suryahadi and Sumarto 2003; Subbarao and Christiaensen 2004; Kamanou and Morduch 2005). To summarize the existing measures of vulnerability to poverty are either for ex-ante analysis (Chaudhuri et al. 2002; Christiaensen and Boisvert 2000; Pritchett et al. 2000; Scaramozzino 2006) or ex-post welfare loss from a negative shock (Hoddinott and Quisumbing 2003) or use poverty indices and consumption smoothing approach on an individual basis, with individual-specific minimum income levels (Dutta et al. 2011) or are utility-based (Ligon and Schechter 2003) or are aggregative as individual measures may not always depict the macro picture (Calvo and Dercon 2007, 2013). Thus, poverty is a static concept, and that of vulnerability to poverty is a dynamic one.

Food insecurity is defined by the Food and Agriculture Organization (FAO) as "A situation that exists when people lack secure access to sufficient amounts of safe and nutritious food for normal growth and development and an active and healthy life" (FAO 2015). The food insecurity literature borrows methodologies from poverty and vulnerable to poverty literature to identify the food poor or food insecure and those vulnerable to food insecurity. Measures of food insecurity include that of FAO undernourishment which is a combination of data from food balance sheets and household income and expenditure surveys, dietary intake data from individual intake surveys, nutritional status data using anthropometric surveys, and qualitative assessment of people's perception of food insecurity and hunger (Napoli et al. 2011). The Global Hunger Index (GHI) is a popular one to monitor hunger at the global, regional, and country level (Wiesmann 2006). Data on the proportion of people with insufficient access to food, underweight children under the age of five, and child mortality under the age of five is used to construct the equally weighted index used to assess global hunger. However, the most popular measure of food insecurity is the identification of households/individuals based on calorie intake below a certain threshold level. Here, calorie (a major nutrient required to perform basic human activities) intake is the indicator used instead of income or other non-monetary measures as in the poverty and vulnerable to poverty literature. This was modified over time to include those deficient in the intake of other nutrients like protein, fat, and micronutrients. Therefore, like different measures of poverty, the conceptual base of measuring food insecurity also expanded over time. Along with measuring the food insecure the concept of vulnerability to food insecurity evolved. Households/individuals in the present period consume adequate levels of nutrients, and due to certain shocks are not able to consume say the minimum level of calories. This shock may be economic due to job loss, catastrophic health expenditure in the form of sudden illness or death of any member in the family, weather-related shocks, which might affect crop production of farmers, sudden loss, or reduced profits incurred by small enterprises or those who are self-employed, etc. This afflicted set comprises the vulnerable to food insecurity (UNWFP 2002a, b; Scaramozzino 2006). Moreover, these shocks or risks may be grouped into poverty, idiosyncratic shocks, aggregate risks, and unexplained factors (World Bank 2001; Ligon and Schechter 2003; Gaiha and Imai 2008; Günther and Harttgen 2009; Hart 2009). The application of vulnerability to poverty techniques is scanty in the space of food security. Food security programs should be forward-looking and dynamic (Bogale 2012). It should not only focus on those who are currently food insecure, but also on those who have a high chance of plunging into the food insecure zone in the future (Bogale 2012). Measurement tools and indicators like the Coping Strategies Index (CSI) and the Food Insecurity Experience Scale (FIES) are already in use by the international scientific community to gauge the extent of food insecurity or household behavior at the onset or during periods of crisis. The Coping Strategies Index (CSI) is an aggregation of strategies adopted by households when they face food insecurity. For example, (i) dietary change: changing the diet and buying less expensive and less preferred food items, limit the

portion of meals or reducing the number of meals taken; (ii) food seeking: borrow food or money to increase the amount of food available in the short-term; (iii) household structure: decrease the number of people to be fed in the short-term, earning members and growing children are fed more; and (iv) rationing: decreasing consumption of street food (Maxwell et al. 1999; CARE/WFP 2003; Food Security Cluster 2020). The FIES builds on a set of items among which one addresses "anxiety and psychological concern", often interpreted as an anticipated alarm for food insecurity (Ballard et al. 2013). Few examples of questions for households/ individuals are: Have you felt anxiety about having enough food at any time during the previous 12 months? Did not eat breakfast, lunch or dinner [or skipped a meal] because there was not enough money or other resources to get food? Went without eating for a whole day? The challenge remains apriori to identify the set of food vulnerable households. Drawing from the poverty and food insecurity literature this paper identifies the vulnerable to food insecurity and identifies the prime causes for the same for rural Indians. Vulnerability to food insecurity is mainly a rural phenomenon (ESAF, FAO 2001; ESAF, FAO 2004a, b; Scaramozzino 2006; Bogale 2012 among others as discussed in subsequent sections). Hence, the focus on the rural poor in this paper. The measurement of vulnerability to food insecurity is important as food policies often only target presently food insecure households and not the other income vulnerable households, which are presently food secure but potentially food insecure and maybe large in number. This policy issue is well discussed in the poverty and inequality literature (Sen 1981; Chambers 1989, 2006; Lipton and Ravallion 1995; Addison et al. 2008; Hulme and Moore 2008; UNDP 2014) with limited discussion in the space of food policy (Scaramozzino 2006; Bogale 2012; Azeem et al. 2017). Food insecure households are identified by existing measures and appropriate policies devised to address their issues. The needs of income vulnerable households are overlooked for the moment. Such an approach in alleviating food insecurity may not be sustainable in the long run. This set of income vulnerable may plunge into the food insecurity zone in the future. Therefore, the proportion of food insecure population will suddenly rise. Moreover, this will call for immediate government attention and reallocation of budgetary resources. Additionally, safety net programs and insurance schemes for targeting both poverty and food poverty or the nutritionally deprived needs to be redesigned (UNHLTF 2008; World Bank 2017). Few recent ex-ante analyses using cross-section data on this topic is by Sileshi et al. (2019a, b) for Ethiopian households, Tarasuk et al. (2019) for the first time for Canada, Ibok et al. (2019) for Nigeria, and Loopstra et al. (2019) using a panel dataset for the United Kingdom. Income, price, age, education, social group, migration status, and livelihood are identified as key determinants of vulnerability to food insecurity.

This paper fills the gap in the literature in the following ways: (i) conceptualizes a modified approach to the measurement of vulnerability to food insecurity and a novel application of the same to pseudo-panel data in the context of India; (ii) provide a unique decomposition exercise of vulnerability to food insecurity into different sets of poverty (i.e. aggregate, idiosyncratic, and unexplained factors); and (iii) analyze the role of different determinants especially that of the level of urbanization and price of staple food items. The key findings are: idiosyncratic risk is the largest driver; states with poor PDS performance are more susceptible; a rise in the price of staple food items increases the chances of food insecurity; gendered disparity persists over time, and finally a higher level of urbanization increases the exposure and sensitivity to shocks (like the spread of contagious diseases), disrupts the supply of food commodities from rural markets, and loss in income and augments rural vulnerability to food insecurity.

2 Review of Measurement and Policy-Related Challenges: Global and India Specific

Food policy implementation has undergone substantial changes over time. The focus has shifted from global, national, and household to the individual level. The 2020 Nobel Peace Prize awardee the United Nation's World Food Programme (WFP) emphasized the fact that food assistance policies in India have also shifted their focus from 'food for the nation' to 'food for the people' to 'food security for the vulnerable' (UNWFP 2002a, b). The vulnerability analysis and mapping (VAM) exercise of the WFP forms the base for any sort of intervention at an individual level. Recent efforts include mobile surveys to collect high-frequency data on market prices, access, and from households on food consumption, coping strategies, and nutrition indicators (UNWFP 2018). Sen (1981) way back emphasized the concept of the entitlement approach as a possible solution to tackle food insecurity related issues. For instance in India, PDS is a large-scale program to ensure food security. The availability of food grains through the PDS does not always protect the vulnerable sections of the population and ensure inclusive growth (Suryanarayana and Silva 2007). Ramachandran et al. (2009) using NFHS-2 found that the set of chronically energy deficient and the vulnerable sections did not coincide. The finding is based on a sample of ever-married in the age group of 15–49 years in the north Indian state of Uttar Pradesh (UP) for the year 1998–99. This finding reinstated the fact that targeting 'potential' deficient persons becomes more important than the present deficient ones.

The term vulnerability (an ex-ante concept which apriori identifies the future poor based on estimated consumption figures) is not synonymous with that of poverty (an ex-post concept which identifies the present set of deprived based on actual consumption figures). Programs that target reducing poverty cannot be used to reduce vulnerability (Chambers 1989). For example, poverty measures help in counting the number of poor people by the policymakers based on the flows of earnings and expenditure. Anti-poverty programs are designed to uplift the income of households. Therefore, poverty indicators are used as a proxy for measuring both poverty (existing set of deprived) and vulnerability to poverty (future poor). However, vulnerability to poverty is linked with assets households possess. For example, poor households may borrow to lift themselves out of the poverty line. Nevertheless, this debt trap makes them vulnerable to poverty. Additionally, vulnerabilities are faced across the entire life cycle and a different set of policies like unemployment insurance and pension schemes may be required (Malik 2014). In the context of food insecurity, poor households may resort to coping strategies like reducing the number of meals, buying cheap calorie-based food items. Nonetheless, in the long-run this takes a toll on their health and nutritional status, and more so for children (Maxwell et al. 1999). The main limitation in measurement is the lack of comprehensive large-scale panel data surveys, especially for developing countries. Even at the regional level, there are no surveys conducted by local governments to devise localized policies. As identified in Klasen and Waibel (2013) specialized surveys are required to address the issues better. There has been no acceptable and agreed-upon methodology for measuring vulnerability to food insecurity which is another major constraint (Dilley and Boudreau 2001; Bogale 2012). What needs to be clearly understood especially from a policy perspective is that insecurity is transitory and subsequent allocation of funds may be highly misleading. Moreover, the identification of factors that raise the risk of being vulnerable to poverty is also important. The shocks may be a singular event or contemporaneous like the recent occurrence of the triple crisis in eastern India of pandemic, cyclone, and locust invasion. Recent solutions to poverty reduction are doling out cash transfers (Ahmed

et al. 2007; Rocha 2009; Sabates-Wheeler and Devereux 2010; Miller et al. 2011; Hoddinott et al. 2013; Tiwari et al. 2016). However, as noted by Sen (1981) and Muralidharan et al. (2011) sole reliance on cash transfers can render households' income vulnerable. Sudden shocks may raise the price of staple food items and suddenly render households food insecure. An agricultural household is more vulnerable to food insecurity if food prices vary a lot even though the level of poverty aggregated at the community level remains the same (Kakawani and Silber 2008). Cash at times may be useful to buy a more diverse diet than food gifts (Bhalla et al. 2018). The success of such programs depends on food availability and rates of inflation or the extent of inflation indexation. Thus, from the policy perspective identifying households susceptible to such shocks is very important.

Another major handicap in policymaking is that the governments usually resort to static measures (country-specific poverty lines which are not updated regularly) to identify the set of beneficiaries who are deprived and those who meet certain basic minimum needs (Baulch 1996; Baulch and Hoddinott 2000).[1] These measures being static do not provide an estimate of the additional expenditure that the government needs to incur to provide for the needs of the additional beneficiaries. If the measures are not updated regularly, then the vulnerable (if synonymous to the poor) may not be brought into the ambit of food security programs (those households identified as poor based on the poverty line cut-off are eligible beneficiaries of the food security schemes).[2] For example, food security programs designed based on these measures (identification of the beneficiaries) will not address the needs of the newly formed food-deprived.[3] Moreover, policies should be designed such that households are permanently lifted out of the zone of vulnerability to food insecurity. Also, most papers on vulnerability to food insecurity use the terms insecurity and vulnerability synonymously without any universal or well-accepted definition on when a household can be defined to be vulnerable to food insecurity (Hart 2009; Kimani-Murage et al. 2014). Vulnerability, in general, reduces capabilities and choices, and human resilience to sustain further shocks (UNDP 2014). Moreover, if food vulnerable households are not protected then the attainment of the Sustainable Development Goals (SDG) hunger target will not be successful (Grimm et al. 2016). India lagged in attaining the Millennium Development Goals (MDG) 2015 hunger target of reducing the proportion of those malnourished. Similarly, if the food vulnerable households are not protected then it would delay the progress even further.

[1] One prime reason for the same is that it is expensive to collect panel data, and developing countries generally lack such detailed information. Thus, poverty lines are static measures usually able to identify those who are 'chronic poor' and not the 'transitory poor' people.

[2] It may be that a household vulnerable to food insecurity this period, not availing any benefits from food security programs, has an option to resort to Employment Guarantee Schemes (EGS). We can assume that income earned from the EGS will be spent on buying food items. However, there are other factors like whether that income earned is enough to buy food during periods of crises, members of the household eligible to avail benefit from the EGS are in a physical condition to do so, there are no sudden health shocks in the family, etc. Therefore, whether the household has access to any other beneficiary program other than food security programs does not dilute the need to address the issues of the vulnerable. In this context the debate between cash versus in-kind transfers is important. An in-kind transfer may be more useful than cash transfer in crises periods or for poor households as it is inflation proof, used more wisely, cannot be cornered by a few and has a wider reach in remote locations (Drèze, 2011).

[3] The general assumption is that the poor are food insecure. However, those above the poverty line may or may not be food secure. These households were not eligible for any benefits whether in cash or kind (eligible for food grains from PDS, wages from NREGS, etc.) in the earlier period along with the poor. However, in this period these households are the new poor as defined in the literature due to the sudden shocks. This incurs an additional expenditure on the government as policy makers now need to make provision for these newly formed poor.

The provision of public goods is as necessary as the availability of public insurance schemes for reducing risk and protecting the vulnerable in general (Devarajan and Jack 2007). In the Indian context this reinforces the importance of the Public Distribution System (PDS), National Rural Employment Guarantee Scheme (NREGS), and possibly designing an insurance scheme or social safety nets for the vulnerable in general, and the would-be food insecure. Grain ATMs developed by the World Food Programme emerged as a digital blessing during crisis periods ensuring quality and transparency (WFP 2020a). Vulnerable Group Development (VGD) Card was designed by Building Resources Across Communities (BRAC) way back in 1986 for doling out World Food Programme grain to the vulnerable in general in Bangladesh (Halder and Mosley 2004; Addison et al. 2008).[4] This scheme was not only about food aid, but a package of training to climb up the poverty ladder as successful entrepreneurs with greater autonomy and social status. Similarly, Ethiopia's Productive Safety Net Programme (PSNP) is one such existing program that tries to incorporate the requirements of the vulnerable to food insecurity (Sabates-Wheeler and Devereux 2010). In recent times digital technologies are adopted to reach out to sudden food insecure households due to catastrophic events (WFP 2020a, b) like drones delivering food in a Japanese town hit by nuclear disaster (BBC 2017) or mobile cash transfers to the conflict-affected IDPs in Myanmar (World Food Programme 2017). Related policy innovations in Indian food policymaking involves the installation of Grain ATMs that dispense food grains based on biometric identification of an individual, JAN DHAN accounts for direct transfer of cash to the needy under the Prime Minister Garib Kalyan Scheme, and in-kind transfers through the Pradhan Mantri Garib Kalyan Ann Yojana (Economic Times 2020). Additionally, One Ration One Card for migrants to access in-kind transfers at any location in India and Garib Kalyan Rozgar Abhiyaan for displaced migrants to avail of jobs locally (Indian Express 2020). Moreover, Pradhan Mantri Fasal Bima Yojana, Gramin Bhandaran Yojana, Livestock Insurance Scheme, National Scheme on Welfare of Fishermen, Pradhan Mantri Kisan Samman Nidhi Scheme, and Pradhan Mantri Kisan Pension Yojana. These insurance schemes aim to provide relief to different distressed agricultural households, fishermen, etc. whose livelihood is jeopardized due to vagaries of nature. Therefore, the measurement of vulnerability to food insecurity remains important for both academicians and policymakers (Scaramozzino 2006; Capaldo et al. 2010; Bogale 2012; Tandon and Landes 2014; Azeem et al. 2017).

3 Theoretical Framework

3.1 Expected Utility Framework

The study is one of the first to measure the extent of vulnerability to food insecurity using the expected utility framework as developed by Ligon and Schechter (LS) (2003).[5]

[4] The set of vulnerable are identified as a subset of the ultra-poor for availing the benefits of this programme.

[5] Methods 1 (Vulnerability as expected poverty: Pritchett et al. 2000; Chaudhuri et al. 2002; Scaramozzino 2006; Sileshi et al. 2019a, 2019b; Tarasuk et al. 2019) and 2 (Vulnerability as uninsured exposure to risk: Hoddinott, and Quisumbing, 2003) are not considered as results can be improved by using a panel, and not a cross-section data. Methods 3 (Decision making under uncertainty: Dutta et al. (2011)) and 4 (Vulnerability measures for both individual and aggregate poverty: Calvo and Dercon 2013), which provide more robust results cannot be adopted due to data limitations. This is because no prior information is available on the probability of the occurrence of a certain event say crop loss or drought.

Limited studies have explored the LS technique to analyze vulnerability related issues in general. A recent study by Magrini et al. (2018) uses the methodology to identify vulnerable households to trade openness in Vietnam using Vietnam Household Living Standard Surveys (VHLSS). Moreover, no other existing methodology allows us to attribute vulnerability to food insecurity to the different sets of poverty (i.e. aggregate, idiosyncratic, and unexplained factors). Identification of the nature of risk is important to allocate funds, and design schemes and programs accordingly (Morduch 1999; Albarran and Attanasio 2003; Barrett et al. 2003; Dercon and Krishnan 2003; Gaiha and Imai 2008). Additionally, in the Indian context, the focus of food security policies has shifted from identifying beneficiaries based on the intake of calories to consuming a diverse diet to ensure sufficient intake of both macro and micronutrients (Gaiha et al. 2012; Das 2014). The paper uses dietary diversity measures for capturing the information on food insecurity which is more broad-based than just focusing on calorie intake as in Azeem et al. (2017). Moreover, Azeem et al. (2017) assumes a cut-off for vulnerability to be 0.29 unlike no specified threshold limit in the present study. This implies that mild to severe levels of vulnerability can be captured using the LS methodology and it is more broad-based. Additionally, the theoretical foundations of the measure are quite well established. Calvo and Dercon (2005) provide the axiomatic foundation of the LS methodology. In simple terms, total welfare loss resulting from vulnerability to food insecurity is decomposed into components due to 'food poverty' (expected consumption of the current food secure falling below the food poverty line), and 'risk' (variability of food consumption over time). An important advantage of using the LS method over the others is that the model assumes two situations concerning the consumption profile of a household: (i) the risk-averse household is certain that expected food consumption in period t+1 (where t denotes the current period) will be just below the threshold for deprivation so that the probability of plunging into the vulnerability zone is one; and (ii) the expected mean value of food consumption is unchanged. There is an equal probability that the household's food consumption is just above the food poverty line (above the mean), and just below the mean value. Since the household is risk-averse it will prefer a certain level of food consumption in the first case, though vulnerability to insecurity is lower in the second case.[6]

Vulnerability to food insecurity is defined as the difference between utility derived from some level of certainty-equivalent consumption (food consumption in our case), at and above which the household is not considered vulnerable. This certainty-equivalent level of food consumption is the same as defining a threshold level for food insecurity. It is not a fixed value, but dependent on the distribution of food consumption. Food consumption fc_i for the *i*th individual/household has different distributions in different states of the world. The measure is given as follows:

$$V^i = U^i(z) - EU^i\left(fc^i\right) \tag{1}$$

U_i is a weakly concave strictly increasing function, and z is the poverty/food deprivation line. Equation (1) can be rewritten as:

$$V^i = \left\{U^i(z) - U^i\left(Efc^i\right)\right\} + \left\{U^i\left(Efc^i\right) - EU^i\left(fc^i\right)\right\} \tag{2}$$

[6] Aggregation of household preferences has minimal impact on the measures of vulnerability as discussed in Calvo & Dercon (2013). Aggregation of income at the household level to that at the state-region level will draw similar conclusions.

The first term is a measure of poverty concerning the difference in utility evaluated at z, and fc for a concave function. The second term measures the risk that the household faces. The latter can be decomposed into aggregate or covariate, and idiosyncratic risk, where $E(fc_i|x_t)$ is an expected value of food consumption expenditure conditional on a vector of covariant variables, x_t. The vector of aggregate variables i denoted by $\overline{x_t}$ and x_t^i is the set of idiosyncratic variables. It is assumed that $E\left(fc_{it}|\overline{x_t}, x_{it}\right) = \alpha^i + \eta_t + x\beta$. Aggregating across households, an estimate of the total level of vulnerability to food insecurity is obtained as follows:

$$V^i = \left\{U^i(z) - U^i\left(Efc^i\right)\right\} + \left\{U^i\left(Efc^i\right) - EU^i[E(fc^i|\overline{x}]\right\} + \left\{EU^i[E\left(fc_t^i|\overline{x_t}\right)] - EU^i\left(fc_t^i\right)\right\} \tag{3}$$

This is a static function, and for estimation purposes, time-series variation needs to be considered. Consumption expenditure data is usually fraught with errors (Field and Viollaz 2013; Gibson 2016; Friedman et al. 2017). To correct for the same, the idiosyncratic risk component is further decomposed into (i) risk arising due to k observed time-varying household characteristics; and (ii) risk arising due to unobserved factors, which lead to measurement error in consumption. Let consumption measured with error be represented by $\widetilde{fc_t^i}$. Then, $\widetilde{fc_t^i} = fc_t^i + \varepsilon_t^i$, where ε_t^i is the error term following the properties that $E(fc_t^i|\overline{x_t}, x_t^i) = E(fc_t^i|\overline{x_t}, x_t^i)$. This implies that measurement error will only have an impact on unexplained risk. Therefore, the decomposition function is of the form:

$$\begin{aligned} V^i = &\left\{U^i(Efc) - U^i\left(Efc_t^i\right)\right\} + \left\{U^i\left(Efc_t^i\right) - EU^i\left[E\left(fc_t^i|\overline{x_t}\right)\right]\right\} + \left\{EU^i\left[E\left(fc_t^i|\overline{x_t}\right)\right] - EU^i\left[E\left(fc_t^i|\overline{x_t}, x_t^i\right)\right]\right\} \\ &+ \left\{EU^i\left[E\left(fc_t^i|\overline{x_t}, x_t^i\right)\right] - EU^i\left(fc_t^i\right)\right\} \end{aligned} \tag{4}$$

This decomposition allows an assessment of whether vulnerability to food insecurity is a result of factors underlying poverty or of aggregate and idiosyncratic shocks, and the inability to cope with them.[7] There are two limitations to this approach. First, the results may differ depending on the form of the utility function assumed. The second limitation is that the measurement is concerning the function as discussed above. The utility function assumed by Ligon and Schechter (2003) is an iso-elastic one. Its properties are as follows:

$$U(fc) = \frac{fc^{1-\gamma}}{1-\gamma}, \quad \text{where } \gamma > 0 \tag{5}$$

A utility function exhibits decreasing absolute risk aversion (DARA) if $\frac{\partial A(fc)}{\partial c} < 0$, where $A(fc) = -\frac{U''}{U'}$ (Mas-Colell et al. 1995). For our analysis purposes, we assume $\gamma = 2$. So, in this case $U'' = \frac{fc}{\gamma}$ and $U' = \frac{1}{fc^\gamma}$. Hence, relative risk aversion $= fcA(fc) = \gamma$, is a constant. Therefore, it represents the Constant Relative Risk Aversion (CRRA). As discussed in Ligon and Schechter (2003) a higher value of γ provides double the estimate of vulnerability to poverty, with the share of poverty at the same levels as that estimated for $\gamma = 2$. For estimation purposes, the normalized value of food consumption expenditure. Just to understand the process of normalization, in a particular region there are n households, and the level of food consumption expenditure for these households is observed over t periods. This means that there are $m = nt$ observations in total. Now, let fc_i denote food consumption for the ith observation. Then, $\overline{fc} = \frac{\sum_{i=1}^{m} fc_i}{m}$. Now, ith observation for food consumption expenditure will be: $fc_i^* = \frac{fc_i}{\overline{fc}}$, i.e. c is normalized such that the average value of c over all

[7] Poverty risk can also be decomposed into expected incidence, intensity, and expected variability as in Celidoni (2015), which may be explored further in the context of food security.

periods equals unity. Therefore, $\frac{\sum_{i=1}^{m}\frac{fc_i}{\overline{fc}}}{m}=\frac{1}{m\overline{fc}}\sum_{i=1}^{m}fc_i=\frac{1}{\overline{fc}}\frac{\sum_{i=1}^{m}fc_i}{m}=\frac{\overline{c}}{\overline{c}}=1$. Therefore, fc_i^* is the normalized value of food consumption expenditure inserted into the utility function. From this, one can conclude that $U\left(fc_i^*\right)=\frac{fc_i^{*1-\gamma}}{1-\gamma}=-\frac{1}{\left(\frac{fc_i}{\overline{fc}}\right)}$ for $\gamma=2$, is increasing in fc_i, and decreasing in $\overline{fc}$ for a given fc_i. This satisfies the homogeneity postulate. This postulate is not satisfied when $\gamma=3$, and therefore $\gamma=2$ is chosen.

This can also be graphically represented. Figure 1 depicts a concave welfare function such that the marginal utility of consumption is decreasing with an increase in the level of food consumption. In the case of an uncertain event, expected utility $EU^i\left(fc^i\right)$ is obtained from an expected food consumption level of Efc^i. Next, the household can face two situations in the future: (i) low food consumption denoted by c_L; and (ii) high food consumption denoted by c_H. However, a certain level of food consumption Efc^i would provide a higher level of utility $U^i\left(Efc^i\right)$ at point D on the curve. Now, given the poverty/food deprivation line z, vulnerability is the distance FC, which can be decomposed into poverty (FD) and risk (DC). Three situations are possible: food poverty with risk, risk without food poverty, and food poverty without risk. The first two situations would render a household vulnerable to food insecurity. The first situation is as conceptualized in Thorbecke (2004) (Fig. 1a) and the rest based on it. The second situation is when the value of FD is negative (implying a situation of no poverty) and that of DC is positive as depicted in Fig. 1b. It is difficult to conceptualize poverty without risk when the welfare function is concave. For example, in the first case, DC can be zero only when the welfare function is linear (Fig. 1).

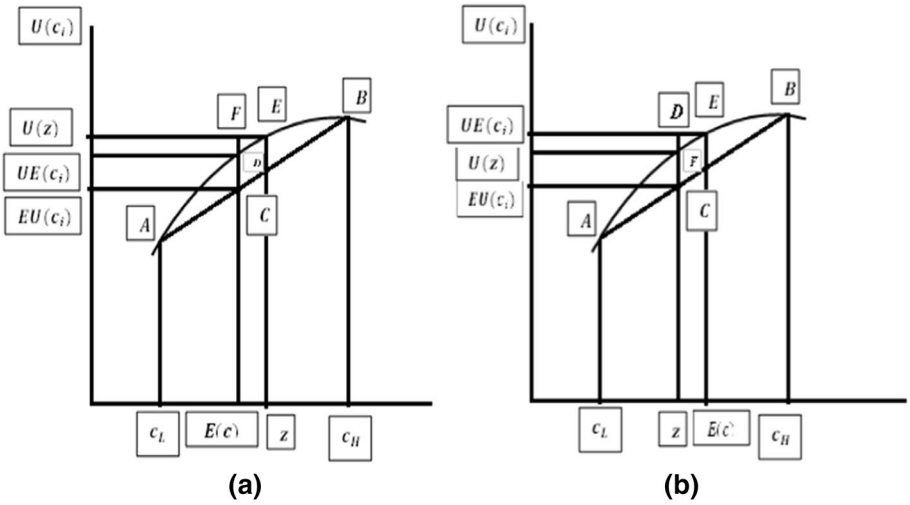

Fig. 1 Conceptual framework for understanding vulnerability. Source: Author's conceptualization based on Thorbecke (2004)

4 Data

A nationally representative household consumption expenditure survey conducted by the National Sample Survey Organization (NSSO) in July 2004—June 2005, July 2009—June 2010, and July 2011- June 2012 across rural India is used for analysis purposes. A stratified multi-stage design was used for the survey. The first stage units (FSUs) comprise the 2001 Census villages in the rural sector and Urban Frame Survey (UFS) blocks in the urban sector. The ultimate stage units (USU) were the households in both sectors. Within each district of a State/UT two basic strata were formed: (i) rural stratum comprising all rural areas of the district, and (ii) urban stratum comprising all urban areas of the district. The sample size for rural India is 79,298, 59,097, and 59,683 households for the three rounds respectively.

The NSS collects information on various demographic and socio-economic characteristics. The survey also collects detailed information on expenditure (in rupees), quantity consumed, and source of purchase for the main food groups: cereal, cereal substitutes, pulses and pulse products, milk and milk products, sugar, salt, edible oil, egg, fish and meat, vegetables, fruits (fresh and dry), spices, and beverages. The recall period for edible oil, egg, fish and meat, vegetables, fruits, spices, beverages, and processed foods was seven days, and for other food items was 30 days. Quantities for food items were collected in kilograms except for a few items like milk (litres), eggs, lemon, banana, pineapple, coconut and orange in units, ice-cream and other milk products in rupees, and spices in grams. Appropriate conversion of food items to kilograms was done wherever possible as in Majumder et al. (2012).[8]

Rapid urbanization has a growing influence on both the demand and supply-side issues of food security (Satterthwaite et al. 2010). The pressing demand for a large variety of food products, with a decline in the number of food producers, leads to rising food prices and reduces the intake of vital nutrients for the urban population. The rural populations are at a higher risk than the urban ones primarily due to lower levels of income, seasonal employment, poor storage and transportation facilities, lower availability, etc. This motivates us to analyze the influence of growing levels of urbanization on rural vulnerability to food insecurity. The level of urbanization is an estimate of the proportion of the district's population living in urban and peripheral urban areas of the district. The share of the urban population in every district is available as part of the Census of India data. But the size of the population living in peripheral urban areas is not available as part of the official statistics given the dichotomous definition of what is rural and what is urban. The term peripheral urban refers to an area around a city or town and is conceptually rural. Estimates of the size of the peripheral urban area are generated by geographers, and for India, they are available as part of the India e-geopolis data set.[9]

[8] The following conversions are used: 1 L milk = 1 kg; 1 egg = 58 gms; 10 bananas = 1 kg; 1 orange = 150 gms; 1 pineapple = 1.5 kgs; 1 coconut = 1 kg.

[9] Source: http://www.ifpindia.org/Built-Up-Areas-in-India-e-GEOPOLIS.html (Accessed at different time periods since 2013).

5 Empirical Strategy

There is some literature on measuring vulnerability to food insecurity (Lovendal et al. 2004; Scaramozzino 2006; Bogale 2012; Kimani-Murage et al. 2014; Azeem et al. 2017). The measure generally used to classify households as food insecure is the Food Insecurity and Vulnerability Information and Mapping Systems (FIVIMS, FAO 2000, 2002) tool or static poverty measures (Ravallion 1996) or an index constructed using household coping strategies (Babatunde et al. 2008). Such measures do not provide decomposition or identify possible sources of vulnerability to food insecurity (Christiaensen and Boisvert 2000; Capaldo et al. 2010). Moreover, food share or intake of calories, which is generally used to identify the vulnerable is not a holistic indicator (Chaudhuri and Ravallion 2004). Ibok et al. (2019) develop a holistic index based on dimensions of exposure, adaptation, and sensitivity. One drawback is that the study apriori identifies what are the sources of vulnerability. Instead of providing for any flexibility in the framework, to incorporate any new determinants like immigration status, a key factor identified by Tarasuk et al. (2019). The weighting of different dimensions when using multiple indicators for each also becomes difficult and a cumbersome exercise with little policy implications especially when analyzing risky events (Decancq and Lugo 2013). It is also very data specific and not universally appealing. This study uses Ligon and Schechter (LS) (2003) methodology to overcome these shortcomings and provide more robust estimates of the vulnerable to food insecurity. This measure (developed for identifying those vulnerable to poverty) along with those developed by Elbers and Gunning (2003) and Cunningham and Maloney (2000) treats vulnerability and 'low-expected utility' as equivalent concepts. Therefore, conversion of consumption to utility terms which improves comparability, forward-looking nature, and flexibility of decomposition justifies the choice of the LS technique over others. Developing a suitable empirical strategy using the theoretical model and interpreting the aggregate results using pseudo panel regression techniques is the main contribution of this paper. The other interesting contributions of this study are to provide: (a) comparable estimates of vulnerability to food insecurity in utility terms at the state-region level; (b) the estimates are based on well-accepted and holistic dietary diversity measures; (c) pseudo-panel regressions are conducted, and existing datasets explored to the last mile instead of refraining from conducting such an exercise due to lack of panel data; (d) results are linked to existing food security schemes, and solutions suggested to solve food insecurity related challenges at the household level and make the food security system more resilient; and (e) provides the theoretical and methodological framework for evaluation studies of recent digital schemes implemented by the government for ensuring food security and eliminating poverty of farmers.

The LS methodology does not exclude poverty as a source of vulnerability unlike Günther and Maier (2008). A solid justification for the same is provided by Kakwani and Silber (2008). Suppose a farmer is expected to face two situations: rain (no poverty) or drought (poverty). Even if there is a good harvest in the first scenario the chances of being vulnerable to poverty do not reduce. Poverty remains as bad a threat as before. By the focus axiom, the poverty line or threshold (say the line of food poverty or minimum calorie intake) classifying households as poor (food insecure) and non-poor (food secure) is at the core of the vulnerability analysis (Kakwani and Silber 2008). One drawback of the LS methodology is that it provides scope for well-off states to compensate for episodes of worse-off periods. However, the Kakwani and Silber (2008) concept of vulnerability always remains distinct from the possibility of being well-off.

The first step is to estimate the predicted value of the logarithm of food consumption expenditure. The study considers information on households for all major states pooled

over three years. A pooled regression of the logarithm of food consumption expenditure on age composition of the population, dependency ratio, household size, its square and type (self-employed in non-agriculture, agricultural labour, other labour, self-employed in agriculture and others), gender of the household head, level of education (not literate, primary, middle, higher secondary, diploma, graduate and post-graduate), incidence of social groups in the population (scheduled caste, scheduled tribe, other backward class, and others), size distribution of farmland (land possessed is categorized as follows: less than 0.001, 0.001–0.004, more than 0.004–0.40, more than 0.40—1, more than 1–2.0, more than 2.0–4.0, and greater than 4.0 hectares), consumption expenditure as a proxy for income (a dummy variable is defined for classifying households into different categories based on consumption expenditure), marital status, religious affiliation, and a dummy variable capturing information on the year in which the survey was conducted. The predicted value of the logarithm of food consumption expenditure obtained is used for all subsequent computation purposes. Next, each of the components described in Eq. (4) is estimated separately.

The different components denoted by u are as follows:

$$u_1 = U^i(Efc)$$

$$u_2 = U^i\left(Efc_t^i\right)$$

$$u_3 = U^i\left[E\left(fc_t^i|\overline{x_t}\right)\right]$$

$$u_4 = EU^i[E\left(fc_t^i|\overline{x_t}, x_t^i\right)]$$

$$u_5 = EU^i\left(fc_t^i\right)$$

This is followed by aggregation of the mean value of the predicted value of the logarithm of food consumption expenditure across different state-regions.[10] As the study uses the NSS data for estimation purposes, that is not panel data, the unit of analysis is the state-region that can be tracked over the three years.[11] The normalized food consumption expenditure is obtained by dividing the predicted value of the logarithm of food consumption expenditure by the mean food consumption expenditure aggregated at the state-region level. This value is then plugged into the utility function as defined in Eq. (5) and is denoted by u_1. As discussed above u_1 is also the food poverty line which is endogenously determined in our case. Next, the mean value of the predicted value of the logarithm of food consumption expenditure across different rounds is estimated. The normalization exercise is replicated once again across different rounds. The normalized values are again plugged into the utility function as defined in Eq. (5), and is denoted by u_2. The predicted value of the level of food consumption expenditure is obtained after regression of the time-invariant factors (household type, social group, religion, gender, and level of urbanization) on it. The

[10] Regions are hierarchical domains of study below the level of State/ Union Territory in the NSS. Source: http://mospi.nic.in/sites/default/files/publication_reports/concepts_golden.pdf (Accessed on Jan 8 2019).

[11] The NSS data is used by the government for all policy and planning purposes and is available for a longer time horizon unlike other datasets like the India Human Development Survey (IHDS) dataset. NSS data is not quite representative at the district-level. Hence, an assessment of vulnerability at the district-level will not be of much relevance.

normalized values are then inserted into the utility function, averaged for different state-regions to obtain u_3. For computing u_4 time varying characteristics like age composition of the population, dependency ratio, household size, its square and type (self-employed in non-agriculture, agricultural labour, other labour, self-employed in agriculture, and others), gender of the household head, level of education (not literate, primary, middle, higher secondary, diploma, graduate and post-graduate), incidence of social groups in the population (scheduled caste, scheduled tribe, other backward class, and others), size distribution of farm land (land possessed is categorized as follows: less than 0.001, 0.001–0.004, more than 0.004–0.40, more than 0.40–1, more than 1–2.0, more than 2.0–4.0, and greater than 4.0 hectares), marital status (never married, currently married, widowed and divorced/separated), religious affiliation (Hindu, Muslim, Christian, Others), level of urbanization, and the quality-adjusted unit value of staple food items like rice, wheat, and pulses (estimation of which is described in the following sub-section) are regressed on the predicted value of the logarithm of food consumption expenditure. The predicted value is used to obtain the normalized food consumption expenditure, which when inserted into the utility function, averaged for each state-region provides u_4. Finally, for computing u_5 the mean value of the predicted value of the logarithm of food consumption expenditure is obtained over different state-regions, normalized and plugged into the utility function, and averaged across each of the three rounds of the survey.

5.1 Estimation of Quality-Adjusted Prices

NSS provides detailed information on the quantity, and value of 142 food items. Unit values are computed for each food item by dividing total expenditure by quantity consumed and expressed in Rs/kilogram. These unadjusted unit values give biased estimates as they do not control for quality and demographic characteristics and are not a true representation of market prices. Unit values suffer from measurement error, quality changes, and the impact of household composition on MPCE (Majumder et al. 2012). Prais and Houthakker (1955) discuss quality effects, which leads to a difference between raw unit value and prices. Quality-adjusted unit values need to be computed to reduce the bias and are used as a proxy for price. Certain food items bought in the urban areas are generally of superior quality than those consumed in rural areas. Also, households in rural areas have a higher proportion of consumption from home produce than in urban areas. The procedure in Majumder et al. (2012) is followed, controlling for both quality, demographics, and income-related factors. The empirical specification is as follows:

$$v_i^{hsjd} - \left(v_i^{sjd}\right)_{median} = \alpha_i D_s + \beta_i D_j + \gamma_i \sum_j \sum_d D_j D_d + \varphi_i x^{hsjd} + \omega_i f_i^{hsjd} + \sum_m b_i Z_{im}^{hsjd} + \varepsilon_i^{hsjd}. \tag{6}$$

where v_i^{hsjd} is the unit value paid by household h for food item i in state j, district d, and sector s, $\left(v_i^{sjd}\right)_{median}$ is the median unit value for the ith food item in the district in which the household lives, x is monthly per capita food expenditure, f is the proportion of meals that are consumed outside by the members of the household, Z_{im} is household characteristics (household details of age, gender, household size, number of adult males and females in the household), and D_s,D_j, and D_d are the dummies for the sector, state, and district respectively. Inclusion of x, f and Z_{im} in the model controls for income and demographic factors, which affects household consumption expenditure. The district-wise quality-adjusted price for each food item p_i is obtained by adding the residual obtned after

estimating the model as specified in Eq. (6) to the district's median value for that food item. The residual contains the unexplained factors not incorporated in the model, and therefore a measure of the quality difference, which is unexplained by the explanatory variables. This residual corrects for the differences in quality across different districts. This procedure is based on Hoang (2009) with a slight modification as in Majumder et al. (2012) that median unit values are used in place of mean unit values. Those observations, which are more than 1.5 times the interquartile range are identified as outliers, are eliminated. Quality-adjusted unit values for the following food groups are considered—rice, wheat, and pulses and pulse products, by aggregating over food items belonging to the respective food groups. From an economic perspective, diet diversity is important to lower prices by reducing the demand for only a particular set of food items.

As discussed above vulnerability to food insecurity can be attributed to poverty, aggregate, idiosyncratic, and unexplained risk factors. From Eq. (4) one can conclude that the difference between u_1 and u_2 is the poverty component, that between u_2 and u_3 is the aggregate risk factors, between u_3 and u_4 is the idiosyncratic risk component, and that between u_4 and u_5 provides the unexplained component.

$$\begin{aligned}
&\text{Poverty} : u_1 - u_2 \\
&\text{Aggregate risk} : u_2 - u_3 \\
&\text{Idiosyncratic risk} : u_3 - u_4 \\
&\text{Unexplained risk} : u_4 - u_5
\end{aligned}$$

On each of the above components, variables discussed earlier are regressed to identify the key determining factors for vulnerability to food insecurity. The explanatory variables included in the model are MPCE (a dummy variable is defined for classifying households into different categories based on consumption expenditure), social group (scheduled caste, scheduled tribe, other backward class, and others), religion (Hindu, Muslim, Christian, Others), household type (self-employed in non-agriculture, agricultural labour, other labour, self-employed in agriculture and others), marital status (never married, currently married, widowed and divorced/separated), education (not literate, primary, middle, higher secondary, diploma, graduate and post-graduate), the number of household members in the age group of 15–24, 25–34, 35–44, 45–59, and 60 and above, size of land possessed by households, gender of the household head, and state-region level dummies. Land possessed is categorized as follows: less than 0.001, 0.001–0.004, more than 0.004–0.40, more than 0.40–1, more than 1–2.0, more than 2.0–4.0, and greater than 4.0 hectares. All characteristics are at the household head level. Standard errors are clustered at the FSU level.[12]

[12] Some of the limitations of this analysis well documented in the literature are: (i) NSS or any other large scale household survey collects information on consumption expenditure at the household level only. However the same dataset is used for all government policy analysis and purposes. In case of conversion of food items into different nutrients it is possible to weigh the intake by consumption units which is based on gender differences. However we control for gender, age, etc. in the regression model; (ii) Also, there is no dataset available which collects information on cold-storage or shipping facilities at the district level which can help to separate the Alchian-Allen effects (Gibson, 2016). For understanding the interplay of the Alchian-Allen effects among different food items one needs to conduct a state-region level analysis, which is beyond the scope of this paper. Also, from our understanding and detailed analysis of the NSS data it is obvious that substitutability among the raw food items which NSS provides is limited in nature particularly for rural areas. Regions primarily consume food items based on local production, tastes, and availability. We are also aware of the other biases attributed to available data, which may lead to over/under estimation used as discussed in Aleksandrowicz et al. (2017).

Table 1 Descriptive statistics. *Source*: Author's computation

Variable	Observation	Mean	SD	Min	Max
Age					
Age group: < 15	155,981	0.0020	0.0442	0	1
Age group:15–24	155,981	0.0206	0.1420	0	1
Age group:25–34	155,981	0.1579	0.3646	0	1
Age group:35–44	155,981	0.2703	0.4441	0	1
Age group:45–59	155,981	0.3457	0.4756	0	1
Age group:60 and above	155,981	0.2036	0.4027	0	1
Education					
Not literate	155,959	0.366	0.482	0	1
Primary	155,959	0.112	0.315	0	1
Middle	155,959	0.079	0.270	0	1
Secondary	155,959	0.053	0.224	0	1
Higher secondary	155,959	0.049	0.217	0	1
Religion					
Hindu	155,974	0.834	0.372	0	1
Muslim	155,974	0.104	0.306	0	1
Christian	155,974	0.023	0.151	0	1
Others	155,974	0.038	0.191	0	1
Gender					
Male	155,982	0.890	0.313	0	1
Female	155,982	0.110	0.313	0	1
Social group					
Scheduled tribes	155,944	0.102	0.303	0	1
Scheduled castes	155,944	0.188	0.391	0	1
Other backward classes	155,944	0.427	0.495	0	1
Others	155,944	0.283	0.450	0	1
Marital status					
Never married	155,970	0.019	0.135	0	1
Currently married	155,970	0.868	0.339	0	1
Widowed	155,970	0.109	0.311	0	1
Divorced/separated	155,970	0.005	0.070	0	1
Employment					
Self-employed in non-agriculture	155,921	0.264	0.441	0	1
Agricultural labour	155,921	0.191	0.393	0	1
Other labour	155,921	0.153	0.360	0	1
Self-employed in agriculture	155,921	0.258	0.437	0	1
Others	155,921	0.134	0.341	0	1
Land possessed					
< 0.001 ha	155,982	0.029	0.167	0	1
0.001 ha < Land owned < 0.04 ha	155,982	0.063	0.242	0	1
0.04 < Land owned < 0.4 ha	155,982	0.454	0.498	0	1
0.4 < Land owned < 1 ha	155,982	0.192	0.394	0	1
1 < Land owned < 2 ha	155,982	0.120	0.325	0	1
2 < Land owned < 4 ha	155,982	0.083	0.276	0	1
Land owned > 4 ha	155,982	0.060	0.238	0	1

Table 1 (continued)

Variable	Observation	Mean	SD	Min	Max
Income					
MPCE: Quartile 1	155,981	0.218	0.413	0	1
MPCE: Quartile 2	155,981	0.202	0.401	0	1
MPCE: Quartile 3	155,981	0.199	0.399	0	1
MPCE: Quartile 4	155,981	0.193	0.395	0	1
MPCE: Quartile 5	155,981	0.188	0.391	0	1
Social group					
Scheduled tribes	155,982	0.102	0.303	0	1
Scheduled castes	155,982	0.188	0.391	0	1
Other backward classes	155,982	0.427	0.495	0	1
Others	155,982	0.283	0.450	0	1
Religion					
Hindu	155,982	0.834	0.372	0	1
Muslim	155,982	0.104	0.306	0	1
Christian	155,982	0.023	0.151	0	1
Others	155,982	0.038	0.191	0	1
Quality-adjusted unit value					
Rice	140,414	13.18	7.94	0.00	403.59
Wheat	125,672	12.05	8.65	0.00	277.32
Pulses	149,168	42.65	17.66	1.69	272.58
Logarithm of food consumption	155,870	6.22	0.55	5.21	7.31
Urbanization	153,089	0.19	0.14	0.01	0.85
Dependency ratio	155,982	0.08	0.14	0	1
Household size	155,982	4.92	2.49	1	43
Household size squared	155,982	30.39	37.66	1	1849

6 Main Findings

Table 1 provides descriptive statistics. Table 2 provides the regression results of the components of vulnerability to food insecurity for rural India. Significant determinants of vulnerability to food insecurity are discussed. With an increase in the price of staple food items like rice and pulses the probability of the chance of vulnerability rises. This has important implications for both calorie and protein intake of the rural population. Overall, the intake of vital nutrients may fall over time. Studies with similar findings exist for India and Africa. Kimani-Murage et al. (2014) find the urban slum dwellers of Nairobi, Kenya to be extremely vulnerable to food insecurity. Doubling the price of staple food like maize flour was one of the main factors reducing the purchasing capacity of households. Another study analyzing the impact of high food prices on diets is that by Tandon and Landes (2014). They find that during the global food price hike from 2006 to 2008 households reduced their consumption of staple food items, which led to the consumption of a less diverse diet, and a substantial fall in the calorie intake of the population.

As compared to the Others category those belonging to the Scheduled Caste and Other Backward Caste are less vulnerable to food insecurity in rural India. One plausible

Table 2 Components and determinants of vulnerability to food insecurity. Source: Author's computation

	Vulnerability	Poverty	Idiosyncratic risk	Aggregate risk	Unexplained risk
Average value (in utils)	(0.001) =	(0.004) +	(0.005) +	(0.002) +	0.006
Dependency ratio	0.000488	0.001224	−0.000723	−0.000500	0.000565
	(0.002154)	(0.002290)	(0.002496)	(0.002772)	(0.001421)
Household size	− 0.000209	− 0.000425	− 0.000012	0.000490	−0.000186
	(0.000275)	(0.000293)	(0.000319)	(0.000355)	(0.000182)
Household size squared	0.000003	0.000022	− 0.000012	− 0.000018	0.000007
	(0.000017)	(0.000018)	(0.000019)	(0.000021)	(0.000011)
Reference: age group:60 and above					
Age group: < 15	0.029590*	0.027077	− 0.001464	− 0.004743	− 0.003187
	(0.016061)	(0.017516)	(0.019090)	(0.020682)	(0.010612)
Age group:15–24	− 0.002237	− 0.001389	− 0.003288	0.006079**	− 0.000338
	(0.002118)	(0.002255)	(0.002457)	(0.002725)	(0.001398)
Age group:25–34	− 0.000689	− 0.001693	− 0.000705	0.001042	0.000485
	(0.001007)	(0.001058)	(0.001153)	(0.001295)	(0.000664)
Age group:35–44	− 0.001302	− 0.001416*	− 0.000320	− 0.000252	0.000507
	(0.000813)	(0.000856)	(0.000933)	(0.001047)	(0.000537)
Age group:45–59	− 0.000362	− 0.000486	− 0.000819	0.000007	0.000914*
	(0.000742)	(0.000781)	(0.000851)	(0.000955)	(0.000490)
Reference: diploma/graduate/post-graduate					
Not literate	0.000971	− 0.000277	− 0.000008	0.001661	0.000665
	(0.001311)	(0.001373)	(0.001497)	(0.001688)	(0.000865)
Primary	0.001653	0.000809	− 0.000844	0.002141	0.000171
	(0.001266)	(0.001322)	(0.001441)	(0.001629)	(0.000835)
Middle	0.001579	0.001019	− 0.000376	0.001917	− 0.000463
	(0.001370)	(0.001431)	(0.001560)	(0.001763)	(0.000904)
Secondary	− 0.000022	− 0.000177	− 0.000035	0.001721	− 0.000271
	(0.001430)	(0.001496)	(0.001630)	(0.001841)	(0.000944)

Table 2 (continued)

	Vulnerability	Poverty	Idiosyncratic risk	Aggregate risk	Unexplained risk
Higher secondary	0.000895	− 0.000761	0.001610	0.000295	0.000173
	(0.001550)	(0.001626)	(0.001772)	(0.001994)	(0.001023)
Reference group: divorced/separated					
Never married	− 0.000671	0.004740	− 0.001669	− 0.012288**	0.004626
	(0.004695)	(0.004941)	(0.005385)	(0.006045)	(0.003102)
Currently married	0.000335	0.004292	− 0.004444	− 0.006236	0.001874
	(0.004152)	(0.004360)	(0.004751)	(0.005346)	(0.002743)
Widowed	− 0.000195	0.004089	− 0.004325	− 0.007553	0.003343
	(0.004188)	(0.004394)	(0.004789)	(0.005392)	(0.002767)
Reference group: land owned > 4 ha					
< 0.001 ha	− 0.000271	− 0.002568	− 0.000185	0.001089	0.001868
	(0.001954)	(0.002028)	(0.002211)	(0.002516)	(0.001290)
0.001 ha < land owned < 0.04 ha	− 0.001402	− 0.002722	− 0.002227	0.000609	0.002664**
	(0.001688)	(0.001737)	(0.001895)	(0.002173)	(0.001114)
0.04 < land owned < 0.4 ha	− 0.002364	− 0.003550*	− 0.002216	− 0.000094	0.003272***
	(0.001762)	(0.001817)	(0.001981)	(0.002269)	(0.001163)
0.4 < land owned < 1 ha	− 0.000380	− 0.002455	− 0.002073	0.002765	0.001812
	(0.001841)	(0.001899)	(0.002071)	(0.002370)	(0.001215)
1 < land owned < 2 ha	− 0.000691	− 0.003251	− 0.000586	0.000056	0.002069
	(0.001930)	(0.001993)	(0.002173)	(0.002484)	(0.001274)
2 < land owned < 4 ha	0.002619	− 0.000259	− 0.001948	0.002176	0.001273
	(0.002051)	(0.002116)	(0.002308)	(0.002640)	(0.001354)
Quality-adjusted unit value					
Rice	0.000075*	0.000013	0.000123**	− 0.000181***	0.000079***
	(0.000045)	(0.000045)	(0.000049)	(0.000058)	(0.000030)

Table 2 (continued)

	Vulnerability	Poverty	Idiosyncratic risk	Aggregate risk	Unexplained risk
Wheat	0.000090*	0.000089*	0.000036	− 0.000055	0.000054*
	(0.000048)	(0.000046)	(0.000050)	(0.000062)	(0.000032)
Pulses	0.000032**	0.000006	0.000028	0.000236***	− 0.000237***
	(0.000016)	(0.000016)	(0.000018)	(0.000020)	(0.000010)
Employment: others					
Self-employed in non-agriculture	− 0.000547	0.001692*	− 0.001021	0.000741	− 0.000353
	(0.000925)	(0.000972)	(0.001059)	(0.001191)	(0.000611)
Agricultural labour	0.000257	0.001250	0.000480	0.000269	− 0.000846
	(0.000993)	(0.001040)	(0.001133)	(0.001278)	(0.000655)
Other labour	0.000856	0.001962*	-0.001336	0.003278**	-0.001920***
	(0.001024)	(0.001069)	(0.001166)	(0.001319)	(0.000676)
Self-employed in agriculture	− 0.000694	0.000748	− 0.001144	0.001211	− 0.000363
	(0.000973)	(0.001025)	(0.001117)	(0.001252)	(0.000642)
Reference group Social group: others					
Scheduled tribes	− 0.004113***	− 0.004356***	0.002253*	0.000705	− 0.001717**
	(0.001226)	(0.001246)	(0.001358)	(0.001578)	(0.000809)
Scheduled castes	0.001512*	0.000888	0.000811	− 0.000290	− 0.000326
	(0.000834)	(0.000881)	(0.000960)	(0.001073)	(0.000550)
Other backward classes	− 0.000184	− 0.000424	− 0.000597	0.001216	− 0.000322
	(0.000679)	(0.000717)	(0.000782)	(0.000874)	(0.000448)
Reference group: religion others					
Hindu	0.003982**	0.003266	0.002454	− 0.002327	− 0.000253
	(0.001941)	(0.002055)	(0.002240)	(0.002500)	(0.001283)
Muslim	0.005724***	0.004463**	0.004372*	− 0.003279	− 0.002145
	(0.002133)	(0.002258)	(0.002460)	(0.002747)	(0.001409)

Table 2 (continued)

	Vulnerability	Poverty	Idiosyncratic risk	Aggregate risk	Unexplained risk
Christian	0.004787	0.003747	0.000812	− 0.002575	− 0.000225
	(0.002923)	(0.002959)	(0.003225)	(0.003764)	(0.001932)
Reference group: gender male					
Female	0.000351	− 0.000363	0.000694	0.001371	− 0.001813**
	(0.001111)	(0.001188)	(0.001296)	(0.001430)	(0.000733)
Urbanization	0.018197***	0.016592***	0.017360***	− 0.015877***	− 0.001521
	(0.002323)	(0.002414)	(0.002631)	(0.002990)	(0.001533)
Constant	0.020664***	0.017861***	0.020559***	0.023439***	− 0.036580***
	(0.005287)	(0.005576)	(0.006078)	(0.006808)	(0.003493)
Observations	83,889	106,680	106,664	83,972	84,064
R-squared	0.060	0.042	0.040	0.036	0.083

explanation for the same is that backward communities share more than the others; forward castes are more individualistic (Jeffrey 2001). Those belonging to the forward communities are increasingly found to be family-centered and individualistic as against exhibiting caste-based social cohesion. Scheduled Caste as a community is found to exhibit greater social connectedness and cooperation (Grootaert and Van Bastelar 2002). Similarly, results hold good for religious groups. Moreover, compared to the minority religious groups the Hindus, Muslims, and Christians are more vulnerable to food insecurity in rural India. This may be due to the individualistic nature of the forward social and religious groups. It is well documented in the literature on caste discrimination observed in the rural labor market in India (Ito 2009; Thorat and Neuman 2012). This implies that backward communities will tend to form their groups or communities to enter the labor market and resort to community support in times of crisis. The homophily theory suggests that individuals belonging to the same caste or religion will refer to or promote each other (Kmec 2007). However, this breaks down for highly educated individuals and bigger workplaces which is dominated by the educated upper castes (Stainback 2008). Another evidence in support of the individualistic nature of the forward castes is that by Deshpande (2000) whereby inequality is much higher among the upper castes than among the Scheduled Castes/Tribes. Suryanarayana and Das (2014) find similar results whereby the sub-group inclusion coefficient, which is a measure of the extent of inclusivity, is more for the Scheduled Caste and Tribes than that of the Others category. Moreover, the poor performance of the Others category can be that they are primarily housed in urban regions. The Scheduled Castes are evenly spread across rural and urban region and the Scheduled Tribes are mainly concentrated in the rural regions (Chandramouli and General 2011). Those residing in urban regions are more susceptible to food price shocks and have lower access to a variety of food items as compared to the rural counterparts (Satterthwaite et al. 2010; Mahajan et al. 2015; Azeem et al. 2017). Also, Scheduled Caste and Scheduled Tribes are the major small-size landholders in rural India (Dev 2012). In fact, small size landholders in rural India are more vulnerable to overall shocks as compared to large-size farm holders, but are more resilient (adaptive and quick recovery from shocks) than the large-size owners (Kumar et al. 2020). Therefore, even though both rural and urban India combined the Others category, and Hindus fare better in terms of income, education, and health-related outcomes (Desai and Dubey 2012) they are more vulnerable to food insecurity in the rural regions. Additionally, this finding can be linked to the broader discussion on what comprises social capital, and how it has enhanced the well-being of communities over time (Grootaert and Van Bastelar 2002). Building horizontal networks and reaping the benefits of social capital for example for availing credit is a well-known strategy for reducing stress during periods of crises (Gordon et al. 2001). Misselhorn (2009) finds that lower levels of social capital are associated with heightened levels of food insecurity in smaller communities in KwaZulu-Natal, South Africa. Sseguya et al. (2018) also find similar results for Uganda. Both studies recommend the inclusion of a measure of social capital in vulnerability and food security analysis. Also, fostering social capital alone is not enough to address food insecurity related problems. Education both acquired through formal and informal channels are important to facilitate the buildup of social capital. Future studies should explore such linkages for India and other countries in the sub-continent.

Female-headed households are more vulnerable to food insecurity across years as compared to male-headed ones. Whether the household head or any woman member faces a greater burden of any kind of threat or shock afflicting mainly poor households (Agarwal 1990). Kassie et al. (2014) also find female-headed households with a higher level of food insecurity. As discussed above social capital and access to credit are again found to be

important factors in reducing gendered inequality in food security outcomes (Kassie et al. 2014; Modirwa and Oladele 2017; Sileshi et al. 2019b).

Next, an interesting finding is that with an increase in the level of urbanization in a state-region, there is a rise in the extent of vulnerability to food insecurity for rural households. The reason for this may be that urban people do not produce for their consumption. The individual urban demands from the market are more susceptible to price variation (Mahajan et al. 2015). In periods of crisis, pandemics, etc. farmers cannot sell their produce to the fullest due to disruption in the supply chain, loss of harvest due to lack of storage facilities, etc. (World Bank 2020). This leads to a fall in income for rural households and vulnerable to food insecurity. Tarasuk et al. (2019) find income to be an important factor rendering Canadian households vulnerable to food insecurity. Additionally, this augments the lack of micronutrients in the diet (Harris 2020). The importance of vegetables as a vital source of nutrients is well established in the literature (Harris 2020). Vegetables are usually consumed close to locations where it is produced. During crisis periods transportation of perishable vegetable production is difficult and negatively impact both the producers (loss in production and sales, reduced income leading to reduced consumption), and buyers (highly elastic demand, reduced consumption due to lower availability, and higher price of available produce) (Harris 2020). Migrant rural households and dwellers of cyclone-prone areas may also suffer during periods of crisis due to lesser income, fall in availability of food items, and thus reduced or minimal food consumption. A similar finding is by Tawodzera (2011) for Harare in Zimbabwe. Urban Harare is inflicted by high rates of unemployment and poverty, dependency ratio, rising inflation of commodities in general and food items, low property ownership, and collapsing food system which explains the high vulnerability to food insecurity of the urban poor. Understanding urban governance and urban food systems is a topic of growing interest (Smit 2016), and intertwined with rural food policymaking. Further research by urban food policymakers in India should explore such governance and food security related issues which will also benefit the agricultural households.

According to the LS decomposition exercise, the study finds that idiosyncratic risk outweighs the impact of poverty and aggregate risks. The loss in total utility derived from consuming a diverse diet due to idiosyncratic risks is almost 51%. Additionally, a Gini decomposition exercise is conducted (Lerman and Yitzhaki 1985; Stark et al. 1988; López-Feldman 2006) to identify the main component rendering households vulnerable to food insecurity. According to both the exercises idiosyncratic risks or the individual or household-specific shocks are found to be the most important. Additionally, the magnitude of unexplained risk is much larger than that of aggregate, poverty, and idiosyncratic risk. Measurement error remains in any kind of pseudo-panel analysis (Fields and Viollaz 2013). This can also probably explain the higher magnitude of unexplained risk other than the ones discussed in Sect. 5. Azeem et al. (2017) also find idiosyncratic shocks to push households into the state of vulnerability to food insecurity as compared to covariate or aggregate shocks in the province of Punjab in Pakistan.

Next, the coefficient of variation of the level of vulnerability across different state-regions over the three rounds of the survey is computed using the two different methodologies. The first involves the construction of the coefficient of variation by dividing the mean level of vulnerability by the standard deviation across different state-regions and then taking the absolute value of the same. The second methodology involves considering the level of vulnerability to be zero for those households whose measure of vulnerability is negative. It implies that households who face no risk at all are excluded. Next, the coefficient of variation across state-regions is computed using the same procedure. According

to the first methodology, the coefficient of variation is lowest for state-regions in the states of Kerala, Punjab, Bihar, Madhya Pradesh, Orissa, and Andhra Pradesh. It is the highest for state-regions in most of the state-regions for Maharashtra and West Bengal. According to the second methodology, the lowest coefficient of variation is observed in the state-regions of Punjab and Kerala. It is highest for most of the state-regions in the states of West Bengal and Rajasthan. Therefore, the worse off states are West Bengal and Rajasthan, and the better off ones are the states of Kerala and Punjab. West Bengal ranked highest with more than three million farmer households with indebtedness of 50% or more, Rajasthan (two million), and Kerala and Punjab around 2.5 million indebted farmers in 2003 (GoI 2006a). Kerala and Punjab are also the high-income states, with a high inflow of foreign remittance, but still suffering from the triple burden of malnutrition (Das 2014). The box plots of the coefficient of variation over the three rounds of the NSS survey is constructed. The distribution for all three rounds is positively skewed with very few outliers. Overall, the findings are in line with the study of Dang and Lanjouw (2018) that conceptualizes a series of vulnerability lines for identifying the poor, middle class, or secure, and the vulnerable to poverty. The key finding is that the share of the vulnerable to poverty for India remains stable over time. The share of the food poor as identified using calorie intake cut-offs is larger than the poor in India (Suryanarayana and Silva 2007). Studies find that the proportion of the population consuming a diverse diet is low but rising (Das 2014). Thus, there remains a

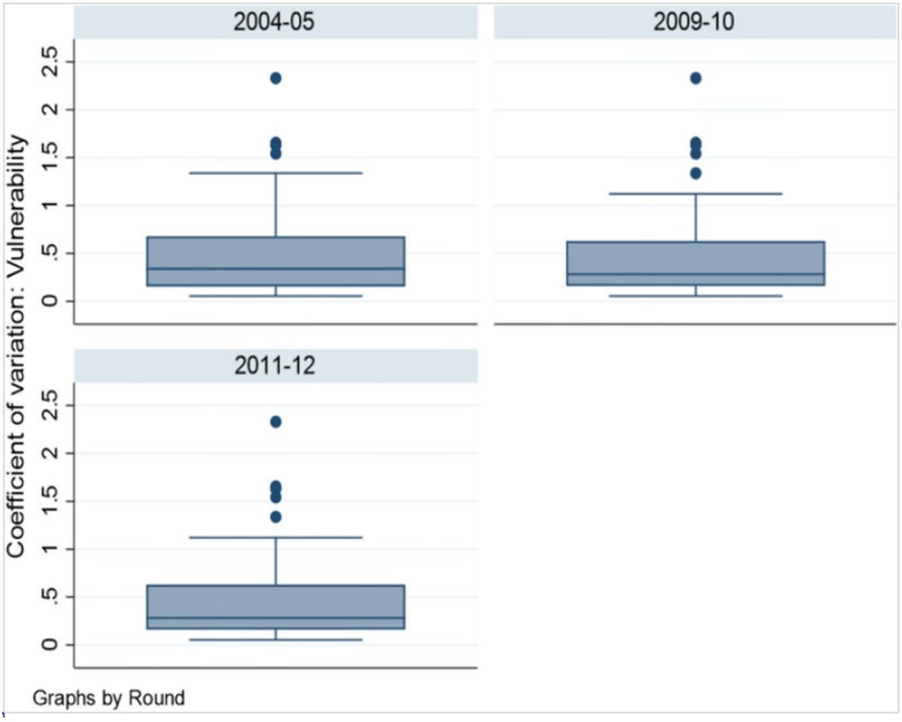

Fig. 2 Coefficient of variation: Vulnerability to food insecurity, Rural India across years. Source: Author's computation

large chunk of the population who are vulnerable to food insecurity as identified using diet diversity measures, and attributable to a variety of factors as discussed (Fig. 2).

One minor limitation of the LS methodology is that households may adopt an income smoothing approach, not due to risks faced, but because they chose to do so. This may happen in case the household's income is not insured. In such a case income poverty is due to the uninsured component of risk (Ligon 2010). This can be improved by using the methodology developed by Elbers and Gunning (2003). It is a stochastic dynamic model with the simulation of household income under different situations. However, it would strictly require household-level panel data. More information needs to be collected on the type of shock, impacts, type of risk, and coping strategies adopted which may be very challenging, and not readily collectible. For example, coping strategies could include: (i) dietary change: changing the diet and buying less expensive and less preferred food items, limit the portion of meals or reducing the number of meals taken; (ii) food seeking: borrow food or money to increase the amount of food available in the short-term; (iii) household structure: decrease the number of people to be fed in the short-term; earning members and growing children are fed more; and (iv) rationing: decreasing consumption of street food (Maxwell et al. 1999).

6.1 Policy Relevance

Given the vulnerability assessment, the paper delves into the question if the states with a lower loss in utility due to vulnerability witnessed successful implementation of the Public Distribution System (PDS), consumption of a diverse diet, and nutritional status.[13] As compared to 2004–05 the amount of purchase of food grains from PDS and share of consumption from PDS to total food grains consumed remained at almost the same level in 2011–12. This implies that overall for all of India the level of vulnerability remained stable, an indication that food security programs have had a minimal role to play in reducing vulnerability to food insecurity. Recent digital innovations in the space of food security and agriculture have helped mitigate some of the challenges related to efficient public service delivery in times of crisis or otherwise. Regional and detailed evaluation studies can provide a better understanding. The findings in this paper are discussed in light of the earlier existing systems and learnings from the same. This paper also provides a solid economic background to the evaluation of recent schemes adopted by linking vulnerability estimates with the proportion, and pre and post-crisis welfare levels of beneficiaries.

Gujarat was one of the states with a fall in consumption from PDS, households consuming a diverse and varied diet due to greater purchasing power (Das 2014). Additionally, households are quite vulnerable to shocks, probably due to a series of calamities (pandemics and natural disasters) that the state has faced (Mwinjaka et al. 2010). An increase in consumption from the PDS in the states of Karnataka and Tamil Nadu was more than double of that in the more vulnerable regions of Assam and West Bengal. All state-regions of Karnataka consume a diverse diet and nutritionally better off. This is commensurate with the fact that the eastern states perform worse concerning food insecurity, and despite the increase in consumption from PDS, there is not much impact on the reduction in the level of food insecurity let alone vulnerability to food insecurity. Kerala and Punjab remain the

[13] Information on PDS is obtained from the NSS consumption expenditure survey for different rounds as discussed earlier in the data section.

best performers in terms of vulnerability to food insecurity and the functioning of PDS. However, Punjab performs poorly in terms of consuming a diverse diet (Das 2014), and along with Kerala house the obese population (GoI 2006b). Orissa performs better as compared to most of the eastern states both in terms of consumption from the PDS and lower level of vulnerability. Low-income eastern states are the major agricultural regions, along with Punjab and Haryana but the former comprises a greater number of small-scale farmers (Birthal et al. 2011; Dev 2012). Small-scale farmers are more vulnerable to shocks, and thus these states perform poorly. Poorer districts in Orissa and Maharashtra also persist to consume a cereal major diet and remain burdened with the double burden of malnutrition (Nithya and Bhavani 2018). Reduction in the rates of malnourishment is observed across the country (GoI 2016) but remains high for states highly vulnerable to food insecurity like the eastern states of the country. The empirical estimation corroborates this.

Based on our findings an immediate policy prescription would be to devise a mix of cash vs in-kind transfers. Vulnerable regions should be given cash transfers to lift themselves out of the poverty zone. It may act as immediate insurance say sudden death of the earning member of the family, epidemic, natural calamity, etc. Given that idiosyncratic shocks (individual or household-specific) contribute more to determining the extent of vulnerability to food insecurity, cash transfers will work better in such cases. Locations, where the households are perennially in poverty and vulnerable to food insecurity should strengthen the PDS/in-kind transfer system further to permanently lift these households out of destitution also suggested by Muralidharan et al. (2011). However, an in-depth region-specific analysis will help us better construct such a mixed strategy in times of crisis or no crisis, and possibly with time for every household. Solid evaluation studies are also called for. The findings of the paper are in line with that of Sabates-Wheeler and Devereux (2010) and Zhang et al. (2020) who study the beneficial impact of Ethiopia's Productive Safety Net Programme (PSNP) and New Rural Pension Scheme in rural China respectively. The first study finds a positive impact of food only and mixed schemes (cash and food) to eliminate food insecurity and improve livelihood status as compared to cash only schemes which are marred during inflationary periods. Vulnerability to food insecurity improves for the rural elderly beneficiaries in China availing social pensions.

7 Concluding Remarks

The lack of household-level panel data for India is a major hindrance for analyzing vulnerability at the household level. Hence, given the data limitations, state-region level conclusions can be drawn. This paper provides new evidence on vulnerability to food insecurity using the expected utility approach. Idiosyncratic risk is the largest driver as compared to the poverty and covariate shocks; states with poor PDS performance are more susceptible; a rise in the price of staple food items increases the chances of food insecurity; gendered disparity persists over time, and finally a higher level of urbanization fuels the occurrence of both uncertain events, and exposure to shocks for rural households. The key policy suggestion is a mix of cash vs in-kind transfers. In recent times such strategies are found to be globally very effective (NCAER 2020; World Bank 2020).

High growth and income-generating programs may not always reduce vulnerabilities. A mix of safety net, insurance, and social protection strategies is important for improving the resiliency of households. These schemes and strategies help reduce horizontal inequality

and overall inequality in society (Brzeska et al. 2015; Tarasuk et al. 2019; IFPRI 2020; Zhang et al. 2020). Additionally, focus on vulnerability and risk assessment mapping at the lowest level of administration, if possible at the household-level is required. The mapping exercise should also involve the identification of contributing factors to vulnerability at the global, regional, and household levels. This is very crucial for the successful design and implementation of sustainable food and nutrition policies. Moreover, resilient policies and resilient households are what policymakers should aim for (Béné et al. 2016). A combination of the salient features of micro-finance, health, insurance, and work-related programs needs to be imbibed in the social protection strategies for the food poor to be more resilient. Nevertheless, future studies should investigate these aspects by building on broader concepts of resiliency, and preferably using a longer panel dataset.

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