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Measuring regional differences in food security from access and stability dimensions: A methodological proposal based on elasticities

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Abstract: One constraint when dealing with food security problems is the absence of measurement tools that allow for mitigation strategies to be targeted on each region individually. The elasticities can be used as a good exploratory instrument of food security. This paper presents a proposal for measuring the food insecurity dimensions of access and stability, integrating the values of the different kinds of elasticities. The methodology was applied to Spain, using data from nine groups of protein-rich foods of animal origin during the 2004–2015 period in 17 regions. The results suggest that, as regards foods rich in animal proteins, Navarra and Galicia are the regions with the highest food insecurity, and pork meat is the most insecure food product. Comparisons can be carried out between and within regions.

Keywords: agricultural economics; applied economics; consumer theory; econometrics

For more than forty years, food security has been an important research topic since malnutrition and hunger are problems that limit the economic and social development of a country. As the number of undernourished worldwide stands at 795 million (FAO, IFAD and WFP 2015), food security remains a relevant issue that requires to be studied (Candel 2014).

One of the major challenges for researchers has been how to measure food security (Jones et al. 2013), and one limitation when assessing food security is that of choosing the measurement strategy. It can be explained by the wide variety and number of food security definitions that are due to the fact that its causes and consequences can be understood in various ways (Hendriks 2015). This has led to a large number of measurement strategies (Masset 2011) which do not take into account all the dimensions of food security such as access, use and stability, availability and utilization (Maxwell et al. 2013). The results obtained from these measurements differ depending on the methodology used (Barrett 2010) and are not comparable, thus becoming a source of confusion because they do not have the analytic foundations to establish their empirical validity as food security measures (Cafiero et al. 2014); do not include new variables that are affecting food security such as the volatility of food prices and the climate change (Headey and Ecker 2013); or, in some cases, include variables conceptually hard to analyze such as the dietary diversity indices (Coates 2013).

In general, availability, access, utilization, and stability are the dimensions widely accepted to measure

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food security; however, it can be considered that stability cuts across the first three (Coates 2013). The dimensions of access and stability have been considered the ones with greater impact. Access is related to the situation in which people have enough economic resources to get a proper nutrition, and stability is a situation in which they should not run the risk of being left without access to food as a result of sudden crises – economic and/or climatic – or cyclical events (Kang 2015). Higher food prices cause budget shocks that reduce the real income of families (Emery et al. 2012), decreasing the amount of food purchased (Naylor and Falcon 2010) and affecting consumer preferences and the ability to decide on the food to be consumed (García-Germán et al. 2018).

Different economic tools have been proposed to describe the relationship between income, prices, and consumption, elasticity being one of them (Nicholson and Snyder 2009). Measuring food elasticities permits the determination of consumer sensitivity when there are changes in food prices (Andreyeva et al. 2010; Green et al. 2013). Elasticities can also be useful to determine the distributional impacts caused by changes in price and income (Lundberg and Lundberg 2012).

One aspect to take into account when implementing strategies to counteract the effects of food insecurity generated by changes in food prices is a necessity to identify in advance which regions or population groups are the most vulnerable to these changes and, in this way, to propose coping mechanisms (Barrett 2002). Motivated by the need to find new methodologies for measuring food security, the aim of this article is to propose a new methodology for measuring regional differences in food security, using an *ex ante* regional food insecurity indicator constructed from price and expenditure elasticities that allows for establishing how consumers could see their access to food affected, and how they would alter their patterns of food consumption, in case of sudden changes in food prices.

To test the methodology, it was applied to 17 regions (NUTS2[1]) in Spain during the period 2004–2015 by using expenditure and price data for nine groups of animal proteins.

MATERIAL AND METHODS

Data. Detailed data on food purchases was used from the Spanish National Statistics Institute (NSI 2016), corresponding to the Panel of Household Food Consumption in Spain that has a sample of 8 000 households and records of their daily food purchases. In the present study, quarterly records over a twelve-year period (2004–2015) were used for 9 food groups in 17 Spanish regions. Each group comprises a pre-established set of foods and information on total volume, total expenditure, and average price, with a sample size of 7 038 records. The products were selected on the basis of their protein contents since proteins from sources such as eggs, milk, meat, poultry, and fish have a high nutritional value (Ariño et al. 2013; Day 2016) and this type of products represents around 45% of total food expenditure in Spain for the study period (Figure 1).

Methodology for assessing food security. The proposed methodology can be broken down into two stages; in the first, the different types of elasticities (cross, own-price, and expenditure) are estimated for the assessed regions by using an Almost Ideal Demand System Model (AIDS). Subsequently, the food insecurity indicator is constructed from those results.

Almost Ideal Demand System. Demand models allow for the identification of some market characteristics related to prices and the consumed quantity of specific goods in order to describe consumer performance. The AIDS model is one of the most commonly used demand analysis models. It was proposed by Deaton and Muellbauer (1980) as a method for estimating cross, own-price, and income elasticities. The AIDS is usually specified as:

$$w_i = \alpha_i + \sum_j \gamma_{ij} \ln p_j + \beta_i \ln\left(\frac{x}{P}\right) \quad (1)$$

where: w_i – expenditure share of the i^{th} good with respect to the total expenditure; p_j – prices of the goods, x – total expenditure; intercept α_i – individual effects; β_i – expenditure elasticities; γ_{ij} – cross and own-price elasticities; P – translog price index defined by Equation (2).

$$\ln(P) = \alpha_0 + \sum_j \alpha_j \ln p_j + \frac{1}{2}\sum_j \sum_i \ln P_i \ln P_j \quad (2)$$

The model is considered a good first-order approximation to a general relationship on w_i, $\ln(x)$ and $\ln(P_j)$, and this satisfies the properties of the additivity, symmetry and homogeneity of the demand theory. The symmetry establishes that $\gamma_{ij} = \gamma_{ji} \ \forall\ i \neq j$, homogeneity $\sum_{i=1}^{n} \gamma_{ij} = 0$, and the additivity implies that $\sum_{i=1}^{n} \alpha_i = 1, \sum_{i=1}^{n} \beta_i = 0$ (Benda and Hanova 2016).

Due to the empirical difficulties in the estimation of P using Equation (2) (Green and Alston 1990), it can

[1]Nomenclature of territorial units for statistics by autonomous communities and cities.

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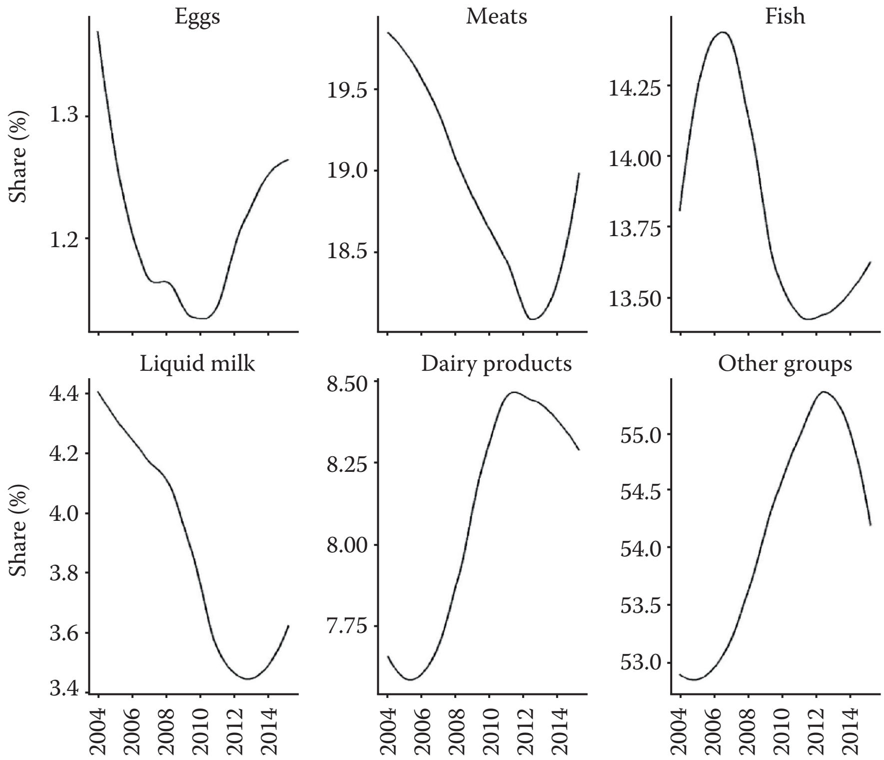

Figure 1. Percentage share of expenditure in some groups of animal proteins foods in Spain (2004–2015)

Source: Author´s processing based on Panel of household food consumption in Spain database (NSI 2016)

be replaced by the Stone Price Index to obtain a linear demand system (LAIDS) models:

$$\ln(P) = \sum_{i=1}^{n} w_i \ln(p_i) \quad (3)$$

Although this new index is not invariant to changes in the units of price measurement, this problem can be solved using the Paasche Price Index and the loglinear analogue of the Laspeyres Price Index (Moschini 1995):

$$\ln(P^S) = \sum_{i=1}^{n} w_i \ln(\frac{p_i}{p_i^0}) \quad (4)$$

where: the upper case 0 for P_i defines the base period for the estimation; for the purposes of elasticity estimation, the micEconAids package for R (Henningsen 2015) was used.

The cross-price elasticity is a measurement of the percentage change in the demand for a good due to a percentage change in the price of another good. The cross-price elasticities from the AIDS model allow for the determination of whether a good is a substitute or complement. If its sign is negative, then the increase in price of one good leads to a fall in the demand for another and the goods are complements. On the contrary, if the sign is positive, an increase in the price of one good leads to a rise in demand for another one and the goods are substitutes.

On the other hand, the own-price elasticity is a measurement of the percentage change in the demand for a good resulting from a percentage change in the price of the good itself. The law of demand establishes that when the price of a good increases, in most cases the demand for it falls, implying that the sign of elasticity would be negative. However, it is important to analyze the differences in magnitude of the own-price elasticities because they allow for establishing the sensitivity of consumption to changes in prices. Therefore, if the elasticity value is higher than 1, the good has an elastic demand (high sensitivity), and if it falls to between 0 and 1, the demand is inelastic (low sensitivity).

The expenditure elasticity lets us detect how a change in income affects the demand for a good. The sign and magnitude are important because they permit the goods to be classified into different categories: (i) if the value is between 0 and 1, the good is a necessity; (ii) if the value is lower than 0, the good is inferior; and (iii) if the value is above 1, the good is a luxury (Hubbard and O´Brien 2013).

Food Insecurity Index. Three aspects inherent to elasticities can serve as a basis for constructing an instrument to measure food insecurity. First, the fact that a set of goods is complementary implies that increasing the price of one good can result in a drop in the

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demand for the other goods and can thus be considered as risky for food security; second, if a product has an own-price elasticity in the [–1,0] interval, this implies lower availability of close substitutes; therefore, in this case, if the price of that product rises, the demand will decrease slightly and the consumers will have few alternative foods they can buy instead; and third, if the expenditure elasticities are high (>1), in case of a reduction in income the consumption of that good will fall greatly with respect to a normal or an inferior good[2].

Taking these three aspects and the results from the elasticities into account, it is possible to construct an *ex ante* Food Insecurity Index (*FII*) for the dimensions of access and stability, which allows us to determine the risk of being in a situation of food insecurity when faced with sudden food price increases and/or income reduction. The *FII* is a composite index and it has three related components: the Cross-Price Food Insecurity Index, the Own-Price Food Insecurity Index, and the Expenditure Food Insecurity Index. This index enables us to define a food insecurity scale by type of food in a specific region. The first component of the *FII* is the Cross-Price Food Insecurity Index (*CPFII*), which is defined as:

$$CPFII_i = \frac{CCPE_i}{TCPE_i} \quad (5)$$

where: $CPFII_i$ – Cross-Price Food Insecurity Index for food *i* in *k* regions, which is the fraction of foods, related to food *i,* that are classified as complementary goods in *k* regions; $CCPE_i$ – Cross-Complementary Price Elasticities, it is based on the cross-price elasticity, it measures the total number of foods that are classified as complementary goods with food *i* in *k* regions, that is, whose cross-price elasticity is negative; $TCPE_i$ – Total Cross Price Elasticities, it is based on the cross-price elasticity, it measures the total number of foods related to food *i* in *k* regions.

The result for the $CPFII_i$ is expressed as a number in the [0,1] interval, 0 being the lowest level of food insecurity and 1 the highest. A value of 1 implies that all foods related to food *i* are complementary; thus, when faced with a situation in which the price of food *i* increases, there will be a reduction in the amount consumed of all the foods related to food *i*, which implies a high risk for access and stability in the consumption of these foods. On the other hand, if the value is 0, it means that no food is considered as complementary with food *i*; hence, an increase in the price of food *i* will not result in a reduction in consumption of other related foods, implying a low risk.

The second component is the Own-Price Food Insecurity Index ($OPFII_i$) for food *i* in *k* regions which is defined as:

$$OPFII_i = \frac{OIPE_i}{TOPE_i} \quad (6)$$

where: $OIPE_i$ – Own Inelastic Price Elasticities, it is based on the own-price elasticity, it measures the number of own-price elasticities for a product *i* in *k* regions whose value is in the (–1,0) interval (inelastic demand); $TOPE_i$ – Total Own Price Elasticities, it is also based on the own-price elasticity, and measures the total number of own-price elasticities for a food *i* in *k* regions[3].

The result of the $OPFII_i$ is also expressed as a number in the [0, 1] interval, 0 being the value that would indicate the lowest level of food insecurity for this component, and 1 the highest. A value of 1 implies that food *i* has an inelastic demand in *k* regions; therefore, when faced with a situation in which the price of food *i* increases, there will be a reduction in the demand for food *i* and the consumer will have few alternative foods to buy instead, which implies a high risk for access and stability in consumption. On the other hand, if the value is equal to 0, this means that in the event that the consumer reduces the consumption of food *i,* it can be replaced by other foods, and, therefore, there will be a low risk.

The third component is the Expenditure Food Insecurity Index for food *i* in *k* regions ($EFII_i$), which is related to the expenditure elasticities and is defined as:

$$EFII_i = \frac{LEE_i}{TEE_i} \quad (7)$$

where: LEE_i – Luxury Expenditure Elasticities, it is based on the expenditure elasticity, it measures the number of times that food *i* behaves like a luxury good in *k* regions, that is, the expenditure elasticity is in the $(1,+\infty)$ interval; TEE_i – Total Expenditure Elasticities, it is also based on the expenditure elasticity, it measures the total number of expenditure elasticities for food *i* in *k* regions.

The result for $EFII_i$ is expressed as a number in the [0,1] interval, 0 indicating the lowest level of food insecurity for this component, and 1 the highest. A value of 1 implies that food *i* is a luxury good in *k* regions;

[2]Using the concepts of Shepard's Lemma, Roy's identity and the Slutsky equation, it is possible to say that expenditure is the same as income in the consumer model (Nechyba 2010).

[3]In case of only one region (k = 1), the maximum value for *OIPE* and *TOPE* is the same.

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thus, in the event that the consumer income decreases, the consumption of food i will fall more than the income, which implies a high risk for access and stability in consumption. If the $EFII$ is 0, i is a necessity good; this implies that despite the reduction in consumer consumption of food i, the proportion of the in k regions will be smaller than that of the drop in the income, implying a low risk.

Finally, the Food Insecurity Index for food i in k regions (FII_i) is the measurement of the arithmetic mean of the three individual indices:

$$FII_i = \alpha CPFII_i + \beta OPFII_i + \gamma EFII_i \quad (8)$$

where: α, β, and γ are the weights for each component.

Due to the subjectivity involved in assigning weights, in this case study the FII_i has been equally weighted. Using similar weights in the three components of the FII implies giving the same importance to complementarity, substitutability, and changes in the personal income. However, the components could be weighted in a different way depending on the focus of the research by using other complementary techniques. The range for the FII will be in the [0,1] interval, 1 being the maximum food insecurity level and 0 the minimum. If there are $i = 1, \ldots, n$ foods in k regions, we can estimate $k(n + 1)n$ elasticities of which $k(n - 1)n$ will be cross-price elasticities, and the number, kn, of own-price and expenditure elasticities will be the same.

RESULTS AND DISCUSSION

Elasticities. Table S1 summarizes the price and expenditure elasticities for the nine food groups in the 17 Spanish regions [Table S1 in electronic supplementary material (ESM); for the supplementary material see the electronic version]. The final column shows the expenditure elasticities, the diagonal results are the own price elasticities, and the rest are cross-price elasticities. The elasticity results exhibit a high degree of heterogeneity, and it is difficult to find a common pattern between products and/or regions. In particular, some similarities with other studies in Spain are found for the results for pork, chicken, eggs, and fish groups (Lasarte et al. 2014; García-Muros et al. 2017), mainly in the sign of the own-price and expenditure elasticities.

In particular, 74% of own-price elasticities results show negative values (50% elastic, 24% inelastic). For example, dairy products have an elastic demand in Cataluña and Galicia, while it is inelastic in Extremadura and La Rioja. The remaining values have positive signs, implying that these foods can be classified as giffen goods (Nechyba 2010). As to the cross-price elasticities, there are differences in signs and values which make it possible to distinguish different relationships between pairs of foods (substitutability and complementarity). 59% of relationships are of complementarity and the rest of substitutability. For example, chicken is a substitute of dairy products and eggs in Canarias, whereas it is complementary with these same products in Cantabria.

The results of the expenditure elasticities enable us to identify the nature of the food items, classifying the foods as necessity, luxury, or normal. Under this scheme, it is possible to observe that in most regions the different kinds of meat (turkey, beef, sheep, pork, and chicken) are classified as a luxury goods, whereas the remaining products are considered as inferior or necessities.

Food Insecurity Index. The FII results for each Spanish region (k = 1) and the whole country (k = 17 regions), estimated from the results of Table S1, are shown in Table S2 [Tables S1–S2 in electronic supplementary material (ESM); for the supplementary material see the electronic version]. It can be observed that pork and sheep meat are the main contributors to the FII, whereas the contributions of eggs and dairy products are the lowest. It must be noted that individual contribution of products to the total FII is between 6.1% (dairy products) and 14.8% (pork). The Food Insecurity Index by region and product is shown in Figure 2.

At the country level, pork is the group that contributes the most to the FII (0.079), which can be explained by its high value in Baleares (0.108), Asturias (0.102), Canarias (0.100), and Castilla la Mancha (0.095) regions; whereas dairy products have the lowest value (0.032). In terms of individual regions, Navarra is the most insecure region (0.602) and Valencia the least insecure one (0.417); with beef being the most insecure product in Navarra (0.106) and the least insecure one in Valencia (0.023). It is not possible to find a pattern that clearly explains the differences between regions. For example, beef is the product that provides the highest contribution (% of total FII) in the regions of Navarra (17.6%) and Galicia (18.4%) while its contribution is lowest in Aragón (3.76%) and La Rioja (8.75%). Similarly, the fish group is the riskiest goup of products in Extremadura (23.5% of the total FII), and the least risky one in País Vasco (4.34%). Although the relationship between elasticities and food security has not been studied in Spain, some studies (Antentas and Vivas 2014; Ministry of Health, Consumption, and Social Services 2018) show an in-

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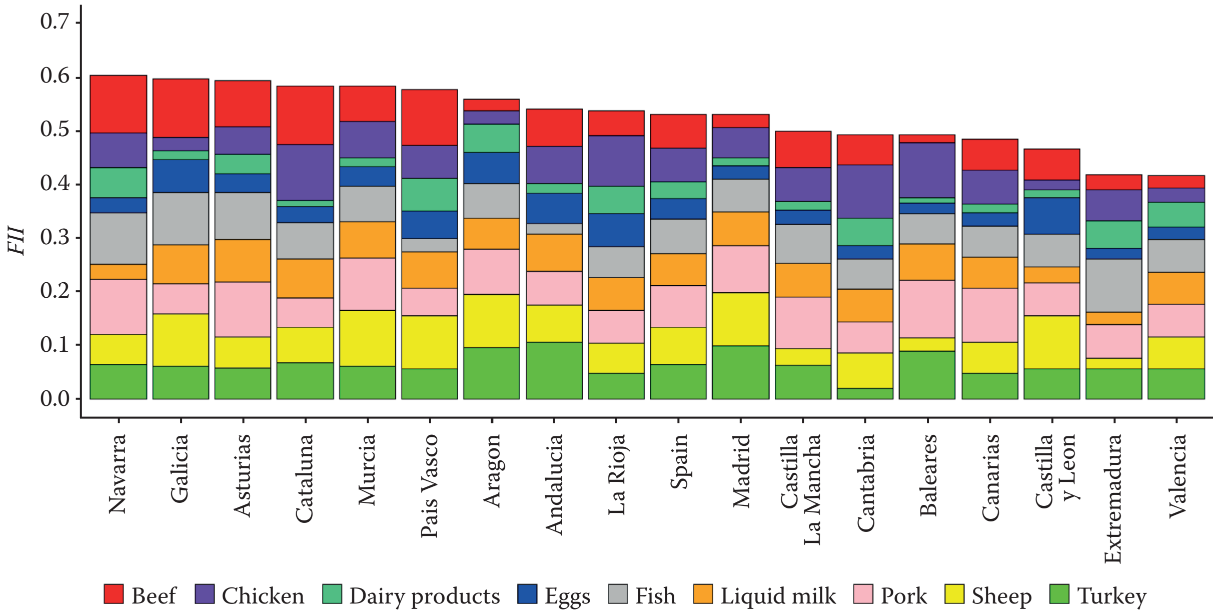

Figure 2. Food Insecurity Index (*FII*) by region and product

Source: Author´s processing based on Food Insecurity Index results from Table S2 [Table S2 in electronic supplementary material (ESM); for the supplementary material see the electronic version]

crease in food insecurity, partially explained by the reduction in access to foods such as beef and fish during the analysed period.

Analyses and proposals for public policy may arise from these results. The foods with a high *FII* in a specific region or group of regions should be considered a priority policy objective. In our case, the consumption of beef could remain stable in the presence of random shocks on prices or income in regions such as Navarra and Galicia through subsidies on these products or taxes on the remaining ones. The proposed methodology has a significant advantage when compared to those already developed because those measure the food security from the stability dimension using variables related to political stability, variability in food supply, the coefficient of variation of food prices and nutrients (Coates 2013; FAO, IFAD and WFP 2015); but neither of these methods directly analyses possible interactions that could exist between price changes and food consumption. Another advantage is its flexibility, because it permits to analyse different types of foods, and compare regions that may have different social or economic characteristics.

CONCLUSION

In this paper, a methodology to determine regional differences in terms of food security from the access and stability dimensions is proposed. The methodology is based on elasticities since they provide useful insights with which to analyze the reaction of food consumption to changes in food prices and income. The results could be considered an early warning sign with a twofold purpose: to determine how unexpected increases in food prices or reductions in the income level would negatively affect the consumption of some foods, and to establish in advance strategies that counteract this situation. In that sense, a low substitutability in the consumption of one food or the fact that many foods behave like luxury goods are a sign that a region can suffer an insecurity situation.

Despite the limitations in finding other elasticity results by region in Spain, this study shows similarities between the regional results of elasticities with the general results found in other studies for Spain as a whole, in the sign of the own price elasticities, and in the fact that beef and fish behave like luxury goods and foods as milk, eggs and some dairy products behave like a necessary good (Lasarte et al. 2014; García-Muros et al. 2017).

As the number of elasticities to be considered in the analysis can be quite high, building the food insecurity index makes it possible to establish a hierarchy of food insecurity either by product or by region, thus having a clearer idea of which kinds of foods or regions are the most exposed to problems of food insecurity.

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The *FII* can be estimated to establish food insecurity scales by food or regions and the results can be analyzed in different ways, since one of the advantages of the indicator is that it can be applied interchangeably to a preset number of regions, which can be defined arbitrarily beforehand, depending on the needs of the researcher.

The complementarity and substitutability effects calculated from elasticities can be useful in explaining the sources of change in *FII*, but there are some habits and actions that are not captured by the model. The results of the case study for the entire country show that *CPFII* and *OPFII* values may be effective in explaining the *FII* in pork and beef, whereas the expenditure component is the most important in case of sheep and turkey. These results can change from region to region depending on consumer habits. From a policy-making approach, the study shows that specific policies must be carried out on variables such as prices or income; but as is suggested for the case of Spain, real income improvement policies would seem to be the most effective in counteracting the negative impacts of sudden shocks in prices and/or income. In addition, some undesired effects of policies on the food consumption may arise, such as a bad nutrition; for example, a policy focused on subsidies on the beef consumption can be effective to counteract the negative impacts from a shock, but the nutritional quality of the diet might worsen in the long term. It must be kept in mind that reducing the food insecurity can be a national or regional challenge requiring collaboration between different disciplines (sociologists, economists, nutritionists) together with the implementation of political instruments so as to give different perspectives and provide new insights.

The results of *FII* can be compared with those from other regions, and with the individual evaluation of the *FII* components it would be possible to carry out a detailed analysis on how important price increases and income reductions are for the final result. The results of the *FII* can act as a guide to define a particular policy for each type of food and region, and a ranking of food security built from the *FII* results could be useful to prioritize public policy actions in terms of their execution time, region, and use of resources.

Finally, the results allow for comparisons to be made both between and within different regions, and the method may also be applied to any type of regional classification that could be provided by the analyst. The results obtained by applying the proposed methodology are suggestive and show that they can be used in advance as a public policy tool aimed at alleviating food security problems more efficiently in terms of resource allocation in regions that can be affected by food insecurity.

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