Food security and regional imbalances in Mexico

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Abstract

This paper seeks to analyze regional dimensions of food security as a development issue, and its geographic imbalances in Mexico. Through the application of principal component analysis, an index was developed at the municipal and regional level. In addition to combining information for different variables which are consolidated into a single measurement, this index numerically synthesizes three of the four dimensions with which the problem is measured: access, availability and biological utilization. Meanwhile, the Dalenius-Hodges stratification method was used to establish food security ranges at different regional scales. The results show that the socioeconomic and geographic inequalities caused by the development models historically applied in Mexico affect the population's internal food security throughout its regional areas.

Keywords: food security; agricultural policy; geographic inequalities; Municipal and Regional Food Security Index; principal component analysis.

1. INTRODUCTION[1]

The change in economic development model, from one based on the protection of the internal market and import substitution to another governed by trade liberalization, had an impact on Mexico's food security. Since the 1980s, the country has faced vulnerability and instability of supplies. However, given its conditions of social and geographical heterogeneity, the available diagnoses are incomplete—traditional measurements use national averages and do not consider regional indicators that allow for the evaluation of local performance as limiting the population's access to sufficient food.

Studies of food problems that involve a broad set of indicators such as Gross Domestic Product (GDP) per capita at the municipal and intermediary levels, production levels of basic grains and meats, child malnutrition based on the prevalence of short stature, or household appliances are almost non-existent at such scales. Accordingly, an analysis of food security from the regional perspective requires developing methodologies and constructing indicators with spatial representations, in order to examine the true magnitude of their effects under an asymmetrical economic development framework.

The goal, then, is to answer the question: why are inequalities in economic development expressed via food security disparities at the regional level, in unbalanced agri-food production environments?

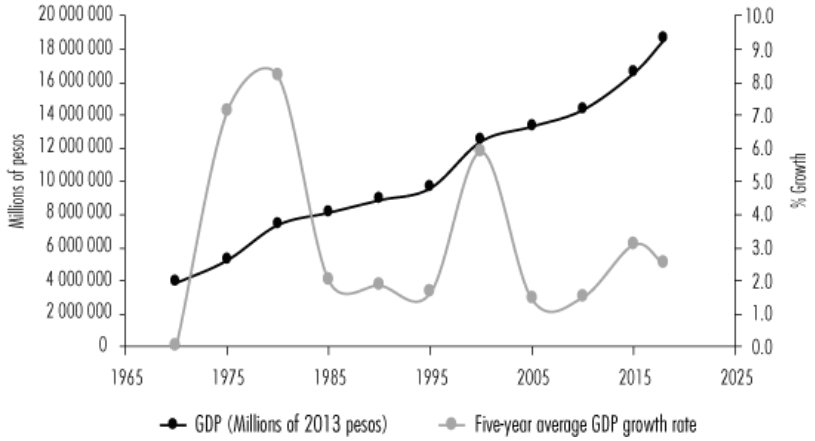
The hypothesis proposed here is that in Mexico, internal food security shows a gradual process of deterioration that is due both to the under-production of basic foodstuffs and to low levels of accessibility—resulting from losses in purchasing power, social inequality, and regional asymmetries in economic development. This situation reproduces food vulnerability in broader sectors of the population and geographical areas, in both rural and urban settings.

The present work is comprised of six sections, including this introduction. In the second section, the current food vulnerability experienced in Mexico is shown; its origins are explained by the inequalities and internal asymmetries generated by the open economy model. The third section presents various conceptual dimensions of food security. In the fourth section, the methodology and process for deriving indicators are described, along with the construction of a food security index, its ranges and its regional representation. The fifth section lays out the results in terms of the problem's analytical description and dimensions, and as they relate to the proposed hypothesis. Finally, the sixth section presents conclusions.

2. MEXICO'S FOOD VULNERABILITY AS A REFLECTION OF ECONOMIC DEVELOPMENT

Official data shows that from the 1990s until 2018, the GDP maintained an average annual growth rate of just 2.6%; without even considering that this is still declining, it is insufficient to strengthen the economy and achieve social well-being in a sustained way. Nor does this state of affairs help develop a dynamic where decreases in monetary resources are compensated for by any means other than adjusting public spending (see figure 1).

Figure 1. Mexico: performance of overall GDP, 1970-2018
(millions of 2013 pesos and % growth)



Note: the 2018 value was calculated by applying the average annual growth rate for the period of 1990-2017.
Source: prepared by the authors based on Sánchez (2018) and the Economic Databank (ED) of the National Institute of Statistics and Geography [Spanish acronym INEGI].

Twenty-five years after the implementation of NAFTA (now USMCA) and with more than three decades of the open economy process, the results in terms of food security are unfavorable. Negative balances include the loss of food self-sufficiency, as well as the increase in external dependence for the most consumed products, which are more sensitive to price increase cycles (Puyana and Romero, 2009; Torres, 2017).

During the 1993-2017 period, rice, corn, beans and wheat saw negative growth. Sorghum and soybeans—essential inputs for the production of meat, milk and eggs—underwent a similar situation, unlike fruits, vegetables and other so-called commercial products such as coffee or sugar cane that register positive growth, though they are not basic (Torres and Rojas, 2018).

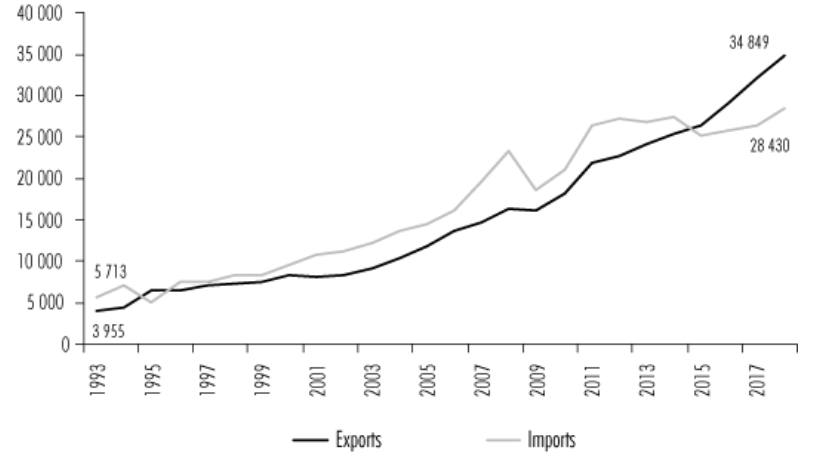
Purchasing food from abroad puts Mexico in a vulnerable situation, since domestic consumption is subject to both the internal production crisis and fluctuations in international prices. This problem has not been possible to correct with the downward trend cycle of international commodity prices, since they are subject to the growth capacity of the domestic economy in order to be acquired.

In the 1993-2018 period, total food exports reported a favorable shift in growth, rising from US$3.955 billion to US$34.849 billion; however, these figures represent an unreal situation, since they incorporate products such as beer and tequila. Total food imports showed a growing trend in the same period of analysis, rising from US$5.713 billion to US$28.43 billion, a situation which exacerbated external dependence and became an important factor in imbalances—in the economy, as well as for internal food security (see figure 2).

Mexico's external food dependency is more evident in products such as fresh or refrigerated meats, soybeans, barley and cotton, or in basic grains such as sorghum, wheat, corn, and beans. These products have seen important increases in value and volume, but their inertia has spread to areas such as beef, pork and eggs. Although the situation with fresh milk has seen relative improvement, milk powder occupies first place in dependence (Torres and Rojas, 2018).

Thus, during the last three decades, food importation has represented one of the biggest problems for food security because its growth reflects the negative orientation of internal production policies and the effect of fluctuations in international food prices. The increase in importation means transferring demand abroad, and constitutes a brake on the growth of the economy as a whole.

Figure 2. Mexico: performance of total food exports and imports, 1993-2018 (millions of dollars)



Source: prepared by the authors based on INEGI's ED.

The accumulated value of imports over the past 26 years exceeds US$433.988 billion; Mexico imports US$16.692 billion on average per year, which represents an impact on the external balance.

In 2017, the country depended on external food purchases for almost 40% of its consumption, and basic grains reached 30% of domestic consumption. A similar situation occurred with the purchase of pork and chicken meat, which increased by 16 and 11%, respectively, entailing that more than US$25 billion was designated to pay for food importation—therefore inhibiting the sector's developmental conditions and those of the economy as a whole (Torres and Rojas, 2018).

To reverse its vulnerability, Mexico must transform its economic policy by diversifying exports that reduce dependence, especially on the United States, and strengthening domestic production of basic grains. The state must increase credit and improve prices for small producers, strengthen investment in agricultural infrastructure, and design an agricultural policy that assumes food security as a basic condition for national security.

3. FOOD SECURITY, CONCEPTUAL DIMENSIONS

Food vulnerability worsens with the appearance of novel natural phenomena associated with climate change; the expansion of consumer markets like China and India; the control and manipulation of open access plant genetic resources by private actors; and the consolidation of futures markets and price control. Additionally, events such as the violent disputes in Middle Eastern countries that lead to massive exoduses of populations to Europe, and recently the caravans of Central American migrants to the United States, are conceptual challenges in locating new ways that economic developmental asymmetries manifest, and are especially complex when looking for ways to solve these problems on a regional scale.

This is because, among other reasons, food security assessments focus on averages that do not give all households equal importance, even though they are in the same range of vulnerability—nor do they take into account all of the regions which have lost the capacity to solve the problem at a local scale.

In this way, in the 1970s and 80s the conceptual debate on food security transcended the scope of multilateral organizations and world forums, to become a necessary element in policy formulation by governments around the world. This in turn allowed for the development of assessments that use a wealth of information.

The concept most widely disseminated by the Food and Agriculture Organization (FAO) of the United Nations regarding food security focuses on the general diagnosis of the problem by country. However, the scale of its scope remains a single goal, and its recommendations do not consider the structural factors that inhibit local economies' performance and which limit their possibility of achieving food security. In general, FAO assessment strategies are casuistic or conjectural.

According to the organization, food security refers to all people having access to a stable and nutritious diet that allows them to lead a healthy life at all times. It is comprised of four dimensions: access, availability, stability of supply and optimal biological utilization (FAO, 2009); however, it also includes the scope of supply, availability or stability of adequate food, lack of fluctuations or seasonal shortages, and the absence of restrictions on access to safe and good quality food caused by the financial inability to acquire them (Rouzaud, 2008).

The global food crisis of 2008 necessitated a new perspective, a multifactor analysis where food security could not be considered simply a safeguard of supply for its speculation, but as the need to achieve adequate distribution and accessibility of food that integrates forecasting methods, in order to counteract the effects of price volatility on vulnerable populations. Additionally, it would strengthen local agricultural structures which are integrated into economic policies permeated by a principle of food sovereignty at all levels (Torres, 2017).

Food security must incorporate this multifactorial-geographic perspective that serves to generate comprehensive assessments and respond to regional particularities, in addition to incorporating a methodology that measures regional dimensions as a structural problem of inequality originating in the imbalances generated by asymmetrical development—which affects increasingly larger population groups and impacts urban and rural areas in an undifferentiated manner.

4. METHODOLOGY FOR THE ASSESSMENT OF FOOD SECURITY: A STRUCTURAL PERSPECTIVE BASED ON REGIONAL ASYMMETRIES

Most food security assessments identify deficits in food production or inequalities in access as the causes of vulnerability. In the last 30 years, the Mexican government's strategies for the treatment of the problem have been framed as social policy, by way of targeted programs that seek to mitigate adverse effects caused by the economic development model—effects which affect the population's food conditions and produce marginalization and poverty.

Although support for assessments represents progress in the production of knowledge about the food security issue, by incorporating the criterion of poverty as measured by a lack of covering the Basic Food Basket (BFB), its spectrum is limited in conceptual and methodological terms, and it is insufficient to tackle food security with all of its implications. This is either because of the limitation of indicators or because assessments are based on averages that hide the particularities of urban areas, rural regions and social groups in terms of their local consumption patterns.

These limitations do not explain the importance they have for food vulnerability—the effect of an asymmetrically structured economic development that generates inequalities and inhibits capacities for regional and social responses. Measuring the scope of food security, with the assumption that it does not affect all individuals in a region equally, is necessary for a comprehensive diagnosis of the problem.

Most of the methodological proposals that support assessments are based on the traditional FAO conception. An example of this is the food insecurity evaluation developed by the FAO in the early 1970s, which combined indicators regarding food availability, accessibility and stability—although it temporarily and unsystematically added various others associated with natural disasters, social inequality, armed conflicts, and in recent years, quality, waste and health problems such as excess weight and obesity (FAO, 2016 and 2018).

Other proposals have emerged recently for the assessment and diagnosis of food security, such as the Global Index of Family Food Security (Morón and Schejtman, 1997), or the Global Food Security Index developed by the Economist Intelligence Unit (EIU and DuPont, 2017), which also include indicators that examine the extent of food security based on the prevalence of obesity and food waste factors. However, these use aggregate calculation scales that do not account for the conditions that prevail on smaller geographical scales.

Beyond the additional scales, the need arises to develop a methodology that allows an indicator to be developed that has greater spatial representation, and that reflects such vulnerability. It should take into account the complex recurrence of assessment factors, the difficulty of incorporating disaggregation, spatial dispersion-groupings within the same geographical area and the development of the concept associated with social complexity.

The proposal made here for measurement and assessment starts with the elaboration of a Municipal and Regional Food Security Index, using the Principal Component Analysis (PCA) method, which allows for the combination of information on various variables in a single measure that numerically synthesizes three of the four dimensions associated with food security: access, availability and biological utilization. The result involves the preparation of vulnerability maps for the entire Mexican territory using the Dalenius-Hodges stratification method, which can also be used for planning and evaluating food policy.

The present investigation analyzes the municipal and regional scales. The latter is based on the average regional level that has been used by State Development Schemes for the purpose of planning different activities for Mexican states, and which groups all of the municipalities into the 214 regions under consideration. Its usefulness lies in identifying rural and urban areas with high and low specialization and production levels, differentiating spaces with common or heterogeneous problems, and in knowing the magnitude of internal imbalances caused by economic developmental asymmetries. In short, it diagnoses the food security situation from a regional perspective.

To create the Municipal and Regional Food Security Index, indicators were selected that measure the regional food security situation, beyond national or state scales—since it must be developed according to the varying levels of human development on the regional scale, and in the context of economic development, as well as attending to three of the four previously mentioned dimensions proposed by the FAO.

Given that the analysis of food security must also be located within a multifactorial-geographic perspective, where multiple internal and external factors come together that undermine it and cause disparities in the territory, it is not possible to measure it with a single variable—less so when the analysis is spatial in nature. A consideration of this led to the selection of 13 indicators, which have disaggregated information available, by municipality and for the five temporal cross-sections (2000, 2005, 2010, 2015 and 2018). This allows for the analysis of changes in the food security situation using the index's behavior over time. In addition to the availability of information for the scale in question, another selection criterion was the fact that this period is at the apex of trade openness and the consolidation of the current development model, where food security presents a different dynamic as compared to previous decades.

Below, the method for calculating the indicators used to construct the index is presented. It should be noted that although the classification corresponds to the FAO proposal in terms of three out of its four dimensions, it primarily points to the possibilities for regional analysis (see tables 1, 2 and 3).

Table 1. Indicators of economic access to food

Name	*Operational definition*	*Unit of Measurement*	*Level of application*	*Information source*
Gross Domestic Product per capita	[Municipal GDP [a]/Municipal population]	Millions of constant 2008 pesos	Municipal	Sánchez (2018)
	GDP by Average Region / Population by Average Region]	Millions of constant 2008 pesos	Average Region	
Percentage of population in a situation of food poverty	[[People in food poverty[b] by municipality / Total population by municipality]*100	Percentage	Municipal	CONEVAL (2017)
	[People in food poverty by Average Region / Total population by Average Region]*100	Percentage	Average Region	INEGI (2015)

Notes: [a]Calculations come from Sánchez (2018); [b] 2000, 2005 and 2010 figures were taken from the food poverty variable of the income poverty methodology. The figure for 2015 corresponds to the variable "Population with income below the minimum welfare line" of the multidimensional poverty methodology.

Source: prepared by the authors.

Table 2. Indicators of food availability

Name	*Operational definition*	*Unit of measure-ment*	*Level of application*	*Information source*
Basic grain sufficiency percentage: rice, beans, corn, wheat	[Municipal Availability (production/population) /Municipal Consumption (consumption per capita*population)] * 100	Percentage	Municipal	Agri-Food and Fisheries Information System of the Ministry of Agriculture and Rural Development
	[Availability by Average Region (production/ population) / Consumption by Average Region (per capita consumption* population)] * 100	Percentage	Average region	INEGI (2000, 2005, 2010a, 2015)
Meat sufficiency percentage: beef, swine, poultry	[Municipal Availability (production/population) /Municipal Consumption (consumption per capita*population)] * 100	Percentage	Municipal	Agri-Food and Fisheries Information System of the Ministry of Agriculture and Rural Development
	[Availability by Average Region (production/ population) / Consumption by Average Region (per capita consumption* population)] * 100	Percentage	Average region	INEGI (2000, 2005, 2010a, 2015)

Source: prepared by the authors.

Table 3. Indicators of biological utilization of food

Name	*Operational definition*	*Unit of meas-urement*	*Level of application*	*Information source*
Percentage of short stature children in first year of primary school	Short stature $< 2\sigma$	Percentage[a]	Municipal	DIF-SEP-INCMNSZ (1994, 1997, 2004); DIF-SEP-SSA-INCMNSZ (2006); Ávila *et al.*(2016)[b]
	Short stature $< 2\sigma$	Percentage	Average region	INEGI (2000, 2005, 2010a, 2015)
Percentage of illiterate population 15 years old or older	[Illiterate population 15 years old or older by Munici-pality/Total population 15 years old or older by Mu-nicipality] * 100	Percentage	Municipal	INEGI (2000, 2005, 2010a, 2015)
	[Illiterate population 15 years old or older by Average Region/Total population 15 years old or older by Average Region] * 100	Percentage	Average region	INEGI (2000, 2005, 2010a, 2015)
Percentage of popula-tion entitled to IMSS health services	[Population entitled to IMSS health services by Municipality/Total population by Municipality] * 100	Percentage	Municipal	INEGI (2000, 2005, 2010a, 2015)
	[Population entitled to IMSS health services by Average Region/Total population by Average Region] * 100	Percentage	Average region	INEGI (2000, 2005, 2010a, 2015)
Percentage of homes with dirt floors	[Homes with dirt floors by Municipality/Total inhabit-ed private homes by Municipality] * 100	Percentage	Municipal	INEGI (2000, 2005, 2010a, 2015)
	[Homes with dirt floors by Average Region/Total inhabited private homes by Average Region] * 100	Percentage	Average region	INEGI (2000, 2005, 2010a, 2015)
Percentage of homes without drainage system	[Homes without drainage system by Municipali-ty/Total inhabited private homes by Municipality] * 100	Percentage	Municipal	INEGI (2000, 2005, 2010a, 2015)
	[Homes without drainage system by Average Re-gion/Total inhabited private homes by Average Region] * 100	Percentage	Average region	INEGI (2000, 2005, 2010a, 2015)
Percentage of homes without toilet or bathroom	[Inhabited private home without toilet or bathroom by Municipality/Total inhabited private homes by Municipality] * 100	Percentage	Municipal	INEGI (2000, 2005, 2010a, 2015)
	[Inhabited private home without toilet or bathroom by Average Region/ Total inhabited private homes by Average Region] * 100	Percentage	Average region	INEGI (2000, 2005, 2010a, 2015)
Percentage of homes without running water from the public system	[Homes without running water by Municipali-ty/Total inhabited private homes by Munici-pality] * 100	Percentage	Municipal	INEGI (2000, 2005, 2010a, 2015)
	[Homes without running water by Average Region/Total inhabited private homes by Average Region] * 100	Percentage	Average region	INEGI (2000, 2005, 2010a, 2015)
Percentage of homes without electricity	[Homes without electricity by Municipality/ Total inhabited private homes by Municipali-ty] * 100	Percentage	Municipal	INEGI (2000, 2005, 2010a, 2015)
	[Homes without electricity by Average Re-gion/Total inhabited private homes by Aver-age Region] * 100	Percentage	Average region	INEGI (2000, 2005, 2010a, 2015)
Porcentaje de viviendas que no disponen de refrigerador	[Homes without a refrigerator Municipali-ty/Total inhabited private homes by Munici-pality] * 100	Percentage	Municipal	INEGI (2000, 2005, 2010a, 2015)
	[Homes without a refrigerator by Average Region/Total inhabited private homes by Average Region] * 100	Percentage	Average region	INEGI (2000, 2005, 2010a, 2015)

Notes: [a)] LThe Prevalence figures for short stature by municipality are presented as percentages. In the case of the Average Region, the average value for the set of municipalities that comprise it is obtained (which are presented as percentages); [b)] because the points of interest are the years 2000, 2005, 2010 and 2015, a linear interpolation was performed with Prevalence data for children of short stature in the first grade of primary school, in each of the municipalities, using data reported in 1994, 1999, 2004 and 2016. Two slopes are used for these interpolations: 1) a constant slope between 1999 and 2004; and 2) a constant slope between 2004 and 2016.

Source: prepared by the authors.

Once the indicators were calculated, PCA was used to construct the Municipal and Regional Food Security Index, the former being a multivariate statistical method that allows a synthetic unit of measurement to be obtained in order to evaluate the global impact of a set of variables, while preserving the maximum amount of information that each contributes to the set (Hair *et al*., 2014). To do this, the total number of municipalities in Mexico was considered for each temporal cross section: 2,443 in 2000; 2,454 in 2005; 2,456 in 2010; 2,457 in 2015; and 2,458 in 2018. In the regional case, for all years, the classification of 214 average regions was maintained, making the analysis consistent in its terms—independently of the incorporation of new municipalities.

To obtain the index, a database was put together that includes information for the selected indicators to which PCA was applied. In accordance with the methodology, the first step consisted of standardizing the indicators in order to make them comparable; that is, homogenizing disparities in length, average and deviation. In the matrix arrangement, each municipality or average region—depending on the scale—represents an observed case and occupies one row. Meanwhile, the values of the 13 selected indicators appear in the columns of each row.

For the Food Security Index by Average Region,[2] standardization was carried out using the formula $Z_{i,j} = \frac{I_{i,j} - \overline{I_j}}{ds_j}$, where:

$Z_{i,j}$: is the standardized indicator *j* of average region *i*,
$I_{i,j}$: is the socioeconomic indicator *j* of average region *i*,
$\overline{I_j}$: is the arithmetic average of the values for indicator *j*, and
ds_j: is the unbiased standard deviation of indicator *j*.

As a result, the standardized matrix of indicators was obtained:

$$Z = \begin{bmatrix} z_{1,1} & z_{1,2} & \cdots & z_{1,13} \\ z_{2,1} & z_{2,2} & \cdots & z_{2,13} \\ \vdots & \vdots & \vdots & \vdots \\ z_{n,1} & z_{n,2} & \cdots & z_{n,13} \end{bmatrix}$$

Subsequently, from *Z*, the correlation matrix was constructed, which shows the relationship between the indicators and new variables; their values range from 0 to 1:

$$Corr = \begin{bmatrix} 1_{1,1} & q_{1,2} & \cdots & q_{13,1} \\ q_{1,2} & 1_{2,2} & \cdots & q_{13,2} \\ \vdots & \vdots & \vdots & \vdots \\ q_{13,1} & q_{13,2} & \cdots & 1_{13,13} \end{bmatrix}$$

From this matrix, eigenvalues $\omega_{1,k}$ were obtained for each one (lowercase letters *w* express a vector *k*, weighted for each indicator). Following this, its hierarchical order was established:

$$\lambda_1 \geq \lambda_2 \geq \lambda_3 \geq \lambda_4 \geq \lambda_5 \geq \lambda_6 \geq \lambda_7 \geq \lambda_8 \geq \lambda_9 \geq \lambda_{10} \geq \lambda_{10} \geq \lambda_{12} \geq \lambda_{13} > 0$$

From the eigenvalues, the eigenvectors (or components) were obtained:

$$\begin{aligned} y_1 &= \omega_{1,1}z_1 + \omega_{1,2}z_2 + \cdots + \omega_{1,13}z_{13} \\ y_2 &= \omega_{2,1}z_1 + \omega_{2,2}z_2 + \cdots + \omega_{2,13}z_{13} \\ &\vdots \\ y_{13} &= \omega_{13,1}z_1 + z_{13,2}z_2 + \cdots + \omega_{13,13}z_{13} \end{aligned}$$

Based on the above, the importance of each component is weighted by the proportion it represents of the total—that is, by the explained variance. Finally, to construct the index, the first eigenvector is multiplied by matrix $\underline{\omega'_1} \bullet \underline{z}$.

The Dalenius-Hodges stratification method was applied to the index produced by PCA, to determine the food security ranges by municipality and average region. These were categorized into the categories of food security, mild food insecurity, moderate food insecurity and severe food insecurity. According to the methodology (INEGI, 2010b), for the formation of strata, let N be the number of observations and L the number of strata; the observations were ordered in ascending order, to later group them into J classes, where J=min (L*10, n). Once the classes were obtained, the limits for each one were calculated as follows:

$$\begin{aligned} \liminf Ck &= \min\{X(i)\} + (k-1) * \frac{\max\{X(i)\} - \min\{X(i)\}}{J} \\ \limsup Ck &= \min\{X(i)\} + (k) * \frac{\max\{X(i)\} - \min\{X(i)\}}{J} \end{aligned}$$

Using these limits, the frequency of cases in each class $fi(i = 1, \cdots, J)$ was obtained; then, the square root of each class' frequency was calculated, and the sum of the square root of the frequencies was accumulated, that is:

$$Ci = \sum_{h=1}^{i} \sqrt{f\,h(i = 1, \cdots, J)}$$

The last accumulated value was divided by the number of $Q = \frac{1}{L}Cj$ strata. The cutoff points for each stratum were taken on the accumulated square root of the frequencies in each class, according to the following: $Q, 2Q, \cdots, (h-1)Q$. The criterion stated that if the Q value fell between two classes, it

was taken as the cut-off point of the class with the same distance to Q. Finally, the limits of the *h*-strata formed would be those corresponding to the lower and upper limits of the classes included in each stratum.

The results obtained from the application of the PCA method and Dalenius-Hodges stratification to the Municipal and Average Region Food Security Index values are presented below.

5. FOOD SECURITY DIMENSIONS IN MEXICO: A REGIONAL APPROACH

The results obtained demonstrate the socioeconomic and geographic inequalities that the open economy development model generated in Mexico, especially the adverse effects it has had on the population's food security. Out of all of the municipalities administratively delimited at the beginning of the period in question, only 25.2% reached the range of food security, where 18.7% were in a state of severe food insecurity, 29.5% in mild food insecurity and 26.6% in moderate food insecurity. Although the combined ranges of mild and moderate insecurity reached just over 50% of those municipalities in a critical situation, the difference between food security and mild food insecurity (even the moderate and severe ranges) was less pronounced compared to 2018—implying that better alimentary conditions were registered at the municipal level, due to the re-concentration of municipalities in metropolitan areas. Additionally, the worst conditions seen also corresponded to the municipalities located in the nine states with the highest degrees of marginalization (see table 4).

However, this situation of lagging food security due to structural problems in the economic development model deepened in 2018: the number of municipalities with food security decreased to 460, representing a loss of 155 municipalities in this state, compared to 2000. Meanwhile, the number of municipalities with severe food insecurity increased to 704, such that critical conditions regarding food security increased even proportionally.

According to the results obtained here, the population segment in a situation of food security located in the municipalities increased by more than 9 million people, in absolute terms; this is due again to typical geographic imbalances that the economic development model has generated, and not to an improvement—as already indicated—among the displaced population in this range (see table 5).

It is shown that 70% of the country's population is located in urban areas and more than 60% in metropolitan areas that, in addition to retaining their status of municipality, expand through the conurbation process towards a significant number of other municipalities. Since the food in cities is generally higher quality and more diverse—regardless of its heterogeneity at different social levels—it helps the overall averages rise but hides the real situation, as the poor population that has changed geographic location maintains generally the same levels of insecurity. Based on this structural lag in the population-municipality relationship in terms of severe food insecurity, it follows that marginalization and degrees of food vulnerability are still far from being overcome.

Table 4. Mexico: municipalities and corresponding food security conditions, 2000-2018 (number and percentage)

Degree of food (in) security / Year	*2000*		*2005*		*2010*		*2015*		*2018**	
	Absolute	*(%)*	*Absolute*	*(%)*	*Absolute*	*(%)*	*Absolute*	*(%)*	*Absolute*	*(%)*
Food security	615	25.2	520	21.2	579	23.6	556	22.6	460	18.7
Mild food insecurity	720	29.5	894	36.4	848	34.5	873	35.5	699	28.4
Moderate food insecurity	651	26.6	683	27.8	549	22.4	702	28.6	595	24.2
Severe food insecurity	457	18.7	357	14.5	480	19.5	326	13.3	704	28.6
Total	2443	100.0	2454	100.0	2456	100.0	2457	100.0	2458	100.0

Note: *estimated figures.

Source: prepared by the authors.

Table 5. Mexico: total population by municipality and corresponding food security conditions, 2000-2018 (number and percentage)

Degree of food (in)security / Year	2000		2005		2010		2015		2018*	
	Absolute	(%)	Absolute	(%)	Absolute	(%)	Absolute	(%)	Absolute	(%)
Food security	64 086 651	65.7	65 667 305	63.6	71 631 313	63.8	77 487 069	64.8	73 130 497	59.0
Mild food insecurity	18 327 672	18.8	22 806 819	22.1	25 178 142	22.4	26 943 191	22.5	26 641 385	21.5
Moderate food insecurity	9 946 671	10.2	10 562 125	10.2	9 560 558	8.5	10 998 189	9.2	13 806 724	11.1
Severe food insecurity	5 122 418	5.3	4 227 139	4.1	5 966 525	5.3	4 102 304	3.4	10 446 940	8.4
Total	97 483 412	100.0	103 263 388	100.0	112 336 538	100.0	119 530 753	100.0	124 025 545	100.0

Note: *estimated figures.

Source: prepared by the authors.

Similarly, these municipal results do not vary significantly with respect to the regional scale. Although in 2000—that is, at the beginning of the period analyzed—59 average regions with adequate coverage of food security were registered and observed a relative increase in number to 63, which was maintained in 2005 and 2010. This decreased to 43 in 2015 as a result of the economic and food crisis, and by 2018 it reached 55. In the opposite but complementary direction to the foregoing, the 64 average regions that at the beginning of the period observed mild food insecurity, the same ones whose rate had decreased to 61 in 2005, began a clear rebound in 2010 with 66 average regions, which then shot up to 84 in 2015 and fell again to 78 in 2018. This is worrying, since the edge of the range is approaching severe food insecurity. A similar situation although less intense occurred with those regions with conditions of moderate food insecurity, which decreased from 54 in 2000 to 44 at the end of the period (see table 6).

Table 6. Mexico: average regions and corresponding food security conditions, 2000-2018 (number and percentage

Degree of food (in)security / Year	2000		2005		2010		2015		2018*	
	Absolute	(%)	Absolute	(%)	Absolute	(%)	Absolute	(%)	Absolute	(%)
Food security	59	27.6	63	29.4	63	29.4	43	20.1	55	25.7
Mild food insecurity	64	29.9	61	28.5	66	30.8	84	39.3	78	36.4
Moderate food insecurity	54	25.2	55	25.7	53	24.8	56	26.2	44	20.6
Severe food insecurity	37	17.3	35	16.4	32	15	31	14.5	57	26.6
Total	214	100.0	214	100.0	214	100.0	214	100.0	214	100.0

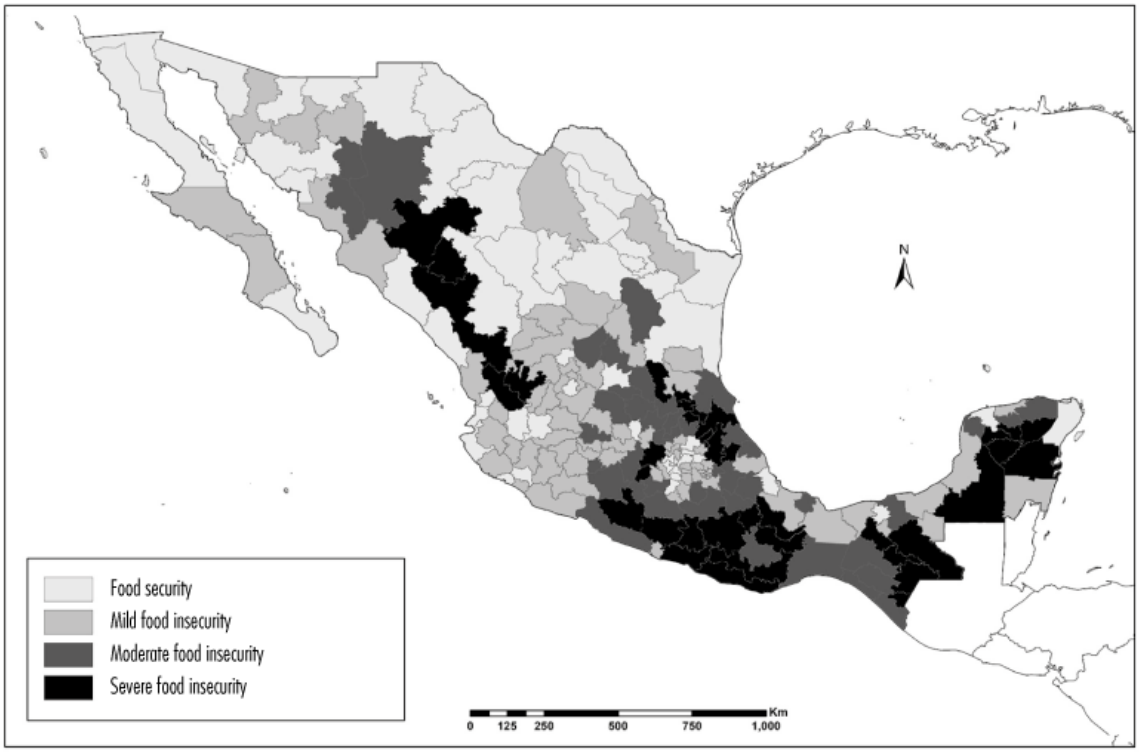
Note: *estimated figures.

Source: prepared by the authors.

In the case of the average regions located in the range of severe food insecurity, which is where the most marginalized populations are concentrated and is close to levels of hunger or extreme poverty according to other metrics, records show that the 37 that were registered in 2000 increased to 57 in 2018, demonstrating the deterioration of conditions for societal reproduction (see map 1).

For one thing, the dynamics of the rural population's mobility, especially towards the United States—which was also concentrated in Mexican urban centers—meant that the population experiencing conditions of severe food insecurity were not counted in those rural regions, but in other regions. Likewise the improvement in providing remittances, of which almost 80% are destined for consumption and most are used to buy food, helped improve stability and consumption levels among poor families and communities. While the amount of such improvements varies, they did not reverse the structural trend towards continual deterioration.

Map 1. Mexico: average regions and corresponding food security conditions, 2018



Source: prepared by the authors.

Moreover, the social welfare programs instituted since the 1990s, which sought to temporarily alleviate the problem of accessibility, also had an important effect. However, lacking any component to stimulate internal production and self-consumption among the poor population, and within the economic model in place—which overcomes cyclical conditions and accommodates solutions for structural problems—these programs did not prevent food insecurity from increasing from one region to another.

Proof of this is that the Mexican state of Oaxaca did not register improvement throughout the period, and only three of its average regions reached the level of moderate food insecurity, while six of them never exceeded the range of severe food insecurity; the same is true of Chiapas, with four and five in each case, or Guerrero with two and four average regions out of the total, though one of these regions managed to reach a state of in mild food insecurity.

A similar situation would apply to the state of Yucatan with three, four and one regions respectively, and to Hidalgo, Tabasco, Durango and Campeche —although the latter presents more polarization, to the extent that of its three average regions, two are found to have mild food insecurity and one severe food insecurity. In the state of Guanajuato, without reaching optimal conditions, three of its six regions are located in mild food insecurity, three in moderate food insecurity and none in severe food insecurity; similar rates are seen in the average regions of Tlaxcala.

One worrying fact is that the implications of deteriorating food conditions at a regional scale also reflect how they increasingly affect the middle class, which loses its position in the range of food security, and finds itself in conditions of mild or moderate food insecurity. This deterioration inhibits present and future possibilities of achieving improved levels of development in a competitive economic environment, since they decrease along with the quality of food.

A constant in results from previous studies, and one that is repeated in the current work, is that most of the average regions with conditions of food security are located in northern Mexico, with some in the central part of the country or in states that do not correspond to such a category as a whole, but include specific areas of high tourism or industrial development.

For example, in Baja California and Baja California Sur, the regions that maintained optimal conditions in 2000 were: Tijuana-Tecate, Ensenada, Loreto Comundú and La Paz; whereas in 2015, only Tijuana-Tecate and La Paz saw these conditions.

A similar situation was observed in the case of Sonora, since in 2000 it registered regions such as Desierto de Sonora, Hermosillo Centro, Guaymas Empalme, Yaqui Mayo, Frontera Centro, Río Sonora, San Miguel, Frontera Norte and Sierra Alta within the range of food security. However, the trend since then has been towards deterioration, given that only Hermosillo Centro, Frontera Centro and Frontera Norte stayed in that category.

It is important to highlight that within the heterogeneous changes in food security, a constant towards worsening conditions is seen in the case of the State of Mexico, where of the average regions that are primarily incorporated in municipalities surrounding Mexico City and that were highest ranked in 2000, as was the case of Cuautitlán Izcalli, Naucalpan, Tlalnepantla, Tultitlán, Ecatepec, Nezahualcóyotl and Texcoco, only the latter lost that status in 2018—though the municipalities corresponding to contemporary Mexico City maintained it throughout the period.

It is also of interest, within the framework of the heterogeneity described here, that some of the average regions located in 2000 as part of federative entities and considered to be the furthest behind, like Region XI Apan (Hidalgo), Metropolitana (Yucatán) and Caribe Norte (Quintana Roo), only the last of these remained in that category; Region XII Tizayuca (Hidalgo) actually moved into this category. These changes have caused almost 1.2 million inhabitants to lose their position in conditions of food security, which comes with the inference that they moved towards mild or moderate food insecurity, and would lead to a gradual deterioration of food quality in the country.

The above reinforces the thesis that lags in internal food insecurity are due, in fact, to a structural problem of economic development, which maintains or tends to deepen inequalities—which may be cyclically delocalized in regional terms—but that leaves the problem intact to the extent that it reproduces poverty and does not resolve other factors of lagging production and agri-food stability that generate the sector's structural dependency.

Therefore, of the 37 average regions recorded as facing conditions of severe food insecurity in 2000, these decreased to 31 in 2015, but rebounded to 57 in 2018. For the latter count, Durango registered one (La Quebrada), San Luis Potosí two (Huasteca Centro and Huasteca Sur), Nayarit one (Sierra Nayarit), Jalisco one (North Jalisco) and the State of Mexico three (Valle de Bravo, Tejupilco and Atlacomulco); the rest are located in the poorest states, which have maintained the same levels over time. For 2018, the only regions to leave the category of severe food insecurity were two from the State of Mexico (Atlacomulco and Tejupilco), one from Querétaro, (Tejupilco), three from Veracruz (Huasteca Alta, Huasteca Baja and Los Tuxtlas) and one from Hidalgo (Zimapán); the rest stayed in the same conditions.

Although the unit of measurement in the present analysis is the average region, these regional results cannot be considered to be on the margins of the population that they incorporate. The proportion in percentages between average regions and the number of inhabitants for different ranges of food security may be different in magnitude, yet they present the same dynamics of behavior over time. Evidence of this is that the absolute number of people in better or worse conditions shows almost no changes during the analyzed period, but a proportional increase is seen which is consistently situated in worse conditions in relation to the total population. To reiterate, the problem of food security remains rooted as a structural problem of development in Mexico.

If these regions are analyzed according to their population concentration levels, it is found that the state of food insecurity in critical rural areas is dispersed towards large population concentrations, in such a way that the latter areas see a decrease in the food security levels. However, the impact on their conditions is not clear, due to the fact that the food insecurity that people transfer geographically remains, though it is spread throughout the urban heterogeneity of major metropolitan areas.

When examining the average regions according to their population size, it can be observed that among those which reach the range of food security—though these increased by 9.1 million people in absolute terms—the proportion contracted from 50.1 to 46.7% between the beginning and end of the 2000-2018 period. This means that more than half of Mexicans experience some degree of food insecurity (see table 7).

Table 7. Total population by average region and corresponding food security conditions 2000-2018 (people and percentage)

Degree of food (in) security / Year	*2000*		*2005*		*2010*		*2015*		*2018**	
	Absolute	*(%)*	*Absolute*	*(%)*	*Absolute*	*(%)*	*Absolute*	*(%)*	*Absolute*	*(%)*
Food security	48 821 787	50.1	53 478 742	51.8	60 624 800	54	49 127 255	41.1	57 979 292	46.7
Mild food insecurity	20 993 339	21.5	21 760 223	21.1	23 446 870	20.9	40 592 943	34	33 561 030	27.1
Moderate food insecurity	16 877 439	17.3	18 096 208	17.5	18 502 794	16.5	19 604 940	16.4	18 084 418	14.6
Severe food insecurity	10 790 847	11.1	9 928 215	9.6	9 762 074	8.7	10 205 615	8.5	14 400 805	11.6
Total	97 483 412	100.0	103 263 388	100.0	112 336 538	100.0	119 530 753	100.0	124 025 545	100.0

Note: *estimated figures.

Source: prepared by the authors.

The population that was previously in conditions of food security moved to the strata of mild and moderate food insecurity, due to the fact that the range of severe food insecurity did not change significantly during the period. This phenomenon is essentially due to the deterioration of people's living conditions, the paralysis of food production, rural exodus and damages to nutritional and health circumstances.

The population experiencing mild food insecurity increased by 12.5 million, which translated in percentage terms represented an increase from 21.5 to 27.1% with respect to the total population. In the case of moderate food insecurity, the population located in those conditions registered a different dynamic; although the proportion increased in absolute terms, going from 16.8 to 18 million people, in relative terms it decreased from 17.3 to 14.6% in the same period.

Finally, the population experiencing severe food insecurity saw their conditions worsen. At the beginning of the period, 10.7 million people suffered from this condition, which dropped to 9.7 million in 2010; however, this rebounded to 10.2 million in 2015 and peaked at 14.4 million in 2018. The proportion increased marginally, in the latter case, from 11.1 to 11.6%. It is worth noting that what actually increased was consumption, on a temporary basis, and not food security, since regional food production did not improve, and less so the complementarity of supplies for self-sufficiency among the rural population. Seen from the perspective of number of regions or population size, more than half of Mexicans currently face some degree of food insecurity.

6. CONCLUSIONS

The negative costs of food insecurity in Mexico during the established period have been as follows: the agricultural sector's crisis and stagnation, and the lag of its productive structure; the dismantling of the farmer base and rural exodus; the loss of food self-sufficiency and greater dependence on food imports; the structural deficit balance of the external agri-food accounts, as well as a deficit in the trade balance. These have been accompanied by low levels of growth in the national economy, falling wages and purchasing power, contracting employment levels, and the rise in poverty, which is primarily a permanent food vulnerability that manifests itself differently throughout the national territory.

The challenge for food security in Mexico—from access through to agricultural production—consists of producing sufficient food at a low cost, while guaranteeing and obtaining the food supply. It also implies preserving the environment through optimal production schemes for resource usage, to avoid regional social outbursts, thus generating direct employment in the field and guaranteeing a degree of certainty in terms of land ownership. Additionally, addressing the challenge would involve regional distribution of agricultural credits for the production of basic goods, as well as temporary and differentiated protectionist measures for prices that would slow down the onslaught of trade liberalization on non-competitive frameworks such as those in place currently.

Food security must be based on the sustained growth of the internal economy through efficient income distribution mechanisms, where the recovery of purchasing power—along with the generation of temporary and seasonal employment in rural areas, though these may not only be related to agricultural activities—should help recover consumption levels and create increasing dynamism in the production chains linked to food production.

BIBLIOGRAPHY

Ávila, A., Juárez-Martínez, L., Del Monte-Vega, M., Ávila Arcos, MA., Galindo-Gómez, C. and Ambrocio-Hernández, R. (2016), *Estado de nutrición en población escolar mexicana que cursa el nivel de primaria*, Mexico, Instituto Nacional de Ciencias Médicas y Nutrición "Salvador Zubirán".

Consejo Nacional de Evaluación de la Política de Desarrollo Social (CONEVAL) (2017), *Medición de la pobreza en México y en las entidades federativas 2016. Resumen ejecutivo*, Mexico, CONEVAL.

Hair, J., Black, W., Babin, B. and Anderson, R. (2014), *Multivariate Data Analysis*, USA, Pearson.

Instituto Nacional de Estadística y Geografía (INEGI) (2000), *XII Censo de Población y Vivienda 2000. Marco conceptual*, Mexico, INEGI.

_____ (2005), *II Conteo de Población y Vivienda 2005. Características metodológicas y conceptuales*, Mexico, INEGI.

_____ (2010a), *Marco conceptual del Censo de Población y Vivienda 2010*, Mexico, INEGI.

_____ (2010b), *Nota técnica. Estratificación multivariada* (Sistema para la Consulta de Información Censal 2010), Mexico, INEGI. Recovered from <http://gaia.inegi.org.mx/scince2/documentos/scince/ chaTecnica.pdf>

_____ (2015), *Encuesta Intercensal* 2015, Mexico, INEGI.

Morón, C. and Schejtman, A. (1997), "Situación de la seguridad alimentaria en América Latina", in C. Morón, I. Zacarías and S. de Pablo (eds.), *Producción y manejo de datos de composición química de alimentos en nutrición*, Chile, FAO.

Organización de las Naciones Unidas para la Alimentación y la Agricultura (FAO) (2009), *Declaración de la Cumbre Mundial sobre la Seguridad Alimentaria*, Roma, FAO.

_____ (2016), *Pérdidas y desperdicios de alimentos en América Latina y el Caribe. Boletín electrónico 3.* Recovered from <http://www.fao.org/3/a-i5504s. pdf>

_____ (FAO) (2018), *Alianzas alimentarias contra el hambre y la malnutrición. Primera Cumbre Parlamentaria Mundial*, Madrid, FAO.

Puyana, A. and Romero, J. (2009), "El sector agropecuario mexicano bajo el Tratado de Libre Comercio de América del Norte. La pobreza y la desigualad se intensifican, crece la migración", in C. Barba Solano (comp.), *Retos para la integración social de los pobres en América Latina*, Buenos Aires, Consejo Latinoamericano de Ciencias Sociales.

Rouzaud, O. (2008), "El concepto 'seguridad alimentaria'", *Revista Universidad de Sonora*, no. 22, Mexico, Universidad de Sonora.

Sánchez, A. (2018), *El Producto Interno Bruto de los municipios de México, 1970-2015. Estimaciones para el análisis territorial*, Mexico, UNAM-IIEc.

Sistema Nacional para el Desarrollo Integral de la Familia (DIF)-Secretaría de Educación Pública (SEP)-Instituto Nacional de Ciencias Médicas y Nutrición "Salvador Zubirán" (INCMNSZ) (1994), *Primer Censo Nacional de Talla 1993*, Mexico, DIF-SEP-INCMNSZ.

_____ (1997), *Segundo Censo Nacional de Talla 1994*, Mexico, DIF-SEP- INCMNSZ.

_____ (2004), *Tercer Censo Nacional de Talla 1999*, Mexico, DIF-SEP- INCMNSZ.

_____ (2006), *Cuarto Censo Nacional de Talla 2004*, Mexico, DIF-SEP-SSA- INCMNSZ.

The Economist Intelligence Unit and DuPont (UIE and DuPont) (2017), *Global food security index 2017: measuring food security and the impact of resource risks*, London, UIE and DuPont.

Torres, F. (2017), “La seguridad alimentaria en la estructura del desarrollo económico de México", in F. Torres Torres (coord.), *Implicaciones regionales de la seguridad alimentaria en la estructura del desarrollo económico de México*, Mexico, UNAM-IIEc.

Torres, F. and Rojas, A. (2018), “El suelo agrícola en México: retrospección y prospectiva para la seguridad alimentaria", *Realidad, datos y espacio. Revista Internacional de Estadística y Geografía*, vol. 9, no. 3, Mexico, INEGI.

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[2] This procedure was replicated for the construction of the Municipal Food Security Index.