ESSAYS ON PRICE DYNAMICS, WELFARE ANALYSIS, AND HOUSEHOLD FOOD INSECURITY IN MEXICO

A Dissertation

by

DAVID MAGAÑA LEMUS

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Chair of Committee,	Ariun Ishdorj
Co-Chair of Committee,	C. Parr Rosson, III
Committee Members,	David A. Bessler
	Oral Capps, Jr.
	Julian E. Gaspar
Head of Department,	C. Parr Rosson, III

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ABSTRACT

Higher and more volatile food prices, as reported in recent years, have consequences on household welfare and potentially on public policy. Analysis of agricultural commodities price dynamics, welfare effects of increased food prices, and determinants of household food insecurity are discussed and presented in three separate essays.

In the first essay, the dynamic information flows among prices of important agricultural commodities in the United States (U.S.) and Mexico for the years 2000-2012 are analyzed. Error correction models and directed acyclical graphs are employed with observational data to identify the dynamic relationships among prices of grains and meats. Unlike previous studies, results here suggest the existence of long-run relationships among prices in both countries. U.S. grain prices have a consistently strong impact on price movements in Mexican agricultural markets in the long-run.

In the second essay, the impacts of rising food prices on poverty and welfare of Mexican households are examined by using a linearized version of the Exact Affine Stone Index (EASI) demand system. The distribution of monetary measures of welfare effects from food price changes is estimated as well as equivalence scales that allow inter-household comparison of welfare changes. After accounting for substitution effects, poverty related impacts are estimated. Findings indicate that the actual increase in prices of five food groups from 2006 to 2010 led to an increase of 1.8 percentage points in the proportion of households with income below the food poverty line.

The third essay uses an ordered probit model with a nationally representative dataset and a newly developed food security scale in Mexico to identify the demographic determinants of household food insecurity. The analysis is conducted for the general population first and then for a subpopulation group of rural lower-income households. It was found that households with younger, less-educated household heads were more likely to suffer from food insecurity. Other groups that were found to be vulnerable in terms of food insecurity include: households headed by a single, widowed or divorced mother, households with disabled family members, households with strong indigenous background, rural households, low-income households, non-agricultural households, and households with children.

DEDICATION

To

Karla,

Daniela,

and Andres.

To

my parents,

siblings,

and in-laws.

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CHAPTER I

INTRODUCTION

World price volatility of food grains was higher during the five-year period, 2007–2011, than during the previous two decades (World Bank 2012). As a consequence of the food price spikes of 2008 and 2011, an increased attention has been paid on improving the understanding of the drivers of food prices, the impacts of higher food prices on poverty, and policy responses (World Bank 2012).

Official figures show that the proportion of Mexican population living below the food poverty line increased from 13.8% in 2006 to 18.8% in 2010 (CONEVAL 2011a). This outcome is believed to be the result of several factors including the increase in local and global food prices.

Likewise, according to official figures, 24.8% of Mexican population experienced moderate or severe food insecurity in 2010. This represents an increase of 3.1 percentage points with respect to the levels reported in in 2008 (21.7%). In other words, this represents an increase of 4.1 million individuals, from 23.9 to 28 million, living under these conditions from 2008 to 2010 (CONEVAL 2011a). Since food insecurity and hunger are possible precursors to nutritional health, and developmental problems, the increase of food insecurity in Mexico has obvious policy implications and relevance.

The ultimate objective of this dissertation is to provide information that could be useful for understanding food price dynamics, poverty impacts of increased food prices, demographic variables associated with household food insecurity, and for designing public policies in Mexico related to market risk management as well as agricultural and social policies in Mexico. The organization of this dissertation is described next.

Chapter II contains the first essay where the dynamic information flows among monthly prices of agricultural commodities in the United States (U.S.) and Mexico for the years 2000-2012 are analyzed. Previous studies have shown that despite lower trade restrictions and the increased grain trade, mainly from the U.S. to Mexico, no clear consensus exists regarding the long-run relationship among grain prices between the two countries. On the one hand, Fiess and Lederman (2004) detect the existence of a long-run relationship between corn prices in the U.S. and Mexico; Araujo-Enciso (2009) finds that U.S. corn price is cointegrated with Mexican corn price; Jaramillo, Yunez-Naude, and Serrano (2012) find evidence of increasing market integration between Mexico and the U.S. corn, sorghum and wheat markets. On the other hand, Motamed, Foster, and Tyner (2008) found no evidence of cointegration between prices of yellow corn in the U.S. and white corn prices in Mexico.

Contributions of this essay to the economic literature include the joint analysis of several commodity prices both in the U.S. (yellow corn, sorghum, wheat, soybeans and crude oil) and in Mexico (yellow corn, white corn, sorghum, wheat, beef and pork) to capture the short-run, long-run and contemporaneous relationship among them. This would be the first time a study attempts to analyze prices of crude oil and grains in the U.S. along with prices of grains and beef and pork in Mexico in the same model. Further, distinction is made between white corn and yellow corn prices in Mexico. The use of direct acyclical graphs, determination of causal ordering and innovation accounting techniques to analyze Mexican market prices is also a relevant contribution of this research. It is reasonable to think that Mexican data used in previous studies that used producer prices, or any prices in general for a period before the year 2000, were affected by the presence of heavy distortive governmental intervention. As mentioned by Motamed, Foster, and Tyler (2008), the use of such Mexican prices undermines long-run test for market integration or linkage with prices in the U.S. markets. For that reason, the dataset used in this paper come from consumer data for a period after 1999. Tests for structural changes in commodity prices are also a contribution of this research. In short, error correction models and directed acyclical graphs are employed with observational data to identify the dynamic relationships among prices for important agricultural commodities in the U.S. and Mexico.

Chapter III contains the second essay, where the impacts of rising food prices on poverty and welfare of Mexican households are examined. This essay presents an application of the Exact Affine Stone Index (EASI) demand system developed by Lewbel and Pendakur (2009) with a nationally representative dataset. Advantages of EASI model over commonly used demand models include: 1) EASI allows for complex Engel curves which vary across goods; 2) the error term can be interpreted as unobserved preference heterogeneity; and 3) an approximate model can be estimated by linear methods. This paper would represent one of the first applications of the EASI model for welfare analysis. Interpretation of error terms as unobserved preference heterogeneity allows the estimation of a distribution of welfare effects instead of only average welfare effects as it is done in traditional methods. Another contribution to the literature is the empirical estimation of equivalence scales for households with different demographic characteristics in Mexico. These equivalence scales allow inter-household comparisons of welfare effects and the estimation of meaningful food poverty impacts due to the actual increase in food prices in Mexico from 2006 to 2010.

The third essay of this dissertation is found in Chapter IV, and it is devoted to identifying the socio-economic and demographic factors that determine household food insecurity. Food insecurity is one of the most important public health challenges, and reducing food insecurity and its associated consequences requires an understanding of the determinants of food insecurity (Gundersen and Garasky 2012).

CONEVAL validated the Mexican Food Security Scale (EMSA, for its acronym in Spanish) as a reliable instrument to measure food security at the national and state level in Mexico (Carrasco, Peinador, and Aparicio 2010). Despite the validity that the food security scale is proved to have, there is no available study that has intended to find association between socio-economic and demographic factors and food insecurity at a national level in Mexico. The data used in this study come from The Socioeconomic Conditions Module (MCS 2010, for its acronym in Spanish) of the National Household Income and Expenditure Survey (ENIGH, for its name in Spanish) where variables for the EMSA are contained.

Finally, Chapter V summarizes the findings of the essays.

CHAPTER II

PRICE DYNAMICS IN AGRICULTURAL MARKETS IN THE UNITED STATES AND MEXICO

II.1. Introduction

Trade liberalization in agriculture, which started in the 1980s in Mexico, has been part of the Mexican government's commitment to reduce State intervention, allowing economic agents to respond to signals from international market prices (Yunez-Naude 2003). With the implementation of the North American Free Trade Agreement (NAFTA) in 1994, trade between the United States (U.S.) and Mexico expanded considerably. Mexican imports of U.S. grains and oilseeds have risen continuously since the 1990's. For the case of corn, the difference between domestic production and national apparent consumption in Mexico has increased during the liberalization period, rising from less than three million tons in the three-year period prior to 1995 to 7.9 million tons, on average, during 2001-2012 (Jaramillo, Yunez-Naude, and Serrano 2012). With the loosening of Mexican trade restrictions, U.S. corn exports to Mexico have increased dramatically (Zahniser and Coyle 2004).

Despite lowered trade barriers and the increased grain trade, mainly from the U.S. to Mexico, no clear consensus exists regarding the long-run relationship among grain prices between the two countries. Fiess and Lederman (2004) detect the existence of a long-run relationship between corn prices in the U.S. and Mexico. Araujo-Enciso (2009) finds that U.S. corn is cointegrated with Mexican corn. Jaramillo, Yunez-Naude, and Serrano (2012) find evidence of increasing market integration between Mexico and the U.S. corn, sorghum and wheat markets. However, Motamed, Foster, and Tyner (2008) found no evidence of cointegration between prices of yellow corn in the U.S. and prices of white corn in Mexico.

Exploring the degree to which market shocks (new price information) are transmitted between markets has become a universal topic in the study of commodity prices (Yu, Bessler and Fuller 2007). World price volatility of food grains was higher during the five-year period, 2007–2011, than during the previous two decades (World Bank 2012). It is important to investigate how the changes in policies in the United States, such as the increased use of corn for ethanol, and increased world price volatility affect agricultural prices in Mexico. Chen and Khanna (2013) discuss that the rise in food commodity prices since 2004, which reached record highs in 2008, has coincided with the tripling of corn ethanol production from 15 billion liters (BL) to 50 BL over the 2004–2010 period. This fact has spurred the food versus fuel debate and raised questions about the extent to which biofuels have contributed to the increase in food crop prices. The authors also mention that estimates of the impact of observed levels of biofuel production differ widely across studies and lie between 20% and 60%. Moreover, Anderson, Anderson, and Sawyer (2008), conclude that the increased demand for corn for ethanol production has helped push grain prices to record levels, and show that the livestock and dairy industries are facing higher feed costs as a result of the increased competition for grains created by ethanol demand.

With this background in mind, the objectives of this paper are: 1) test if there is a structural break in agricultural prices due to full implementation of NAFTA in 2008, or because of the increased use of corn for ethanol during the first decade of the 21st century; and 2) to analyze price dynamics of the main grains traded between the United States and Mexico and determine price information flow between grain markets and cattle markets in Mexico.

In order to achieve the first objective, a Bai-Perron (Bai and Perron 2003) test for multiple structural changes is performed. As for the second objective, it is achieved through the use of advanced methods of multivariate time series, along with directed acyclic graphs with Bernanke structural decomposition.

This study contributes to the literature in several ways. First, this study examines the contemporaneous causal relationship among multiple markets with strong contemporaneous correlations. The use of innovation accounting techniques to analyze price information flow between agricultural prices in the United States and Mexico also is a contribution. In previous studies, the authors focus on cointegration and determination of long-run equilibrium between prices in both countries, but none of them use directed graphs and innovation accounting techniques, such as forecast error variance decomposition to measure the direction and strength of the relationship for different time horizons. Unlike previous analysis, this study takes into consideration only prices after the deregulation of the agricultural Mexican market that occurred in 1999 (when State trader CONASUPO disappeared), which allows a clearer focus on Mexican price responses to international market shocks. A distinction is made between white corn and yellow corn prices in Mexico and the relationship between grain prices and cattle/meat prices are explored.

The remainder of this chapter is organized as follows: Section II.2 describes background information on trade and provides a brief review of relevant literature on price analysis of commodity prices in the United States and Mexico; Section II.3 contains description of the data used for the analysis; Section II.4 describes methods used, in particular, the Vector Autoregression Model (VAR) and its derived Vector Error Correction Model (VECM), as well as post-estimation techniques, Direct Acyclical Graphs (DAG) techniques, and DAG/Bernanke procedures to perform innovation accounting; Section II.5 presents a discussion of the results from the VECM and post-estimation techniques, analysis of impulse response functions and forecast error variance decompositions are also discussed. Finally, Section II.6 summarizes the main findings of the paper and points out opportunities for further research.

II.2. Background and Literature Review on Trade and Price Analysis

During most of the second half of the twentieth century the Mexican agricultural sector was one of the most protected in the world (Casco Flores 1999).This was achieved through trade and non-trade barriers, guaranteed prices, direct and indirect subsidies, and the Government acting as the main buyer of grains and oilseeds. Consumers did not have access to grains and oilseeds at international prices (Casco Flores 1999). Trade liberalization started in 1980’s. In 1988 Mexico became a GATT member and unilaterally lowered its tariffs, and in 1994 Mexico implemented NAFTA with the

United States and Canada. However, until 1999 Mexico's corn market operated under the strict management of the State buyer and seller, National Company of Popular Subsistence (CONASUPO, Spanish acronym). This agency guaranteed prices for producers and governed all imports, effectively nullifying market forces, both domestic and international (Yunez-Naude, 2003). In 1999, the Mexican Government declared the final elimination of the subsidies on tortilla consumption, as well as the end of more than fifty years of direct state intervention in corn marketing (Casco Flores 1999).

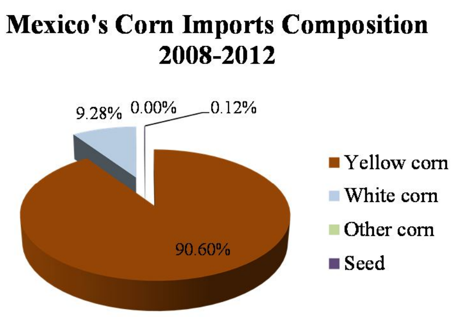
In 2008, according to NAFTA's schedule, all trade barriers were eliminated for all agricultural products between the United States, and Mexico. Mexican grain market dependence on imports is high. From 2008 to 2012 Mexican corn production averaged 21.3 million metric tons, while the mean for apparent national consumption (which is calculated as production plus imports minus exports) was 29.6 million tons. Corn imports remained relatively stable during this period, averaging 8.6 million tons annually, yielding an import to production ratio of 40.3%. As for decomposition of Mexican corn imports by corn type, more than 90% of total imports are of the yellow type, white corn accounts for 9.28% of imports, whereas the remaining is corn for seed and other types of corn (Figure 2.1). Mexican corn exports are relatively unimportant (Secretaría de Economía, 2013a, and SAGARPA 2013b)[1]. For a graphical presentation of the dynamics of corn production, consumption and trade in Mexico, see Appendix A.

Corn production in Mexico is mainly of the white type (91.3%). Less than ten percent of the national production comes from yellow corn, colored corn, and other types

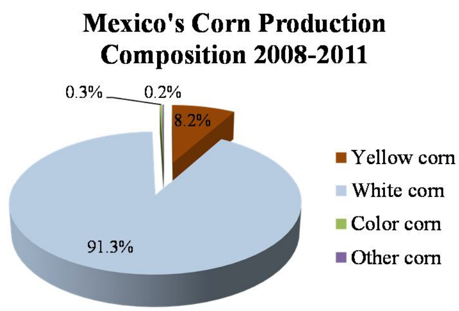
[1] Information from these sources is provided monthly for calendar years (January-December).

of corn, such as the special type of corn to make *pozole*, a traditional Mexican dish. These statistics are averages from agricultural marketing years for the 2008-2011 period[2] (SAGARPA 2013b). See figure 2.1 and Appendix A.

Figure 2.1. Percentages of corn imports and corn production by corn type in Mexico.



Source: SIAVI Secretaría de Economía.



Source: SIACON SAGARPA.

In alternative terms, although Mexico is the fourth largest corn producer in the world, it is also one of the main importers of corn. Mexican corn production has been consistently outpaced by national consumption, a situation that makes the country increasingly dependent on imports from the United States. All yellow corn and most of the white corn imported from Mexico come from U.S. suppliers (Mejia and Peel 2009).

It is relevant to point out the difference between yellow corn and white corn as two different markets. While white corn dominates production in Mexico, yellow corn accounts for most of U.S. corn production. Yellow corn is primarily used as animal feed and to manufacture ethanol, high-fructose corn syrup, corn starch, oil and other products. White corn is cultivated mainly for human consumption (Zahniser and Coyle 2004).

[2] Information for the year 2012 was still not available at the moment this paper was written.

White corn is used to produce corn tortilla. It is also the main culturally palatable variety and is the main staple food in Mexico (Motamed, Foster, and Tyner 2008).

In the United States, few farmers grow white corn. The main white corn producing states in the United States are Kentucky, Nebraska and Texas; 65 percent of U.S. white corn is produced under contract and 30 percent is exported. Mexico is the main recipient of U.S. white corn exports (Mejia and Peel 2009). White corn in the United States is produced mostly on a contract basis and is sold at a premium to yellow corn (Chowdhury and Allen 2005). While Mexico's per capita demand for food corn is relatively stable, demand for feed corn is expanding as Mexico's consumers are eating more meat and other animal products (Zahniser and Coyle 2004).

Mexico is one of the world's three largest producers of sorghum, and the largest importer of sorghum sourced from the United States (Juarez 2013). Mexican sorghum production is 6.7 million tons, with imports reaching 2.1 million tons and a national apparent consumption of 8.8 million metric tons.[3] Soybeans production in Mexico is only 0.2 million tons, hence most of the 3.6 metric tons consumed are imported. For these two crops, sorghum and soybeans, the exports are practically non-existent, while imports from the United States account for almost all Mexican imports (Appendix A).

Regarding wheat, Mexican domestic production averages 3.8 million metric tons annually, and national apparent consumption is 6.5 million tons. Total wheat imports are 3.6 million tons, while exports are 0.9 million metric tons. Mexican wheat imports from

[3] Production, consumption, and trade figures described for sorghum, wheat and soybeans in this section are averages for the 2008-2012 period. It refers to calendar years. Sources are SAGARPA SIAP and Secretaría de Economía SIAVI, datasets.

the United States represent 60% of the imports. Canada is the origin for most of the remaining wheat imports.

As for the uses of imports of U.S. grains and soybeans in Mexico, using data from 2004 Adcock, Rosson, and Varela (2007) estimated that 54 percent of U.S. corn used in Mexico was animal feed, 37 percent corn starch, and rest for flour, cereals and snack foods. Grain sorghum is used only for animal feed in Mexico. Moreover, U.S. wheat exported to Mexico is used almost entirely for human consumption. Finally, they find that all U.S. soybeans exported to Mexico are crushed for meal and oil.

Many studies analyze trade patterns for NAFTA partners. However, only a few studies focus on price dynamics and market integration between Mexico and U.S. agricultural prices using time series techniques.

Araujo-Enciso (2009) uses a bivariate Vector Error Correction Model (VECM) that includes prices of yellow corn in the United States and the price of corn in Mexico. The latter type of corn is not specified but most likely refers to white corn. Using weekly data from the first week of 2000 to the twentieth week of 2009, he investigated if a national or each of five regional corn prices in Mexico is cointegrated with the corn price in the United States. The author finds evidence that corn market in the United States is cointegrated with national and regional corn prices in Mexico. Since the estimations are performed in a bivariate VECM, it fails to capture the interaction among corn prices in different regions of Mexico. Moreover, possible interactions of corn prices with other commodity prices are left out.

Jaramillo, Yunez-Naude, and Serrano (2012), using monthly price data from 1981 to 2010, show empirically that trade liberalization between Mexico and the United States has implied structural change in prices received by Mexican producers of corn, sorghum and wheat, and that this has been accompanied by price convergence with U.S. prices of these crops. In particular, they find evidence of the existence of a long-term relationship between the price series analyzed, greater flows of trade, and an increase in the speed of adjustment of domestic Mexican prices in response to variations in international prices. One possible drawback is that the data for Mexico are yearly producer prices, the monthly prices are imputed by adjusting the yearly price using the national producer price index.

One study that discusses the difference between white corn and yellow corn is Motamed, Foster, and Tyner (2008). In their analysis, the authors use a detailed dataset of weekly white corn prices at wholesale level for 11 states across Mexico. The sampling period goes from 1998 through 2005. The authors claim that due to the data frequency and the relative detachment from a government intervention, these prices reflect responses to market forces. In other words, these authors point out the advantage of using consumer price data from the period after heavy State intervention. Using cointegration analysis and the error correction model they find that white corn prices in Mexico are determined by local conditions including the degree of integration to other regions within Mexico. They find that corn prices between the United States and Mexico do not share a common long-run relationship.

Fiess and Lederman (2004) also analyze the linkage between U.S. and Mexican corn markets. They use producer prices in both countries and, for the Mexican case, derive monthly prices from these annual series using monthly deflators. By testing producer prices in both countries for cointegration and detecting the convergence of each country's prices to a long-run relationship, the authors infer that linkages between the two markets do indeed exist, thus establishing a plausible mechanism for price transmission. In their paper, prices of white and yellow corn do not receive separate analyses.

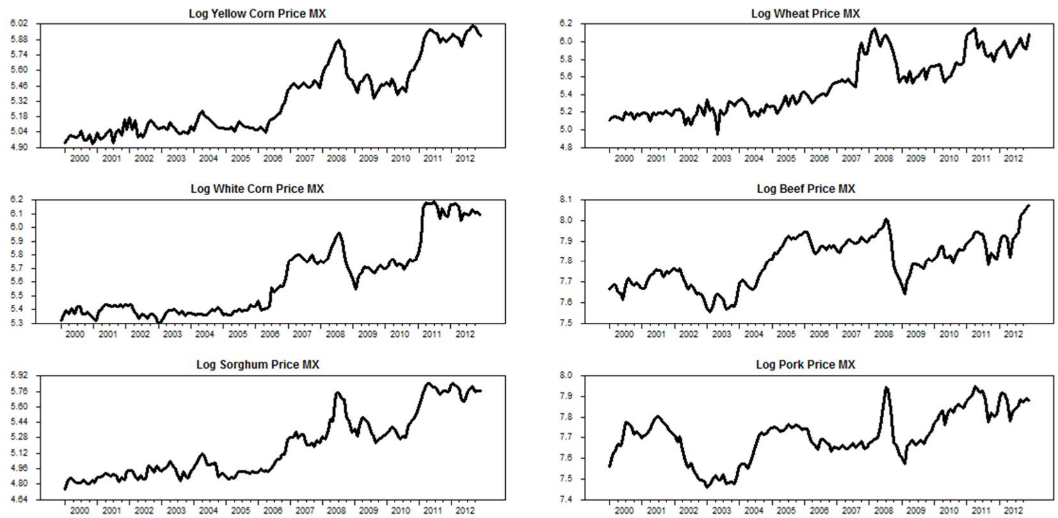
In the present document, data described in the next section are used. Contributions of this paper include the joint analysis of several commodity prices both in the United States (yellow corn, sorghum, wheat, soybeans and crude oil) and in Mexico (yellow corn, white corn, sorghum, wheat, beef and pork) to capture the short-run, long-run and contemporaneous relationship among them. This would be the first time a study attempts to analyze prices of oil and grains in the United States along with prices of grains and beef and pork in Mexico in the same model. The use of direct of direct acyclical graphs, determination of causal ordering and innovation accounting techniques to analyze Mexican market prices is also a relevant contribution of this research. Further, it is reasonable to think that data used in previous studies that used producer prices, or any prices in general for a period before the year 2000, was affected by the presence of heavy distortive governmental intervention. As mentioned by Motamed, Foster, and Tyler (2008), the use of such prices undermines long-run test for market integration or linkage with the United States. For that reason, in this paper data used come from consumer datasets after 1999. Tests for structural changes in commodity prices are also a contribution of this research.

II.3. Price Data

The prices used in the analysis are monthly averages from January 2000 to December 2012, which yields a total of 156 observations. Commodity prices analyzed for Mexico are 1) yellow corn, 2) white corn, 3) sorghum, 4) wheat, 5) pork carcass, and 6) beef carcass.[4] All data were obtained from the online database maintained by *Secretaría de Economía* (2013b), which provides weekly price information, in Mexican pesos per kilogram, at the main storage facilities (*centrales de abasto*) across the country. Nationwide monthly price averages are calculated and converted to U.S. dollars per metric ton using the monthly exchange rate FIX published by Banco de México (2013). Figure 2.2 shows the plots of natural logarithms of Mexican commodity prices.

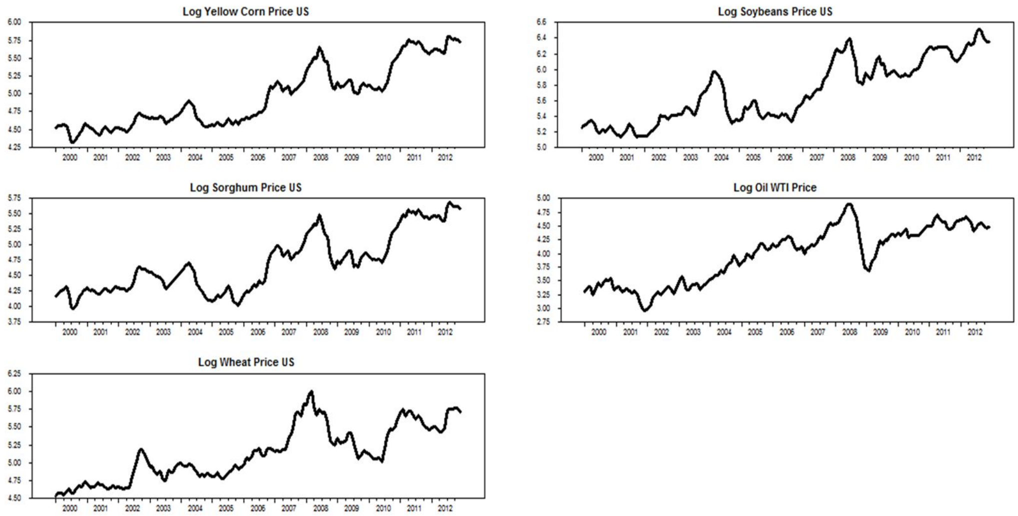
[4] Thanks to José R. Navarrete and Salvador D. Gaucín of FIRA-Banco de Mexico for collecting and providing prices and trade data.

Figure 2.2. Time series plots of natural logarithms of prices (USD/metric ton) of yellow corn, white corn, sorghum, wheat, beef and pork in Mexico, monthly observations January 2000-December 2012.



As for the U.S. prices, the commodities considered are: 1) yellow corn No. 2 FOB at the Gulf of Mexico, 2) yellow sorghum No. 2 spot at Nebraska, 3) hard red winter No. 1 spot at Kansas, 4) yellow soybean FOB at Chicago, and 5) crude oil price is West Texas Intermediate (WTI). We were unable to find a parallel price series of white corn in the United States. All grain prices are converted from original measures ($ per bushel) to U.S. dollars per metric ton while WTI crude oil price is expressed in U.S. dollars per barrel. All U.S. prices were obtained from Bloomberg datasets. Time plots of natural logarithms of U.S. commodity prices are shown in figure 2.3.

Figure 2.3. Time series plots of natural logarithms of prices (USD/metric ton) of yellow corn, sorghum, wheat, soybeans and West Texas Intermediate crude oil, in the United States, monthly observations January 2000-December 2012.



At a first glance, commodity prices, both in the United States and Mexico, seem to be non-stationary. That is, minimum price for each series is reported early in the period under analysis, whereas the maximum price occurs towards the end of the series. For most of the commodities the minimum price occurs during the first two years of the time interval (i.e. 2000 and 2001). Exceptions are the price of white corn, the price of wheat, the price of beef and the price of pork in Mexico, which report a minimum value during the first half of 2003. Maximum price occur late in each series. That is, maximum price is reported during 2012 for yellow corn in Mexico, beef in Mexico, yellow corn in the U.S., sorghum in the U.S., and soybeans in the U.S. Maximum wheat prices, in the U.S. and Mexico, occur in 2008. This is the same time period as maximum price for crude oil (table 2.1).

Table 2.1. Descriptive Statistics on Natural Logarithms of Monthly Commodity Prices, Jan. 2000-Dec. 2012.

Price Series	Units of Measure	Mean	Standard Deviation	Coefficient of Variation	Minimum, month occurred		Maximum, month occurred	
Yellow Corn MX	US$/Ton	5.35	0.33	0.06	4.94	Nov-00	6.01	Sep-12
White Corn MX	US$/Ton	5.61	0.27	0.05	5.30	Feb-03	6.19	Jul-11
Sorghum MX	US$/Ton	5.19	0.33	0.06	4.74	Jan-00	5.85	May-11
Wheat MX	US$/Ton	5.50	0.32	0.06	4.95	May-03	6.15	Mar-08
Beef MX	US$/Ton	7.80	0.12	0.02	7.56	Feb-03	8.07	Dec-12
Pork MX	US$/Ton	7.71	0.12	0.02	7.46	Jan-03	7.95	Apr-11
Yellow Corn US	US$/Ton	4.96	0.43	0.09	4.32	Jul-00	5.66	Jul-12
Sorghum US	US$/Ton	4.70	0.48	0.10	3.97	Aug-00	5.80	Aug-12
Wheat US	US$/Ton	5.13	0.38	0.07	4.54	Jan-00	6.00	Mar-08
Soybean US	US$/Ton	5.71	0.40	0.07	5.12	Oct-01	6.51	Aug-12
Oil WTI	US$/Barrel	3.97	0.51	0.13	2.96	Dec-01	4.90	Jun-08

Ton refers to a metric ton. MX=Mexico, US=United States, WTI=West Texas Intermediate.

As measured by the coefficient of variation (CV), which is the ratio of the standard deviation to the mean, crude oil price is the most volatile (CV=0.13), followed by the price of sorghum in the U.S.(CV=0.10), and the price of yellow corn in the U.S. (CV=0.09). Price of beef and price of pork in Mexico show the lowest volatility level (CV=0.02).

II.4. Modeling Considerations

A Vector Autoregressive model (VAR) is a suitable model class for describing the data generation process of a small or moderate set of time series variables. In these models, all variables are often treated as being *a priori* endogenous, and have the advantage of allowing rich dynamics (Lutkepohl and Kratzing 2004). However, if variables that have a common trend are present in a system of variables, the VAR form is not the most appropriate model (Lutkepohl and Kratzing 2004). It is useful then to consider specific parameterizations that support the analysis of the cointegration structure. The resulting model is known as Vector Error Correction Model (VECM) (Lutkepohl and Kratzing 2004). The error correction model with $k-1$ lags, derived from a levels vector autoregression model (VAR) with k lags can be expressed as:

$$\Delta P_t = \Pi P_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \Delta P_{t-i} + \mu + \varphi' D_t + e_t \; (t = 1, \dots, T) \qquad (2.1)$$

$$e_t \sim Niid(0, \Sigma)$$

The difference operator (Δ) for the dependent variable P_t represents the expression $\Delta P_t = P_t - P_{t-1}$. Also, P_t is a (11x1) vector of prices measured at time t; Γ_i

is a (11x11) matrix of coefficients related to price changes for the ith lag with respect to contemporary changes in prices. Likewise, $\Pi = \alpha\beta'$ is a (11x11) matrix of coefficients that correspond to lagged levels of prices and current changes in prices in the VECM; φ' is a (11x11) vector of coefficients that associates with the (11x1) vector of seasonal (monthly) dummy variables (D_t). μ is a (11x1) vector of constants, and e_t is a (11x1) vector of innovations, which is new information that comes from each of the eleven price series.

Some of the desirable properties of the VECM include: 1) the multicollinearity effect is significantly reduced, since differences are more "orthogonal" than the levels of variables; 2) information about long-run effects is summarized in the level matrix Π; 3) the coefficients can be classified into short-run (α and Γ_i), and long-run effects (β) (Juselius 2006). That is, the inclusion of differences and levels in the same model in the VECM allows the investigation of short-run and long-run effects in the data. Contemporaneous structure is captured in e_t .

After the VECM model is estimated, exclusion and weak exogeneity of price series are tested. The exclusion test is performed to determine if a specific commodity is excluded in all the long-run relationships identified in the model (tested as restrictions on β). Weak exogeneity test on each series indicate if prices respond to deviations from the long-run relationships (tested as restrictions on α) (Juselius 2006). Detailed descriptions of these tests and discussion of results is provided in Section II.IV.

In order to conduct innovation accounting, the VECM is estimated in its equivalent VAR form, which after algebraic manipulation is:

$$P_t = \mu + (1 + \Pi + \Gamma_1)P_{t-1} - \sum_{i=1}^{k-2}(\Gamma_i - \Gamma_{i+1})P_{t-i-1} - \Gamma_{k-1} P_{t-k} + \varphi' D_t$$

$$+ e_t \, (t = 1, \dots, T) \qquad (2.2)$$

$e_t \sim Niid(0, \Sigma)$

Further, Direct Acyclic Graphs (DAG) and Bernanke ordering (Bernanke 1986) were used to obtain contemporaneous causal ordering. This method is discussed in detail in Bessler and Akleman (1998) and in Babula, Bessler and Payne (2004). A similar method is used in Swanson and Granger (1997).

A graph consists of a group of nodes (variables) and edges (relationships between pair of variables). A directed graph has directed edges, showing an arrowhead in the direction of causality among variables. For example, X→ Y indicates that changes in variable X result in changes in variable Y. A path in a graph is a sequence of connected nodes (variables). It is said that an acyclic graph has no direct cycles (no path returning to the same variable). A graph that is both directed and acyclic is called a Directed Acyclic Graph (DAG). See Pearl (2009) for more details. Directed graphs use d-separation as an explicit link to conditional independence. This idea allows the detection of causal flows when working with observational data, effects not captured by traditional multivariate methods (Bessler and Akleman 1998).

II.5. Results and Discussion

Above it was hypothesized that price series were non-stationary. In this section, non-stationarity is formally tested. Before conducting tests for the presence of unit root in the price series, the stability and potential structural change is analyzed. Wang and Tomek (2007) suggest that in case a structural break has occurred in the series, and it is not taken into consideration, then the Augmented Dickey-Fuller (D-F) test would be biased toward a false acceptance of a unit root.

Table 2.2. Bai-Perron Test for Multiple Structural Breaks.

	Number of Breaks Found	Bayesian Information Criterion	Modified Schwarz Information Criterion
Yellow Corn MX	0	-5.86	-5.48*
White Corn MX	0	-6.19	-5.81*
Sorghum MX	0	-5.74	-5.36*
Wheat MX	0	-4.91	-4.53*
Beef MX	0	-6.59	-6.20*
Pork MX	0	-6.54	-6.16*
Yellow Corn US	0	-5.24	-4.86*
Sorghum US	0	-4.73	-4.35*
Wheat US	0	-4.88	-4.50*
Soybean US	0	-5.14	-4.76*
Oil WTI	0	-4.61	-4.23*

*Minimum value.

In order to rule out the existence of a structural change, the Bai-Perron test for multiple structural changes (Bai and Perron 2003) was performed using RATS 8.2. This procedure makes use of information criteria to determine the number of structural breaks in the series. It computes the Bayesian information criterion (BIC) and the modified

Schwarz information criterion of Liu, Wu and Zidek (1997). Table 2.2 shows the results of the Bai-Perron tests, finding that the information criterion is minimized at zero structural break points for all the price series.

Table 2.3 presents the Augmented Dickey-Fuller (D-F) tests, which were performed by selecting the number of lags (k) that minimized the Schwarz-loss metric. As in the rest of this document, all estimations and tests are performed using the natural logarithms of the commodity price series. D-F tests indicate that the null hypothesis (the levels of commodity price series are non-stationary) is not rejected at the 5% significance level. For every series, the D-F t-statistic for the natural logarithm of levels is less than -2.89, which is the 5% critical value to reject the null hypothesis.

The second panel of table 2.3 includes the Augmented Dickey-Fuller test on first differences of natural logarithms of commodity price series. The null hypothesis of non-stationarity is strongly rejected once price series are first-differenced (D-F t-statistic is more negative than -2.89 in all cases). Stated alternatively, all prices are I(1).

Nelson and Plosser (1982) suggests that to impose the trend specification to test the nature of non-stationary time series is to assume away long-run uncertainty in these variables and to remove much of their variation a priori. Hence, the D-F tests were performed without including trend.

The Ljung-Box Q test is estimated on the residuals from the regression, and the number of lags, specified in each line of table 2.3. The null hypothesis is that the errors are not correlated (white noise residuals). The Q-statistic is distributed chi-squared with 36 degrees of freedom.

Table 2.3. Augmented Dickey-Fuller (D-F) t-tests and Ljung-Box Q-statistics*.

Price Series	D-F t-test (k)		Q-statistic (p-value)	
Natural logarithm of levels				
Yellow Corn MX	-0.77	(0)	35.74	(0.48)
White Corn MX	-0.44	(0)	53.79	(0.03)
Sorghum MX	-0.79	(0)	51.13	(0.05)
Wheat MX	-1.42	(0)	34.01	(0.56)
Beef MX	-1.65	(1)	43.39	(0.19)
Pork MX	-2.02	(1)	26.54	(0.88)
Yellow Corn US	-0.34	(0)	74.45	(0.00)
Sorghum US	-1.06	(1)	48.83	(0.08)
Wheat US	-1.52	(1)	36.67	(0.44)
Soybean US	-1.41	(1)	35.65	(0.49)
Oil WTI	-1.66	(1)	36.51	(0.44)
First differences of natural logarithms				
Yellow Corn MX	-12.56	(0)	39.69	(0.31)
White Corn MX	-9.96	(0)	39.88	(0.30)
Sorghum MX	-11.43	(0)	50.07	(0.06)
Wheat MX	-13.41	(0)	34.64	(0.53)
Beef MX	-9.53	(0)	47.61	(0.09)
Pork MX	-9.37	(0)	30.84	(0.71)
Yellow Corn US	-9.86	(0)	55.41	(0.02)
Sorghum US	-8.95	(0)	51.84	(0.04)
Wheat US	-9.38	(0)	38.70	(0.35)
Soybean US	-7.96	(0)	38.79	(0.35)
Oil WTI	-9.00	(0)	37.83	(0.39)

*The null hypothesis is that prices series are non-stationary, which is rejected at the 5% significance level for D-F t values that are more negative than -2.89, meaning that the series is stationary.

(k) are the number of lags that minimizes the Schwarz-loss metric.

In order to determine model specification and the number of lags to be included in the model two loss metrics are calculated to alternative levels VAR models. Table 2.4 shows both loss metrics (Schwarz loss as well as Hannan and Quinn loss metrics) on the number of lags in levels VAR model on logarithms of commodity prices and the inclusion of monthly seasonal components as exogenous variables. Schwarz loss metric is minimized (-66.54) for one lag of prices and no seasonal components included in the model. Hannan and Quinn loss metric (minimum value is -68.13) also suggest that the appropriate lag length is one.

Table 2.4. Schwarz and Hannan and Quinn's Loss Metrics on Model Specification.

Number of lags (k)	Schwarz Loss	Hannan and Quinn
Constant, no seasonal components, and no lags of prices		
0	-51.02	-51.15
Constant, with seasonal components, and no lags of prices		
0	-47.67	-49.26
Constant, no seasonal components, and lags of prices		
1	-66.54*	-68.13*
2	-63.78	-66.83
3	-60.97	-65.49
4	-58.09	-64.06
5	-55.50	-62.94
6	-53.37	-62.28
Constant, with seasonal components, and lags of prices		
1	-63.86	-66.92
2	-61.21	-65.73
3	-58.32	-64.29
4	-55.54	-62.98
5	-53.19	-62.09
6	-51.32	-61.68

*Minimum value.

Both loss metrics are minimized when seasonal components are left out of the model. The fit of VAR to the data is improved when monthly dummy variables, aimed to capture seasonal effects, are not included in the model.

Since all price series are non-stationary in levels, we next consider the number of cointegrating vectors. This is typically determined by performing the trace test. Johansen (1992) recommends to test if the constant of the model is within the cointegrating space or not. Two alternative models are tested. The left panel of table 2.5 shows the trace statistics and the 5% critical values, C(5%)[5], to test if the constant belongs to the cointegrating space, whereas the right panel shows the corresponding statistics for the alternative model (i.e. constant does not belong to the cointegrating space). The column with heading "D" shows the decision to either reject, R, or fail to reject, F, the null hypothesis for the number of cointegrating vectors (column labeled "r"). The results of the trace test are interpreted starting from top to bottom and from right to left until the null hypothesis is not rejected the first time. This is the stopping point of the test as proposed by Johansen (1992). Following this logic, the null hypothesis is rejected in both (left and right) panels for $r = 0, r \leq 1, and\ r \leq 2$. The first time the null hypothesis of the trace test is not rejected correspond to $r \leq 3$, for the model with the constant within the cointegrating space, suggesting there is a maximum of 3 cointegrating vectors in the model.

[5] Taken from Hansen and Juselius (1995).

Table 2.5. Trace Test among Logarithms of Commodity Prices.

r*	Constant within the cointegrating space			No constant within the cointegrating space		
	Trace test statistics	C (5%)	D	Trace test statistics	C (5%)	D
= 0	355.28	289.71	R	352.80	276.37	R
≤ 1	271.95	244.56	R	269.73	232.60	R
≤ 2	208.82	203.34	R	206.62	192.30	R
≤ 3	155.53	165.73	F#	153.36	155.75	F
≤ 4	112.26	132.00	F	110.15	123.04	F
≤ 5	76.36	101.84	F	74.29	93.92	F
≤ 6	49.24	75.74	F	47.19	68.68	F
≤ 7	29.33	53.42	F	27.72	47.21	F
≤ 8	16.10	34.80	F	14.53	29.38	F
≤ 9	6.81	19.99	F	5.39	15.34	F
≤10	1.87	9.13	F	0.59	3.84	F

* Number of cointegrating vectors.
C=Confidence Level. D=Decision.
R=Reject. F=Fail to reject.
# indicates first decision F.

The trace test does not perform well in small samples (Johansen 2000). Wang and Bessler (2005) recommend the use of statistical loss metrics as alternatives to the trace test for the selection of the number of cointegrating vectors. Schwarz loss (SL) and Hannan and Quinn loss (H&Q) are calculated on the number of cointegrating vectors in the VECM fit for the commodity price series. This is done as a check on the selection of the number of cointegrating vectors and for model selection on the constant within or outside the cointegrating space.

The SL and H&Q metrics yield results that are consistent with the trace test in regards to the constant pertaining within the cointegrating space. Note that both metrics are minimized on the left panel on table 2.6, which corresponds to the model with constant inside the cointegrating vectors.

Fiess and Lederman (2004) explain the specific case of two commodity prices. If a constant is introduced in the cointegration space and if this constant proves statistically significant, it can be interpreted as the long-run spatial price differential between these two prices.

On the number of cointegrating vectors, conversely, SL and H&Q suggest different number of cointegrating vectors compared to the results from the trace test. After Wang and Bessler (2005) the number of cointegrating vectors suggested by H&Q metric is considered for modeling purposes. Accordingly, two cointegrating vectors were imposed on the model.

Table 2.6. Schwarz Loss (SL) and Hannan and Quinn Loss (H&Q) on the Number of Cointegrating Vectors in an Error Correction Model Fit with Commodity Prices with Constant Inside and Outside of the Cointegrating Space.

r	Constant Inside		Constant Outside	
	SL	H&Q	SL	H&Q
1	-65.86*	-67.54	-65.55	-67.34
2	-65.62	-67.53*	-65.34	-67.35
3	-65.38	-67.50	-65.13	-67.34
4	-65.14	-67.44	-64.92	-67.31
5	-64.91	-67.38	-64.73	-67.27
6	-64.69	-67.31	-64.54	-67.21
7	-64.50	-67.22	-64.38	-67.15
8	-64.32	-67.14	-64.23	-67.09
9	-64.18	-67.08	-64.13	-67.04
10	-64.09	-67.03	-64.06	-67.01
11	-64.03	-67.00	-64.03	-67.00

r= Number of cointegrating vectors.
Minimum metric for SL and H&Q shown by *.

The determination of the cointegration rank is one of the most crucial, since all results are conditional on the chosen rank. If the rank is too large, it is likely that the true long-run relationships are rejected too often (Hansen and Juselius 1995). The result of two cointegrating vectors was robust to the specification of different sample periods. In particular, this result was also obtained for samples from January 2000 to December 2009 and from January 2003 to December 2012.

Stationarity, exclusion, and weak exogeneity tests

Once the model is estimated with two cointegrating vectors, three usual tests are performed to study the time series properties of the data, namely stationarity, exclusion, and weak exogeneity.

First, stationarity test is to identify if one of the series is a cointegrating vector all by itself. This test is to make sure that none of the two long-run relationships in the model arises because a series is stationary. The null hypothesis here is that the series is by itself one of the stationary relationships in the cointegrating space that were found in the previous section. The likelihood ratio test for stationarity is distributed chi-squared with ten degrees of freedom and the corresponding 5% critical value is 18.31. As shown in table 2.7, panel labeled "Stationarity", the null hypothesis is strongly rejected for all commodity price series (p-values=0), suggesting that none of the eleven series is stationary. These results are consistent with the outcome from the formal D-F test, which is shown in table 2.3 and, with intuition from visual inspection of price series in Figures 2.2 and 2.3, as well as in Appendix B.

As for exclusion test, the null hypothesis is that a particular series does not belong to the cointegrating space. The likelihood ratio test for exclusion is distributed chi-squared with two degrees of freedom and 5% critical value of 5.99. From the corresponding panel in table 2.7, it can be noticed that exclusion is not rejected for the price of pork in Mexico (p-value=0.34), price of crude oil (p-value=0.58), and the price of sorghum in the U.S. (p-value=0.16). This last result was not expected since it is believed that price of corn and price of sorghum move together. Exclusion of the price of corn in the U.S. from the cointegrating space is rejected at the 7% significance level. The evidence that the prices for grains in Mexico (yellow corn, white corn, sorghum and wheat) belong to the cointegrating space is strong (p-values less than or equal to 0.05).

Table 2.7. Test for Stationarity of Levels, Exclusion from the Cointegrating Space, and Weak Exogeneity of Logarithms of Commodity Prices (*p*-values in parentheses).

Test	df	C (5%)	Commodity Price Series					
			MYC	MWC	MXS	MXW	MXB	MXP
Stationarity	10	18.31	61.06	61.00	61.08	61.03	60.91	60.93
			(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Exclusion	2	5.99	6.16	9.02	9.68	21.94	5.93	2.17
			(0.05)	(0.01)	(0.01)	(0.00)	(0.05)	(0.34)
Weak exogeneity	2	5.99	11.43	19.15	15.73	11.09	8.82	9.52
			(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)

Test	df	C (5%)	Commodity Price Series					
			USC	USS	USW	SOY	OIL	Constant
Stationarity	10	18.31	61.08	61.08	61.00	61.00	60.89	
			(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	
Exclusion	2	5.99	5.25	3.66	7.00	20.00	1.09	6.63
			(0.07)	(0.16)	(0.03)	(0.00)	(0.58)	(0.04)
Weak exogeneity	2	5.99	0.62	0.91	0.00	0.00	2.86	
			(0.73)	(0.63)	(1.00)	(1.00)	(0.24)	

MYC=Yellow corn in Mexico, MWC=White corn in Mexico, MXS=Sorghum in Mexico, MXW=Wheat in Mexico, MXB=Beef in Mexico, MXP=Pork in Mexico, USC=Yellow corn in the U.S., USS=Sorghum in the U.S., USW=Wheat in the U.S., SOY=Soybeans in the U.S., OIL=West Texas Intermediate crude oil, df=degrees of freedom, C(5%)=5% significance level.

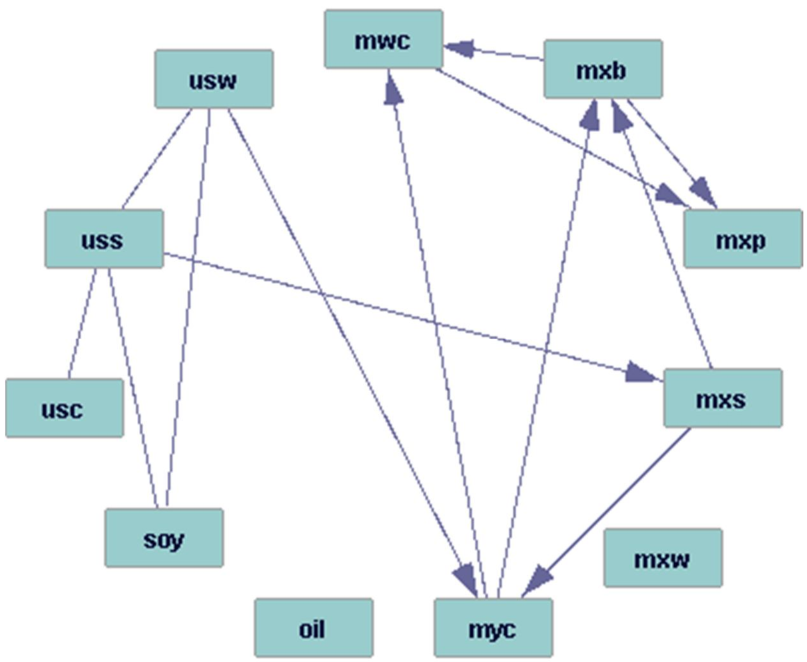
Turning to the weak exogeneity test, the hypothesis tested (null) is that one specific series does not respond to perturbations in the cointegrating space. The likelihood ratio test for weak exogeneity has the same distribution and the same critical value as the exclusion test. Results are shown in the lower panel in table 2.7. Evidence that all the commodity prices in Mexico (yellow corn, white corn, sorghum, wheat, beef, and pork) respond to shocks in the long-run equilibrium is strong (p-values of 0.01 and lower). The null hypothesis of weak exogeneity is not rejected for any of the U.S. prices. These results suggest that the long-run relationships embedded in the data are of interest for price discovery in Mexico, but not for price discovery in subsequent periods in the case of U.S. commodities. The fact that price discovery takes place in commodity price series in the U.S. is consistent with previous expectations since trade flow of grains is practically unidirectional (from the U.S. to Mexico, see Appendix A).

Innovation accounting

Contemporaneous innovations from the error correction model are introduced to TETRAD IV (TETRAD IV 2004). The causal structure from the greedy equivalence search (GES) algorithm (Chickering 2002) is shown in figure 2.4. Contemporaneous price information flows from sorghum in the U.S. to sorghum in Mexico influences price of yellow corn and price of beef in Mexico. This is a relevant finding on how price information in U.S. agricultural markets flows within the same period of time into agricultural markets in Mexico. Information from the U.S. market flows in contemporaneous time to the Mexican market also through the edge that goes from U.S.

wheat price to yellow corn price in Mexico. The price of yellow corn in Mexico passes information to price of white corn in Mexico, while this last price contemporaneously affects the price of pork in Mexico. Innovations of wheat price in Mexico stand alone in contemporaneous time, as well as the innovation of crude oil price.

Figure 2.4. Patterns of causal flows among eleven commodity markets, as determined by the GES* algorithm embedded in TETRAD IV (2004).



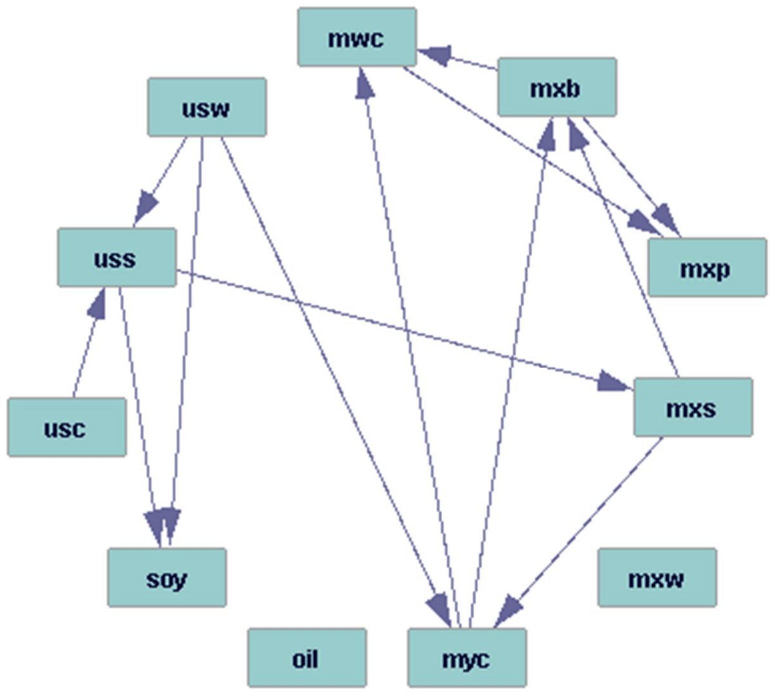
*GES=greedy equivalence search.

Particularly interesting is the finding that the Mexican yellow corn market, along with domestic sorghum prices, passes information directly to the beef market. Historically, Mexican cattle were mainly grass-fed (Zahniser and Coyle 2004). As discussed in Peel, Mathews, and Johnson (2011), in much of Mexico market preferences for grain-fed beef are increasing rapidly, relative to traditionally produced grass-fed beef. Growing consumer demand for meat and changing consumer preferences for high-quality beef is driving the expansion of semi-intensive and intensive cattle production systems in Mexico. More intensive production usually implies younger animals at slaughter with leaner meat, brighter meat color and smoother meat texture. Grain-fed beef production results in greater use of feed grains. Traditionally, grain sorghum has been the principal feed grain in Mexico, while white corn and yellow corn are both used (and preferred) in some regions. Wheat is predominantly used in other areas for feed purposes. The use of yellow corn in feedlot rations in Mexico has increased dramatically in recent years (Peel, Mathews, and Johnson 2011). In contemporaneous time beef market is receiving information from the domestic sorghum price as well as the domestic yellow corn price, which in turn are affected by innovations in grain prices in the U.S. market. Supporting this finding is the fact that industry estimates indicate that cattle production cost in Mexico has increased at least 37 percent because of higher international and national higher grain prices, due to the recent U.S. drought (Hernandez and Branson 2012).

It is also worth noting that increased demand and growing preferences for higher quality meat in Mexico are being met with a larger share of U.S. beef exported to Mexico. Mexico is the largest export market for U.S. beef and beef products (Peel, Mathews, and Johnson 2011). This may represent another important channel of information flow among prices in the two countries.

Turning back to the description of the directed graph, the GES algorithm (See Chickering 2002) was not able to unambiguously assign the direction of edges that connect some prices in the U.S., namely the relationship between corn and sorghum, sorghum and wheat, and sorghum and soybeans. In order to obtain information about the direction of the cited edges, a PC algorithm (see Palma et al. (2010) for description) embedded in TETRAD IV was used at a confidence level that allows detecting a direction of all edges. Awokuse and Bessler (2003) provide an example where a significance level in the neighborhood of 30% is required to find a clear structural ordering. A confidence level of 30% yields unambiguous causal ordering. Specifically, for the U.S. market, in contemporaneous time innovation in corn price affect the price of sorghum (usc→uss), innovations in wheat price move prices of sorghum as well as soybean prices (usw→uss, and usw→soy), and innovations is sorghum price affect the price of soybeans (uss→soy). This new information was included in the estimation of the impulse response functions. Modified causal information flows are given in figure 2.5.

Figure. 2.5. Complete patterns of causal flows among eleven commodity markets, as determined by the GES* algorithm and PC algorithm embedded in TETRAD IV (2004).



*GES=greedy equivalence search. **PC=algorithm based on independence tests.

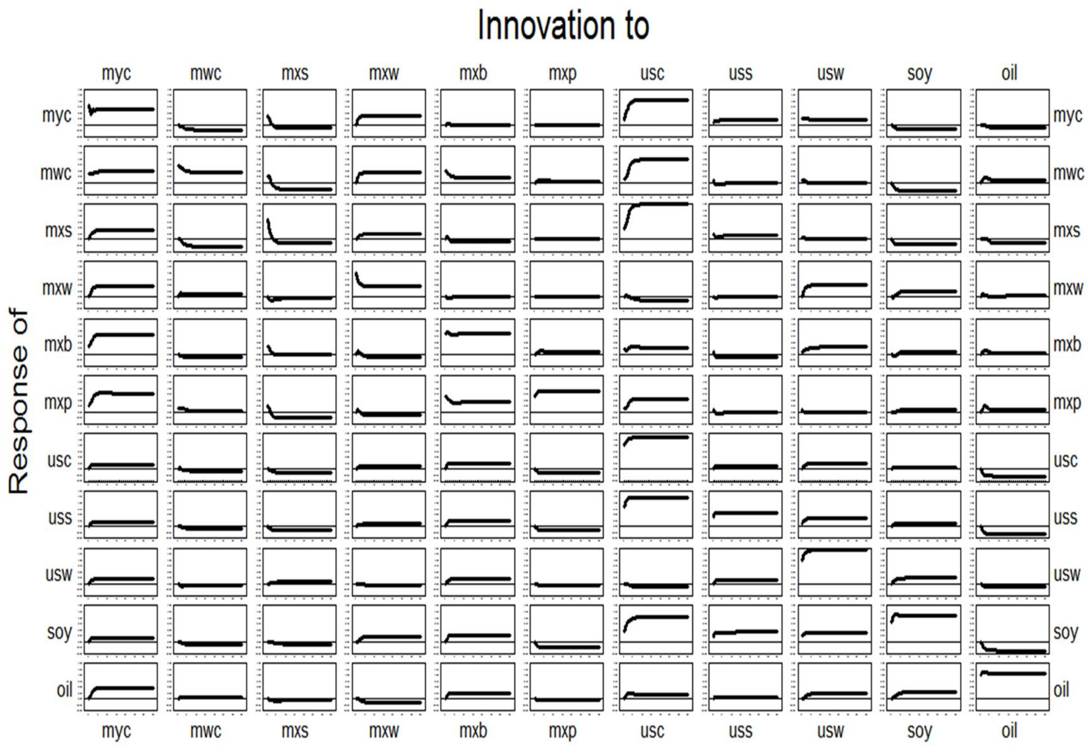
Complete patterns of causal flows among the eleven commodity markets were used for innovation accounting. As far as impulse response functions, Figure 2.6 gives the dynamic response of each commodity price series to a one-time only shock in each series. This is estimated through the equivalent levels VAR representation. Each sub-figure (row-column combination) shows the response of each series labeled in the corresponding row to a one-time shock in the series labeled in the corresponding column (top identifier). Diagonal elements in figure 2.6 show the responses to an own price shock, all of which are positive. All commodity prices in Mexico respond positively to shocks in the yellow corn price in Mexico. Shocks in wheat price in Mexico affect positively grain prices within the same country (yellow corn, white corn, and sorghum), but not meat prices (beef and pork). As for the meat market in Mexico, shocks in beef price affect positively the price of pork, a result that was expected since these products are substitutes. Given a price shock in the pork market, the price of beef has a positive, although small, response.

Shocks in yellow corn in the U.S. market appear to have the strongest positive responses not only in the Mexican market (yellow corn, white corn, as well as sorghum) but also in the U.S. market (sorghum and soybeans).

As discussed in Becketti (2013), unlike impulse response in stationary VAR, the orthogonalized impulse response functions in a VECM need not die out over time. Impulses that die out are called transitory, while those that so not are termed permanent.

An impulse response function is an innovation accounting technique that has the objective of showing graphically how each series reacts to a one time shock in each series, including itself. It is not the purpose of this device to give precise metrics. For a more precise measure of the dynamic interactions among the eleven commodity price series, the forecast error variance decomposition is described next.

Figure 2.6. Response of each commodity price series to a one-time-only shock in each series from the equivalent levels vector autoregressive representation.



Analysis of forecast error variance (FEV) decomposition is a well-known innovation accounting method for disentangling relationships among the time series in the system. As pointed out by Bessler (1984) the analysis of FEV decompositions is related to Granger causality, in the sense that both methods provide evidence on the existence of a causal relation between variables. The FEV decompositions offers more than does Granger causality analysis since FEV decomposition also provides a measure of the strength and dynamic timing of the relationship among variables, while Granger causality only provides evidence of existence of such a relation. As discussed in Babula, Bessler and Payne (2004), FEV decomposition reflect the causal relations embedded in the levels VAR model (equation 4.2) and the causal ordering among the eleven variables in contemporaneous time that was obtained using Bessler and Akleman's DAG/Bernanke modeling methods.

As mentioned before, forecast error variance for each series is decomposed at different time horizons. In this particular case, the timeframe reported in table 2.6 includes zero, one, twelve and twenty-four months ahead. Each sub-panel of the table shows the percentage of uncertainty in each series (in every row) that is accounted for by previous information discovered in its own past and the past of the other ten series (from every column). The values (percentages) in each row sum up to a hundred (within rounding error). Description of forecast error variance decomposition for each price series follows.

Decompositions on yellow corn price in Mexico show that almost three fourths (72.71%) of the variations in that price is accounted for its own innovations at contemporaneous time, and 14.5% coming from innovations in the domestic sorghum price. The yellow corn price in Mexico is increasingly affected, as moving to the longer-run, by innovations in the U.S. yellow corn price. At 1 period-ahead horizon innovations in the latter affect the former in 19.51%. This contribution increases to 52.43% when considering 12 periods ahead.

White corn price in Mexico is hardly exogenous in the very short-run, with 52.62% and 48.67% of its behavior attributed to own variation at zero and one periods ahead, respectively. As time progresses, white corn prices innovations' importance in explaining variability in white corn price behavior falls below 20%. Aside from own variation, the two most important influences on the Mexican white corn price behavior are movements in prices of U.S. yellow corn, which increases up to 46.71% in the long-run and innovations in the domestic price of yellow corn in Mexico. It is worth noticing that the contribution from the domestic yellow corn price is steady between 12% and 13%, which may be related to some substitutability between yellow and white corn. As mentioned by Zahniser and Coyle (2004), yellow corn is mainly used as animal feed and white corn is cultivated primarily for human consumption; however, food-grade yellow corn is also used to make corn flakes, chips, beer, and other foods, whereas white corn can be used as animal feed.

Prices of yellow corn and white corn in Mexico are greatly affected in the longer-run by innovations arising in the U.S. corn market, which is not a surprising result given the important trade relationship between the two countries. Finally, the third source of variation for white corn in Mexico is the domestic wheat market, which accounts for more than 10% of the white corn price behavior in the longer-run. This relationship would be explained from substitution for human consumption, since both grains (white corn and wheat) can be used to make tortillas, an important staple food in Mexican diet.

Price of sorghum in Mexico is the most endogenous of all modeled prices in the long-run, since its own variation accounts for only 2.23% of the sorghum price movements at a 24-month horizon. This price is highly exogenous in contemporaneous time, short-run near-exogeneity rapidly falls to about 47% at 1 period-ahead horizon. In the longer-run horizons, more than 80% of the variation in the price of sorghum in

Mexico is explained by information arising in the U.S. yellow corn market. Innovations in the yellow corn market in Mexico are the second major source of variability of Mexican sorghum price in the longer-run. The impact of yellow corn prices, from both markets, on Mexican sorghum at the longer-run horizons likely reflects the high substitution between sorghum and yellow corn as animal feed in Mexico.

As for price of wheat in Mexico, it is exogenous in the very short-run, as the total variation of its price is explained from own innovations in contemporaneous time. In the longer-run it maintains as its own main source of variation, although it drops to one third of the total variation as self-explained. In the long-run U.S. wheat price noticeably explains up to 31.11% of the variation in the Mexican wheat market. Interestingly, innovations in the Mexican white corn market explain only 2.64% of the national wheat price variation.

Price of beef is highly exogenous to the system, with more than 70% of own price innovation explaining its behavior during contemporaneous time and one period ahead. Innovations in the Mexican yellow corn market explain almost 40% of the beef price variation in the long-run.

Regarding pork price in Mexico, it is the second most endogenous variable (only second with respect to endogeneity level to U.S. sorghum price) in contemporaneous time. Information arising in the pork market explains only 40.24% of the behavior of its own price. Beef price variation accounts for 40.37% of pork price variation at the first horizon (contemporaneous time). Substitution effects may tie the prices of these two meats together in the short-run. At longer-term horizons variations in the price of yellow corn in Mexico have important influence on the pork price (around 30%). Given that 12 and 24 months ahead is a long enough period to make production decisions in the hog industry, higher feed cost, such as higher yellow corn price, can influence production levels, and hence pork prices.

Yellow corn price in the U.S. is highly exogenous in the very short-run, as it explains 100% of its own variation at horizon 0 and 93.3% in one period ahead. In the longer-run (12 periods ahead), yellow corn price in the U.S. is modestly explained by innovations in crude oil price (3.25%). Error variance decompositions for 24 periods ahead are very similar as those for 12 periods ahead. Among the variables modeled, U.S. corn is one of the most exogenous variables in the long-run.

U.S. sorghum price is clearly an endogenous player in the system. Actually, it is the most endogenous variable in contemporaneous time, with only 17.70% of its own variation explained by information discovered in its own series. U.S. yellow corn variation accounts for most of the sorghum price movements in all time horizons considered, being 68.62% the lowest contribution at 24 periods ahead. As expected, U.S. sorghum price, and prices of all U.S. agricultural commodities in the model, are only affected in a negligible manner from innovations arising in agricultural Mexican markets.

Turning to the case of price of wheat in the U.S., it is the most exogenous variable at every time horizon considered in this analysis, with more than 90% of its behavior attributed to own variation.

Soybeans price in the U.S. is an exogenous variable in the short-run, with more than 60% of the price variation self-explained. However, as moving to the longer-run information discovered in the U.S. yellow corn market becomes more relevant at explaining innovations in the soybean market. This result can be explained as the two crops compete for land. Over the long-run, the demand for land to grow corn would affect soybeans production, and hence the price of soybeans. See table 2.8 for detailed information on forecast error variance decomposition.

Finally, with respect to the price of crude oil, it is exogenous in the very short-run. However, for larger periods ahead there are shocks in other markets that affect the price of oil. In particular, the price of yellow corn in Mexico seems to have the larger impact on oil price for 12 periods (10.91%) and for 24 periods ahead (12.15%). Although this is a surprising result, it is not necessarily a “bad” result. One way to interpret would be the presence of a latent variable that is affecting both prices. Such a variable may be related to the level of economic growth or a policy that is linking the price of yellow corn and crude oil. Stated alternatively, Mexican corn price receives information from commodity prices in the U.S., while oil price reflects worldwide economic activity; as price in Mexican corn increases this may signal increased economic activity in the U.S. and in the world.

Table 2.8. Forecast Error Variance Decomposition of Eleven Commodity Prices.

Horizon (months ahead)	MYC	MWC	MXS	MXW	MXB	MXP	USC	USS	USW	SOY	OIL
Yellow Corn MX (MYC)											
0	72.71	0.00	14.50	0.00	0.00	0.00	5.02	1.10	6.67	0.00	0.00
1	53.94	0.07	10.56	4.39	0.35	0.03	19.51	2.47	8.33	0.35	0.00
12	27.43	1.54	1.62	8.31	0.06	0.01	52.43	2.39	3.87	1.76	0.59
24	24.32	1.82	1.20	8.43	0.04	0.00	55.87	2.38	3.29	1.84	0.81
White Corn MX (MWC)											
0	12.85	52.65	6.90	0.00	23.33	0.00	2.39	0.52	1.36	0.00	0.00
1	12.98	48.67	6.62	3.51	21.19	0.04	3.42	0.44	1.18	1.02	0.94
12	12.40	19.06	3.83	10.38	5.87	0.32	40.06	0.25	0.18	6.39	1.26
24	12.06	14.21	4.41	10.78	3.98	0.27	46.71	0.15	0.10	6.60	0.73
Sorghum MX (MXS)											
0	0.00	0.00	70.05	0.00	0.00	0.00	24.23	5.30	0.42	0.00	0.00
1	3.71	0.06	47.77	0.43	0.71	0.00	41.87	3.83	0.71	0.76	0.14
12	6.87	2.45	4.39	2.18	0.45	0.02	80.05	1.29	0.07	1.66	0.57
24	6.83	2.79	2.23	2.21	0.46	0.01	81.87	1.21	0.04	1.56	0.79
Wheat MX (MXW)											
0	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	1.81	1.90	0.57	88.52	0.29	0.07	0.47	0.12	5.30	0.08	0.88
12	20.69	2.36	1.24	42.55	0.11	0.04	1.08	0.04	26.99	4.53	0.38
24	23.33	2.64	0.82	33.56	0.09	0.02	2.01	0.03	31.11	6.10	0.29
Beef MX (MXB)											
0	10.26	0.00	10.57	0.00	73.48	0.00	3.66	0.80	1.24	0.00	0.00
1	14.46	0.14	7.67	0.98	71.35	0.17	2.76	0.48	1.57	0.06	0.35
12	37.15	0.83	1.14	0.52	48.57	0.84	5.05	0.59	4.24	0.47	0.58
24	39.92	0.91	0.52	0.62	45.91	0.82	4.85	0.54	4.82	0.69	0.40
Pork MX (MXP)											
0	7.34	1.87	6.55	0.00	40.37	40.24	2.27	0.50	0.86	0.00	0.00
1	10.17	2.06	4.23	0.29	32.44	46.83	2.32	0.24	0.39	0.01	1.02
12	28.36	0.64	2.99	0.85	11.67	41.63	12.17	0.19	0.08	0.38	1.04
24	30.55	0.40	3.18	1.02	9.86	39.96	13.66	0.14	0.04	0.54	0.67
Yellow Corn US (USC)											
0	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00
1	1.05	0.11	0.04	0.12	2.10	0.31	93.30	0.56	0.98	0.25	1.17
12	1.94	0.13	0.58	0.79	2.87	0.70	85.99	0.75	2.64	0.36	3.25
24	2.05	0.15	0.70	0.84	2.85	0.74	85.18	0.78	2.78	0.37	3.55
Sorghum US (USS)											
0	0.00	0.00	0.00	0.00	0.00	0.00	80.89	17.70	1.41	0.00	0.00
1	0.83	0.03	0.39	0.07	1.42	0.41	75.38	17.42	2.52	0.21	1.32
12	1.61	0.21	1.10	0.35	2.19	1.07	69.31	14.65	4.66	0.49	4.36
24	1.68	0.24	1.20	0.37	2.24	1.13	68.62	14.37	4.88	0.53	4.73
Wheat US (USW)											
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00
1	1.18	0.17	0.00	0.00	0.45	0.02	0.02	0.39	97.26	0.38	0.12
12	1.72	0.24	0.24	0.07	1.81	0.11	0.43	0.93	91.70	2.16	0.58
24	1.78	0.21	0.36	0.11	2.02	0.12	0.68	0.94	90.75	2.47	0.57
Soybean US (SOY)											
0	0.00	0.00	0.00	0.00	0.00	0.00	19.42	4.25	7.27	69.07	0.00
1	0.92	0.00	0.00	0.00	1.06	0.80	22.62	5.59	5.92	61.89	1.19
12	0.65	0.50	0.21	1.22	2.14	2.23	32.92	5.55	4.75	45.48	4.35
24	0.62	0.62	0.32	1.46	2.09	2.33	35.10	5.51	4.52	42.68	4.76
Oil WTI (OIL)											
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
1	1.66	0.22	0.00	0.00	1.01	0.02	1.43	0.20	0.03	0.29	95.15
12	10.68	0.25	0.18	0.95	3.47	0.16	2.62	0.33	2.34	3.55	75.48
24	12.10	0.25	0.15	1.29	3.89	0.18	2.22	0.34	2.90	4.44	72.23

The underlying relationship between corn price and crude oil price, as well as the identification of economic variables related to these two prices could be analyzed in a more general model, including all relevant variables that determine commodity prices. A model that can comprise all such information is a Factor-Augmented Vector Autoregressive (FAVAR) model. The analysis of all relevant variables, to include all possible latent variables in the model, is beyond the scope of this research.

As a forecasting exercise, the parameters estimated by the VECM were used to perform recursive forecasts of the commodity price series. From these estimates, the Theil's U statistics (measure of relative forecast accuracy) for the case of yellow corn and white corn in Mexico are 0.974 and 0.959, respectively. This means that the forecasting using model's parameters is better than a random walk forecast. Graphical representations of the recursive forecasts are presented in Appendix C.

II.6. Conclusions and Opportunities for Further Research

In this paper, the dynamic information flows among monthly prices of agricultural commodities in the U.S. and Mexico for the years 2000-2012 are analyzed. Error correction models and directed acyclical graphs are employed with observational data to sort-out the dynamic causal relationships among prices for important agricultural commodities in both countries.

First, no structural change in commodity prices for the period under analysis was found for any of the commodity prices. Unlike in previous studies using VECM the results in this paper indicate the existence of long-run relationships among grain prices in the U.S. and Mexico. This may be because of the use of more recent data, emanating from an environment with lower trade restrictions and distortions between the two countries. Analyses of impulse response simulations and forecast error variance decompositions shed light into price dynamics in these markets. Results suggest that price discovery takes place in U.S. grain markets. Commodity prices in the U.S. market are highly influenced by its own historical innovations. U.S. grain prices have a consistently strong impact on price movements in Mexican agricultural markets in the long-run. Information flow among grain markets in Mexico and from grain to cattle markets is also identified finding that price of beef is affected contemporaneously by innovations in the sorghum market as well as in the yellow corn market.

Given the recent increase in grain price volatility (World Bank 2012) and the increased level of integration in agricultural markets between Mexico and the U.S., as found in this study, it makes more relevant the use of price risk management tools. It is worth mentioning that in late 2012, the Mexican Derivatives Exchange (MexDer) launched a local corn futures contract for the first time. This will bring opportunities to Mexican agricultural producers and consumers to interact in the price formation process and to be able to take advantage of risk management instruments.

Opportunities for further research include the use of data to be generated by the newly established local corn futures market in Mexico. The estimation of a model using prices in domestic currencies for Mexico and the U.S. to capture the effects from the exchange rate represents also another research opportunity. The use of probability forecasting techniques is also a way to extend the present work. Factor analysis models are an alternative approach to analyze the market integration including all possible relevant variables that affect commodity prices in both countries. Another alternative is to study consumer prices and how they differ from processor or producer prices. That is, study price transmission across the food marketing chain in Mexico. Inclusion of transportation cost to the model is yet another way in which this work can be extended.

CHAPTER III

FOOD DEMAND, FOOD PRICES AND WELFARE ANALYSIS UTILIZING EASI MODEL

III.1. Introduction

The proportion of Mexican population living below the food poverty line[6] increased from 13.8% in 2006 to 18.8% in 2010. The proportion of population with income below the assets poverty line increased from 42.7% to 51.3% over the same period (CONEVAL 2011a). This outcome is believed to be the result of several factors including the increase in local and global food prices. The increase in food prices has affected the purchasing power of the Mexican households in a more significant way from the third quarter of 2008. From then until 2010, the food basket price in Mexico increased faster than the global consumer price index (CONEVAL 2012).

Following the world food price spike in 2008, an increased attention has been paid on improving the understanding of the drivers of food prices and their impacts on poverty (World Bank 2012). Several studies have focused on evaluating this impact, especially in developing countries. Ivanic and Martin (2008) pointed out that despite widespread concern about the impacts of high food prices on poverty and on social

[6] The Evaluating National Council of the Social Development Policy (CONEVAL, Spanish acronym) is in charge of defining official poverty lines in Mexico. Poverty lines are measured in monthly per capita income, adjusted monthly by the consumer price index, and classified for rural and urban households. The food poverty line is a monetary measure of the resources needed to buy a representative food basket in Mexico. For the last quarter of 2010, the food poverty line was MX$797.29 for a rural household, and MX$1,074.28 for an urban household. Likewise, the assets poverty line is defined as the income needed to afford food, education, health, clothing, housing and transportation. The assets poverty line was MX$1,446.76 for a rural household, and MX$2,155.43 for a urban household during the last quarter of 2010.

stability; little information appears to be available on actual impacts. The authors calculated first-order welfare changes in households for nine low-income countries. Among the findings they describe that overall impact of higher food prices on poverty is adverse especially for net consumers of food. They found that the welfare impact varies by commodity and by country.

As for studies that have focused on Mexico, Porto (2010) found that increase in price of corn, one of the most important food products consumed in rural in Mexico, leads to a negative economic impact. The author stated that poor households tend to suffer higher losses since they consume more corn than rich households. Chávez Martín del Campo et al. (2008) concluded that the recent upsurge in global food prices affected more than proportionately the poorer sectors of the population. They also found that the substitution ability of households helped to cushion the wealth loss of society's poorest segments.

Wood, Nelson and Nogueira (2012) predicted the number of Mexican households falling below the food poverty line because of hypothetical increase in food prices. They used a subsample from the 2006 ENIGH Mexican household survey and an Almost Ideal Demand System (AIDS), assuming linear Engel curves. In particular, a 50% increase in the price of cereal and meat was estimated to cause an increment of up to 6.0% in poverty. They calculated compensating variations for food groups, accounting for differences between urban and rural population and poverty status. The authors indicated the need for estimating a complete food demand system that accounts for substitution in order to obtain accurate measures of welfare and poverty effects due to food price escalation.

The objective of this research is to analyze the impact of rising food prices on poverty and welfare of Mexican households by accounting for the substitution among food commodity groups and relaxing the assumption of linear Engel curves. This paper presents an application of the Exact Affine Stone Index (EASI) demand system developed by Lewbel and Pendakur (2009). Advantages of this model over commonly used demand models include: a) EASI allows for complex Engel curves which vary across goods; b) the error term can be interpreted as unobserved preference heterogeneity; and c) an approximate model can be estimated by linear methods. This paper would represent one of the first applications of the EASI model for welfare analysis. Interpretation of error terms as unobserved preference heterogeneity allows the estimation of a distribution of welfare effects instead of only average welfare effects as it is done in traditional methods. Contributions of this paper also include the empirical estimation of equivalence scales for households with different demographic characteristics in Mexico. These equivalence scales allow inter-household comparisons of welfare effects and the estimation of meaningful food poverty impacts due to the actual increase in food prices in Mexico from 2006 to 2010.

This chapter is organized as follows: Section III.2 presents details about the model and a brief description on welfare effects estimation methods; Section III.3 describes the household survey data used in this paper, as well as a discussion of consumer price indexes of food used in welfare effects estimations. Next, Section III.4

contains the discussion of the estimation results for semi-elasticities, elasticities, equivalence scales, welfare effects as well as implications for food poverty in Mexico. Section III.5 concludes the chapter and discusses possible extensions of this research.

III.2. The Model

The analysis is performed using the Exact Affine Stone Index (EASI) implicit Marshallian demand system. This approach is superior to the Almost Ideal Demand System of Deaton and Muellbauer (1980) in the sense that EASI demand can have any rank and its Engel curves for every commodity are not constrained by Gorman rank restrictions (Lewbel and Pendakur 2009). EASI error terms can be interpreted as random utility parameters that represent unobserved heterogeneity of preferences. EASI demand functions are linear in parameters, a property that parallels AIDS in terms of convenience at estimation (Lewbel and Pendakur 2009).

The model, without two-way interactions between variables y, $\boldsymbol{z}\ and\ \boldsymbol{p}$, is specified as follows:

$$w^j = \sum_{r=1}^{R} b_r^j\,(y)^r + \sum_{t=1}^{T} g_t^j\, z_t + \sum_{k=1}^{J} a^{jk} ln\, p^k + \varepsilon^j \qquad (3.1)$$

Where w^j, the budget share of good j; z_t is a vector of demographic characteristics of the households; $ln\, p^k$ is the log of prices of good k; ε^j is a vector of unobserved preference heterogeneity parameters for the consumer; while b_r^j, g_t^j, and a^{jk} are parameters to be estimated. The parameters b_r^j define the shape of the Engel curve. The implicit utility is given by

$$y = \ln x - \sum_{j=1}^{J} w^j ln\, p^j + \frac{1}{2}\sum_{j=1}^{J}\sum_{k=1}^{J} a^{jk} ln\, p^j\, ln\, p^k$$

which can be approximated with $\tilde{y} = \ln x - \sum_{j=1}^{J} \overline{w}^j ln\, p^j$ to obtain initial values for estimation. The estimation is performed by iterated 3-stage-least-squares (3SLS) as described in Pendakur (2009). Standard demand restrictions, such as adding up, homogeneity and symmetry are imposed as described in Lewbel and Pendakur (2009).

Using this model, elasticities are estimated and welfare effects of shocks in food prices are assessed. The Hicksian (compensated) price semi-elasticities for the implicit Marshallian demand system is calculated as the first derivative of (3.1) with respect to price. As mentioned by Lewbel and Pendakur (2009) in this framework price effects are most easily evaluated by analyzing budget-share semi-elasticities. As specified by Pendakur (2009), the EASI demand system is dual to cost function and consumer surplus measures originated from price changes are not complicated to calculate. It is assumed that the expenditure reported by a given household is the minimum nominal expenditure to attain a utility level u, giving a vector of prices $\boldsymbol{p}$. Let $C(\boldsymbol{p}_0, u, \boldsymbol{z}, \varepsilon)$ be the cost function of a household reporting budget shares $\boldsymbol{w}_0$ and implicit utility level $y = u$, and unobserved utility parameters ε, the welfare change measure for the price change from $\boldsymbol{p}_0$ to $\boldsymbol{p}_1$ is the log cost of living index and can be written in terms of observables as:

$$\ln\left[\frac{C(\boldsymbol{p}_1, u, \boldsymbol{z}, \varepsilon)}{C(\boldsymbol{p}_0, u, \boldsymbol{z}, \varepsilon)}\right] = \sum_{j=1}^{J} w_0^j \left(lnp_1^j - lnp_0^j\right)$$

$$+\frac{1}{2}\sum_{j=1}^{J}\sum_{k=1}^{J} a^{jk}\left(lnp_1^j - lnp_0^j\right)\left(lnp_1^j - lnp_0^j\right) \qquad (3.2)$$

This cost of living index captures two effects: 1) first-order effects are driven by expenditure shares, and 2) the second term captures substitution effects –second-order effects- (Lewbel and Pendakur 2009). The welfare effect calculated by equation (3.2) is related to the reference household. A distribution of welfare effects is obtained after replacing w_0^j for the budget shares of every household in the sample.

In order to be able to make inter-household comparison of welfare effects, equivalence scales are estimated. Lewbel (1997) formally defines an equivalence scale for a household with demographic characteristics $\boldsymbol{z}$ as “the amount by which a reference household’s expenditures would need to be multiplied to yield expenditures sufficient for the given household to attain the same utility level as the reference household”. Alternatively, Lewbel and Pendakur 2006 define an equivalence scale as a measure of “the cost of living of a household of a given size and demographic composition, relative to the cost of living of a reference household (usually a single adult), when both households attain the same level of utility or standard of living.” Selected reference household in this work include a unitary household, with a median age, living in an urban setting. This definition follows the usual definition of a reference household as a unitary household, plus two demographic variables typically used in this kind of analyses, such as defining rural and urban households and the age of the household head.

In this paper, estimation of equivalence scales is performed by Generalized Method of Moments (GMM). Independent of base (IB) equivalence scales are considered (see online appendix of Lewbel and Pendakur (2009) for technical details). The corresponding net welfare effect is subtracted from the per capita income for every household. Updated per capita income is then compared to the Mexican food poverty line to evaluate the effects of increasing food prices on poverty levels.

III.3. The Data

The data used in this study was obtained from the National Household Income and Expenditure Survey (ENIGH, Spanish acronym) collected by the Mexican Statistical Institute (INEGI) during the third quarter of 2010. ENIGH is a survey of a nationally representative sample of Mexican households, which contains detailed information on household composition, income and expenditure. The dataset provides detailed information on food consumption (at home and away-from-home) and the money value of food consumed during one week. From this dataset, six food commodity groups that represent the Mexican diet were created –from a disaggregated list of about 250 commodities- to estimate a complete food demand system. The food groups used in our analysis are: 1) corn tortillas and corn products, 2) cereals, 3) meats, 4) dairy, 5) fruits and vegetables, and 6) other foods. Our final sample consists of over 27,000 households, which purchased at least one of the foods during the week of data collection.

For welfare effects, the actual variation of prices from 2006 to 2010 was taken into consideration. Variation of consumer price index for every food group was calculated for the period under analysis. Data on price indexes was obtained from INEGI, which is the official source for this type of information in Mexico. The information on the official food poverty lines was obtained from the National Council for Evaluation of Social Development Policy (CONEVAL).

III.4. Results

The summary statistics of the variables used in the model are presented in table 3.1. With respect to budget shares of the food groups under study, we observe that the average food budget share devoted to corn tortilla is 10%, which is higher than the corresponding budget share for the overall cereal group, 8%. This is consistent with the importance of corn tortilla in the Mexican diet. The average budget share for dairy products is 13%, whereas for fruits and vegetables is 16%. Meat products account for an average of 20% of the food budget share, and other foods, which include prepared foods and food-away-from-home, has a mean of 33% of the total food budget share.

It is worth noting that, since we are working with aggregated food commodity groups, censoring is not an issue. The percentage of zeroes in budget shares is at or less than 10 percent for each food category. It is assumed that this low percentage of zeroes does not cause a problem in the estimation.

The EASI model allows us to take into consideration a reference household. In this paper, we will consider as a reference a unitary household (a one-person household), whose age is 47 years old, and does not live in a rural community. The reference household is located in a town/city with more than 2,500 inhabitants[7].

The vector of demographic variables, $\boldsymbol{z}$, consist of: 1) $z1$, a count variable that indicates the number of household members minus one, yielding a value of zero for the unitary (reference) household; 2) $z2$, a variable that indicates the age of the head of the household minus 47, here the variable takes on value zero for those households with household head's age equals 47; and 3) $z3$, a dichotomous variable that takes on a value of zero for the reference household type, which is a urban household, and one otherwise. In summary, following Lewbel and Pendakur (2009), the vector of demographic variables for the reference type is a vector of zeroes. For the reference type the vector of unobserved preference characteristics satisfies $\boldsymbol{\varepsilon} = 0$. Summary statistics for the described demographic variables normalized with respect to the reference household can be found in table 3.1.

Prices are normalized with respect to the price vector that the reference household faces. This would be a unitary household headed by a 47-year-old person that resides in an urban setting and has median food expenditure among the households in this group. The normalized price vector for the reference consumer is (1,1,1,1,1,1). These observations define the base price vector, with log prices this vector is (0,0,0,0,0,0). The descriptive statistics for the normalized log of prices and normalized log of food expenditure for the reference household are presented also in table 3.1.

[7] The analysis was performed taking an alternative reference household in estimation. Final results on welfare and poverty impacts were practically unafected by this change in reference household.

Table 3.1 Summary Statistics (n=27,398)

Variable		**Mean**	**Std. Dev.**
Budget Shares	Tortilla	0.10	0.11
	Cereal	0.08	0.08
	Meat	0.20	0.15
	Dairy	0.13	0.10
	Fruits and Vegetables	0.16	0.12
	Other Food	0.33	0.24
Demographics	Household Members - 1	2.90	1.98
	Household Head Age - 47	1.39	15.69
	Rural Setting = 1	0.22	0.41
Log-Prices*	Tortilla	-0.12	0.29
	Cereal	-0.30	0.47
	Meat	-0.51	0.33
	Dairy	0.14	0.48
	Fruits and Vegetables	0.03	0.37
	Other Foods	-0.51	1.01
Log-Expenditure*	x	0.16	0.75

*Normalized with respect to the reference household type.

As for the shape of Engel curves, there is evidence of non-linearity for most commodity groups, which justifies the use of a model that accounts for unrestricted Engel curves, such as the EASI model, to consistently estimate elasticities and welfare effects. The package developed by Hoareau et al. (2012) was used to graph the Engel curves for the six food groups. In figure 3.1, Engel curves from the EASI package of Hoareau et al. (2012) are presented. As described by the authors, curves (black, blue and red) correspond to three increasing levels of smoothing. Likewise, each green circle in the graph represents the median of the budget share for the given percentile of total expenditure.

An advantage of the EASI model is that one does not need to know nor impose in advance the shape of Engel curves, but instead we can let the data show the underlying shape. In our case, it seems that the non-linearity of Engel curves for the six food groups under analysis can be captured by a quadratic term. The system given by equation (3.1) was estimated with $r = 2$. Finding Engel curves not too far from linear for the case of food is consistent with previous literature. Using data from the U.K., Banks, Blundell, and Lewbel (1997) found that linear formulation provides a reasonable approximation for the food share curve. Lewbel and Pendakur (2009) found that the non-linearity of Engel curves for food-at-home and food-away-from-home in Canada is less pronounced than that of other budget shares, such as rent, furniture, household operation, recreation, etc. Wood, Nelson, and Nogueira (2012) found slight curvature of the shares of food categories against the log of total food expenditure in Mexico.

Figure 3.1 Engel curves for Tortilla, Cereals, Meat, Dairy, Fruit and Vegetables, and Other Goods using the package developed by Hoareau et al. (2012).

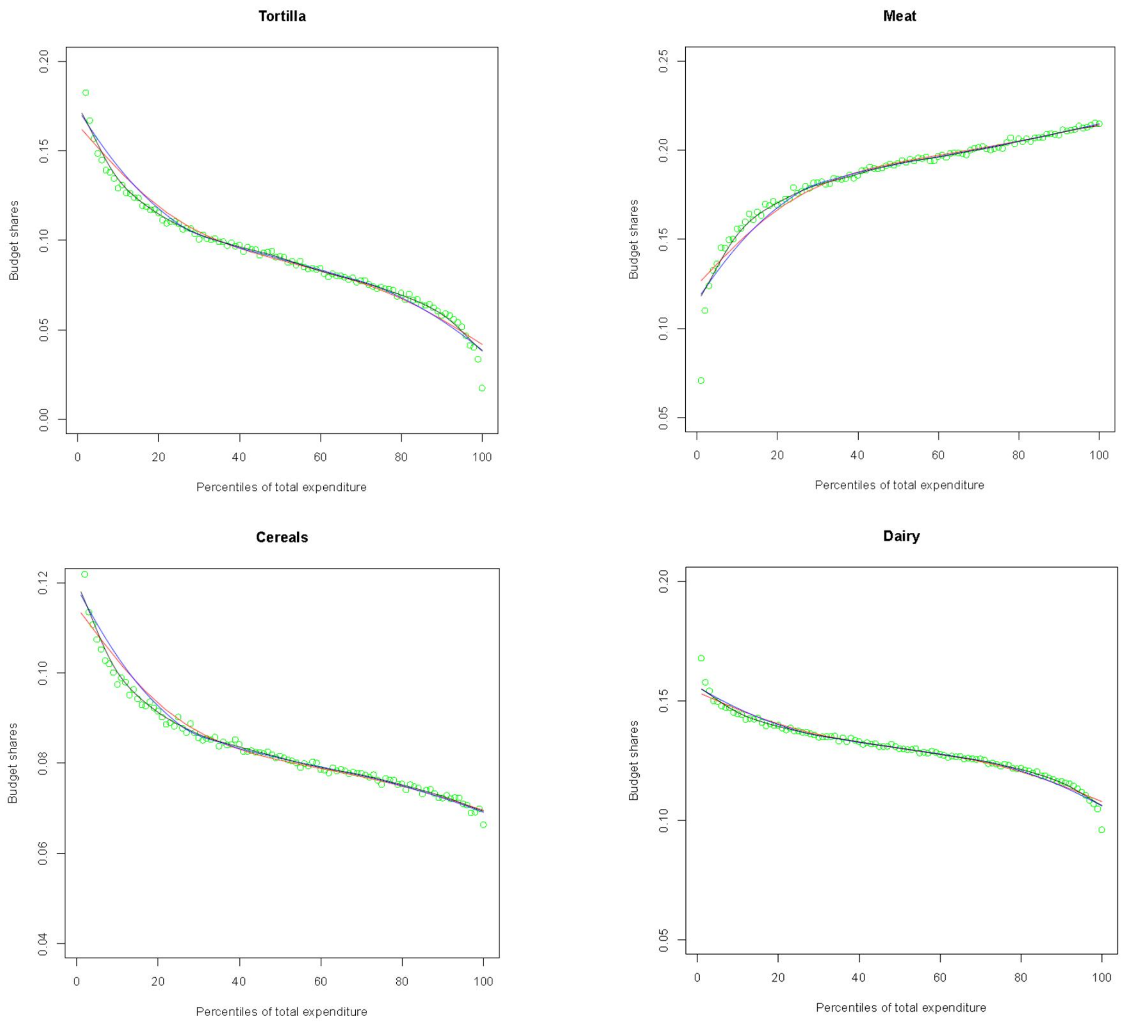
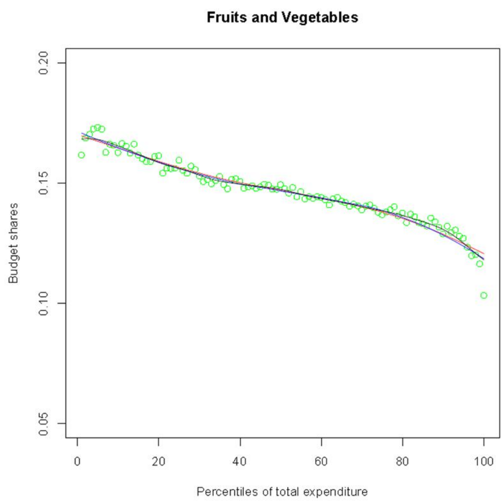
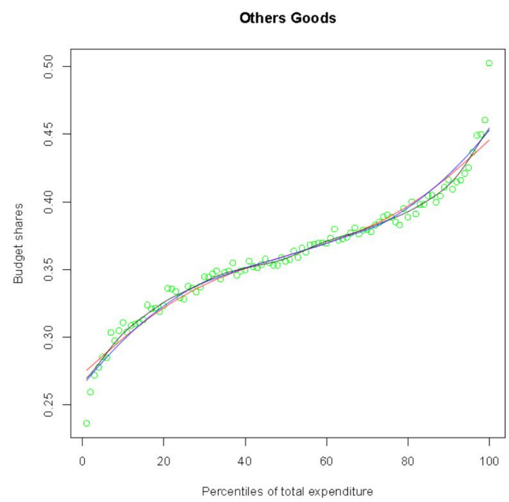


Figure 3.1 Continued.





Utilizing the data and the model described by equation 3.1, parameter estimates were obtained. Appendix E contains parameter estimated for the linearized EASI model for the reference household. Variable y presents the parameters for the implicit utility, which is followed by a number that represents the exponent of the polynomial. The last equation -other foods-, was dropped from the system to avoid the singularity problem of the error covariance matrix.

Regarding semi-elasticities of the budget shares for the reference household, these are reported in table 3.2. As for cross-price effects, the fact that most of the cross-price semi-elasticities are significant suggests that substitution effects are important. As an example, we can describe the case of tortillas with respect to fruits and vegetables, whose compensated cross-price semi-elasticity is 0.015. This implies that an increase of 10% in the price of fruits and vegetables is associated with an increase of 0.15

percentage points in the budget share for tortillas, as substitution effect. Similar analysis can be done for the rest of the off-diagonal elements of table 3.2.

The own-price compensated semi-elasticity for the cereal budget share is 0.015. This implies that a 10% increase in the price of cereal would be associated with a budget share 0.15 percentage points higher once expenditure is increased to reach the original level of utility. If the tortilla price rises by 10%, the tortilla budget share would be 0.07 percentage points lower, once expenditure is increased to compensate for the price increment and to reach the original level of utility.

Table 3.2 Compensated Budget-Share Semi-Elasticities for the Reference Household

Variable	Tortilla	Cereal	Meat	Dairy	Fruit & Veg.	Other Foods
Tortilla	-0.007***	0.004***	0.002*	0.007***	0.015***	-0.023***
Cereal	0.004***	0.015***	-0.004***	-0.002***	-0.006***	-0.007***
Meat	0.002*	-0.004***	0.002	0.013***	0.003***	-0.017***
Dairy	0.007***	-0.002***	0.013***	-0.01***	0.007***	-0.015***
Fruit & Veg.	0.015***	-0.006***	0.003**	0.007***	-0.007***	-0.012***
Other Foods	-0.023***	-0.007***	-0.017***	-0.015***	-0.012***	0.074***

*** p<0.01, ** p<0.05, * p<0.1

Note that not all own-price budget share semi-elasticities are negative. This does not imply that the concavity of the cost function is violated. In order to test this, a concavity test is conducted using the package developed by Hoareau et al. (2012). It was found that the EASI cost function is concave in more than 90% of the sample.[8]

[8] Concavity of cost is necessary and sufficient for negative semidefiniteness of both the Slutsky matrix and the normalized Slutsky matrix (Lewbel and Pendakur (2009).

It is possible to recover the compensated quantity derivatives. That is, the Slutsky terms can be recovered. Lewbel and Pendakur (2009) specify that the normalized Slutsky matrix, $\boldsymbol{S}$, is related to the compensated semi-elasticity matrix by $\boldsymbol{S} = \boldsymbol{\psi} + \boldsymbol{w}\boldsymbol{w}' - \boldsymbol{W}$. Here $\boldsymbol{\psi}$ is the compensated semi-elasticity matrix and $\boldsymbol{W} = diag(\boldsymbol{w})$. Table 3.3 shows the Slutsky matrix for the reference household type. Note that all own-price elements are negative. It was found that the demand for tortilla is highly inelastic, result that is consistent with the findings of the existing literature.

Table 3.3 Normalized Slutsky Matrix for the Reference Household Type

Variable	Tortilla	Cereal	Meat	Dairy	Fruit & Veg.	Other Foods
Tortilla	-0.040***	0.006***	0.007***	0.010***	0.018***	-0.002**
Cereal	0.006***	-0.024***	0.002*	0.001*	-0.002***	0.018***
Meat	0.007***	0.002*	-0.116***	0.025***	0.016***	0.066***
Dairy	0.010***	0.001*	0.025***	-0.092***	0.016***	0.039***
Fruit & Veg.	0.018***	-0.002***	0.016***	0.016***	-0.093***	0.045***
Other Foods	-0.002**	0.018***	0.066***	0.039***	0.045***	-0.166***

*** p<0.01, ** p<0.05, * p<0.1

Welfare analysis

The welfare effects of increased food prices for the reference household are calculated using equation (3.2) and parameter estimates from equation (3.1). Instead of considering hypothetical price changes, as done in previous studies, we are considering actual food price increments measured by the consumer price index for food groups in Mexico. All welfare estimation in this section takes into consideration the increase in price, as well as substitution effects, of five food groups: tortilla, cereal, meat, dairy, and fruits & vegetables. The price and substitution effects of the group *other foods* was not considered.

Figure 3.2 shows the histogram of welfare effects as proportion of food expenditure that is obtained after replacing w_0^j in equation (3.2) for the budget shares of every household in the sample. The mean of this variable is 0.16 with standard deviation 0.056. Once the welfare effects as proportion of food expenditure is multiplied by food expenditure it yields monthly gross welfare effects in monetary terms. The corresponding histogram, with mean MX$302.73 and standard deviation MX$203.34, is presented in figure 3.3. Since these welfare effects are not yet comparable across households we called them gross welfare effects. Net (comparable) welfare effects are those adjusted by household equivalence scales. Figure 3.4 presents the histogram for estimated equivalence scales. Monthly net welfare effects have a mean of MX$253.64, a median of MX$219.94, and a standard deviation of MX$179.67. Figure 3.5 shows the histogram of net welfare effects in Mexican pesos per month. The estimated net welfare effects differ considerably across households.

Figure 3.2 Gross welfare effects as proportion of food expenditure.

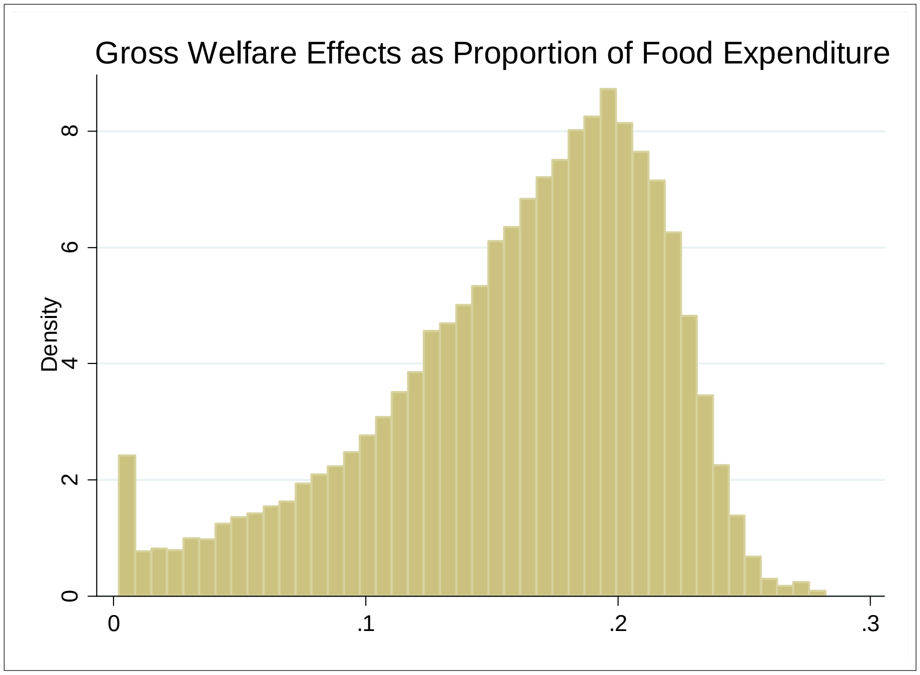


Figure 3.3 Gross welfare effects in Mexican pesos per month.

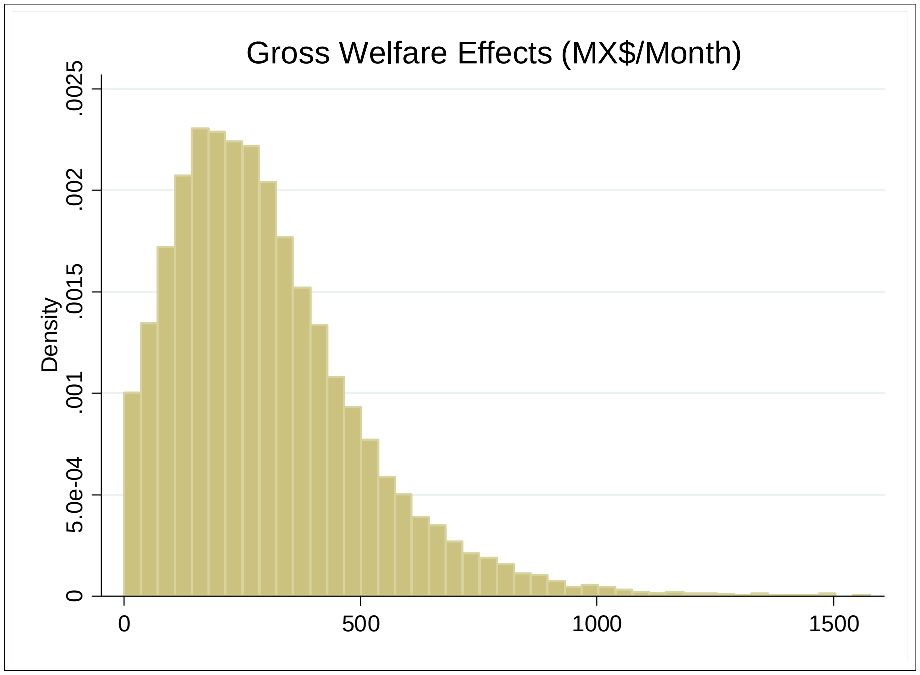


Figure 3.4 Estimated equivalence scales.

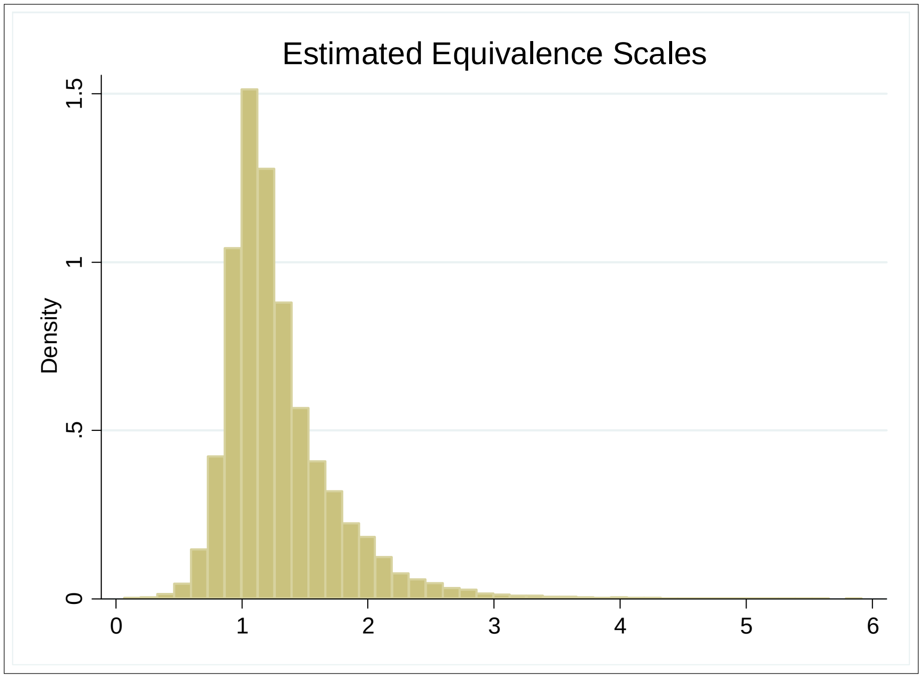
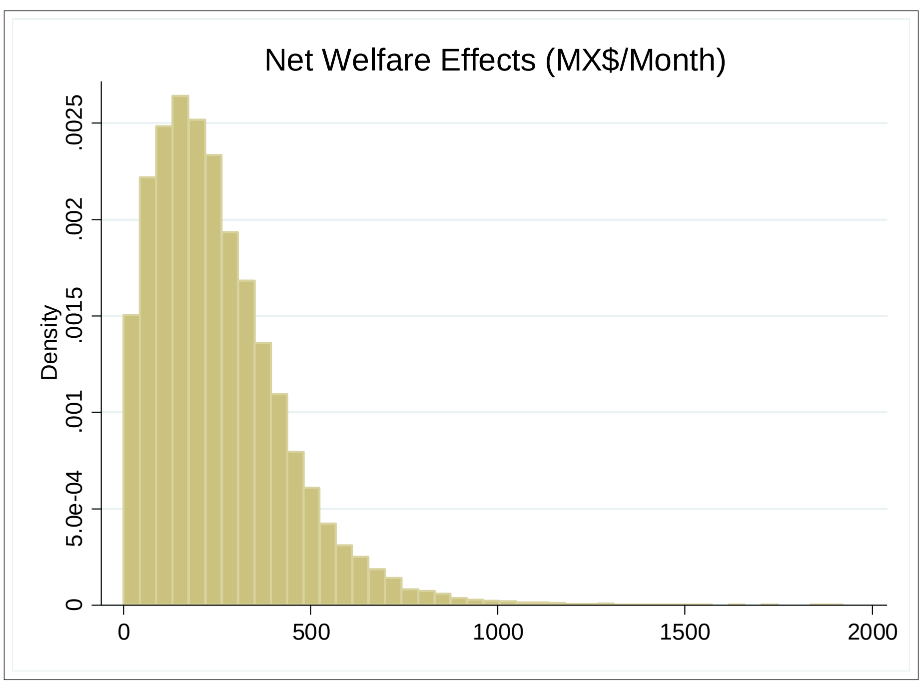


Figure 3.5 Net welfare effects in Mexican pesos per month.



Since the group named *other foods* was not considered for welfare estimation purposes, households that devote most of their food expenditure to this omitted group have lower estimated net welfare effects in this exercise. Households that have a more diversified diet, including prepared foods and food-away-from-home suffer minor welfare effects given a price increase in a specific food group. Such households are the ones that have welfare effects on the left side of the histogram in figure 3.5.

As for welfare analysis relative to poverty, we used the official food poverty line defined by CONEVAL in our calculations. In particular, we take the average value of the food poverty line for the last quarter of 2010, to be consistent with the time household data was collected. It is measured in monthly per capita income and classified for rural and urban households. For a rural household, the food poverty line was MX$797.29 and for an urban household it was MX$1,074.28. This amount represents a monetary measure of the resources needed to buy a representative food basket in Mexico and it is adjusted monthly by the consumer price index.

Per capita income, calculated from the original dataset, was compared to the food poverty line for every household before and after the subtraction of the per capita net welfare effects to evaluate the impacts of increasing food prices on poverty levels. The difference indicates an increase of 1.8 percentage points in the proportion of households with incomes below the food poverty line. This represents nearly 514,000 households in Mexico falling into food poverty due to the actual increase of price of five food groups from 2006 to 2010. The latter figure was estimated using the sampling weights provided in the ENIGH dataset.

Wood, Nelson and Nogueira (2012) showed the importance of substitution effects. They demonstrate that analysis performed considering only first-order effects overestimates the impact of rising food prices on poverty. We found similar results, since omitting substitution effects would result in about 603,000 households falling into food poverty. This would represent an overestimation of 18% in the number of households compared to the results from the model that accounts for substitution ability.

Regarding the poverty impacts on rural households, we found that the proportion of households living below the food poverty level in rural communities increased 2.12 percentage points. This results in the number of households in the disadvantaged condition increasing by 130,000 households. As for urban households, the proportion increased 1.70 percentage points, which means that nearly 384,000 additional households are now below the food poverty level.

III.5 Conclusions

In this paper a linearized EASI demand system was estimated in order to obtain the parameters needed to calculate the welfare effects due to food price increase for a specified reference household type in Mexico. Equivalence scales were estimated in order to compare welfare effects across households. After accounting for substitution effects, poverty related impacts were estimated. We found that increase in prices of five food groups from 2006 to 2010 has led to an increase of 1.8 percentage points in the proportion of households with income below the food poverty level in Mexico. This shows that nearly 514,000 additional households fell below the food poverty level. In terms of proportion of households, welfare effects on poverty seem to be higher on households located in rural communities than in urban households.

Limitations of this study include the use of unit values and broad food groups, which may hide important substitution effects within a food group. Household income is assumed fixed for welfare analysis ignoring the benefits of higher food prices to agricultural households.

One possible way to extend this research would be to estimate a more comprehensive demand model, using other expenditure groups, such as clothing, transportation, health care, education, recreation, etc., along with a food group. The use of this model would allow the estimation of the expected welfare effects of a potential implementation of a food tax in Mexico. Given that with EASI model a distribution of welfare effects can be estimated, it would be possible to identify vulnerable sub-population groups that would suffer the most given a policy change. Although the question of whether compensating the consumers or not after a price or policy change is a normative one, the fact that it is feasible to estimate welfare effects in monetary terms, tailored for sub-population groups, has important implications and relevance for public policy in Mexico.

CHAPTER IV

DETERMINANTS OF HOUSEHOLD FOOD INSECURITY IN MEXICO

IV.1. Introduction

The importance of food security has been addressed nationally and internationally. Food security is defined as the situation when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for a healthy and active life (FAO 1996).

At a global level, the number of people suffering from hunger and poverty exceeds one billion, which represents one-seventh of the world's population (FAO 2009). As for the situation in Mexico, in 2010 the population proportion that suffered from any level of food insecurity was 44.3%. In particular, 10.8% of the Mexican population reported severe food insecurity, 14.0% reported moderate food insecurity, and 19.5% of the population was very low food insecure. The proportion of Mexican population under moderate food insecurity and severe food insecurity in 2008 was 12.8% and 8.9%, respectively. The two most severe levels of food insecurity in Mexico increased from 2008 to 2010 (CONEVAL 2011b). In terms of the number of persons, 49.9 million of Mexicans were classified under any of the three levels of food insecurity in 2010 (CONEVAL 2011b). The increase of food insecurity in Mexico has obvious policy implications and relevance.

Food security is an essential dimension of household welfare and an important subject whether viewed globally, within a nation, a state, or in local communities (Bickel et al. 2000). Food insecurity and hunger are possible precursors to nutritional health, and developmental problems. Negative consequences of food insecurity have been documented extensively. Ramsey et al. (2011) found that children in food-insecure households may be at risk of poor health, developmental or behavioral problems. The potential developmental consequences of food insecurity during childhood may result in serious adverse health and social implications. Jyoti, Fronjillo, and Jones (2005) provide strong empirical evidence that food insecurity is linked to nutritional and non-nutritional developmental consequences for children, in particular, academic performance and social skills are found to be affected by food insecurity. Cook et al. (2006) found that household food insecurity is positively associated with fair/poor health and hospitalizations in young children. Ensuring food security may reduce health problems, including the need for hospitalizations (Cook et al. 2004). Carmichael et al. (2007) suggest that increased risks of certain birth defects may be included among the negative consequences of food insecurity.

Food insecurity is one of the most important public health challenges. Reducing food insecurity and its associated consequences requires an understanding of the determinants of food insecurity (Gundersen and Garasky 2012). Despite the fact that food insecurity and hunger are consequences of constrained financial resources, traditional income and poverty measures do not provide clear information about food security. Evidence supported by analysis of food security data indicates that many low-income households seem to be food secure, while a small proportion of non-poor households appear to be food insecure (Bickel et al. 2000). Likely reasons for such differences include variations in household decisions about how to handle competing demands for limited resources, as well as geographic patterns of relative costs and availability of food and other basic necessities. The food security measure provides independent, more specific information on this dimension of welfare than the measure that can be inferred from using only income data (Bickel et al. 2000). In the case that food insecurity was completely determined by other measures of constrained resources, poverty for example, establishing a measurement of food insecurity would be irrelevant. Research has shown that income-based measures and other measures of well-being are not necessarily highly correlated with food insecurity and hunger (Gundersen 2008).

The main objective of this research is to identify social-demographic factors that determine the level of food insecurity in Mexico. Vulnerable groups in terms of food security are to be identified. This is achieved through the use of the newly established Mexican Food Security Scale and a nationally representative dataset containing relevant demographic variables. This would be the first paper to attempt measuring association between household food insecurity and social-demographic variables at a national level in Mexico.

As pointed out by Bickel et al. (2000), monitoring food security can be useful to identify and understand this basic welfare aspect and to recognize population subgroups or regions with particularly severe conditions. Therefore, determining the food security status of the households comprising the community can provide a tool for assessment and planning of governmental programs and policies aimed to enhance food security and reduce hunger.

A clearer understanding of the factors that determine food insecurity can improve the design of future agricultural and development policies aimed to promote household food security and child nutrition in Mexico.

This chapter is organized as follows: Section II contains background information and literature review; Section III describes the data used in this study; Section IV introduces quantitative methods used to obtain food security estimates; Section V presents discussion of results, and Section VI concludes and points out opportunities to extend this work.

IV.2. Background and Literature Review

During the last decade a renewed interest in the concept of food insecurity at the household level has emerged (González et al. 2008). Interest in household food insecurity within scientific and policy groups has motivated efforts to develop methods to measure it. As recent experience suggests, household food insecurity and its severity can be measured/captured through simple and short questionnaires, allowing collecting valuable information with low cost and low respondent burden (González et al. 2008).

One of the first experiences on developing a food security scale can be found in the United States. In 1995, Food Security Supplement, a cornerstone of the Food Security Measurement Project in the United States, was implemented for the first time to the Current Population Survey (CPS). The food security measure was developed for households in the United States, reflecting the relevant range of conditions in this country. After several annual surveys, the food security scale has been found reliable for describing the status of the population (Bickel et al. 2000).

The literature has established socioeconomic and demographic factors associated with food insecurity in the United States. Among the groups of people that are found more likely to be food insecure are: households headed by an African American, Hispanic households, a non-married person, a divorced or separated person, a renter, younger persons, and less educated persons. Households with children are more likely to be food insecure than households without children. In previous studies, the aforementioned characteristics are generally positively associated with food insecurity (Gundersen, Kreider, and Pepper 2011). These authors also recognize that an important factor is the amount of money available to a household, which in some cases is included in estimation methods as income normalized by the poverty line. Similarly, Hager et al. (2010) reports that in the U.S., black or Hispanic households with single parents, young children, and incomes below the federal poverty line were identified to have increased risk for food insecurity in 2008.

Bickel et al. (2000) observe that the terms food insecurity and hunger refer to conditions resulting from financial resource constraints. The measurement procedure is concerned only with food insecurity and hunger that occur because the household does not have enough resources or money to buy food. This measure rules out the fact of experiencing hunger "voluntarily" in situations such as dieting, fasting and not having time to eat.

USDA's methodology has been successfully applied in the U.S. to measure food security and can be applicable in other settings, with appropriate linguistic and cultural conversions, reflecting the characteristic patterns of perception and response within the sampled population (Bickel et al. 2000).

As for the performance of this type of measures of food insecurity in developing countries, Melgar-Quiñonez et al. (2006) examined the association between food insecurity, determined by a modified version of the U.S. Household Food Security Survey Module, and total daily per capita consumption -measured as household expenditures- in Bolivia, Burkina Faso, and the Philippines. Daily per capita food expenditure, which represented over 60% of the total household consumption, as well as expenditures on specific food groups correlated with food insecurity both as a continuous Food Insecurity Score and a tri-categorical food insecurity status variable. Regression analysis was executed adjusting for social and demographic covariates. Food secure households have significantly higher total daily per capita food expenditures as well as expenditures on animal source foods, vegetables, and fats and oils than moderately and severely food-insecure households. The authors concluded that the results offer evidence that the U.S. Household Food Security Survey Module is able to discriminate between households at different levels of food insecurity status in diverse developing world settings. They also emphasize that the food insecurity scale is a practical and cost-effective approach whose results correlate well to expenditure estimates, making this scale a good option for practitioners.

Gonzalez et al. (2008) developed a 14-item questionnaire to measure household food insecurity in urban Costa Rica. They conclude that the developed questionnaire is a valid measurement of household food insecurity. They observe that this is a simple and quick method to apply in a household setting.

Related to a validation of the scale in Mexico, Melgar-Quiñonez et al. (2005) conducted a study to validate a version of the Food Security Survey (FSS), used by the USDA, in communities located in Sierra de Manantlán, Jalisco –western Mexico-. The FSS was modified to fit the Mexican context. The questionnaire was translated to Spanish and the questions were reworded in a way that they were unambiguously understood by locals. Moreover, the authors recorded a 24-hour diet recall as nutritional assessment in every interviewed household; this metric was compared to the food security survey. The modified FSS was validated in correlation with a household food inventory and the household dietary variety. They found that food insecurity was associated with low dietary variety. Food insecurity was inversely correlated with the number of food items in the household, animal source foods, dairy products, fruits, and vegetables. These authors concluded that the FSS is a useful tool for monitoring food insecurity in rural regions of Jalisco, Mexico.

Pérez-Escamilla, Paras, and Hromi-Fiedler (2008) tested the validity of the Latin American and Caribbean Food Security Scale (ELCSA) in a representative public opinion survey in the state of Guanajuato, Mexico. ELCSA was applied in Spanish, contained 16 items and used a reference period of 3 months. Authors conclude that using a food security scale, such as ELCSA is a valid tool for assessing household food insecurity in Mexico.

Pérez-Escamilla et al. (2004) validated a food security scale in Brazil. They also reported that food security is strongly associated with the likelihood of daily consumption of fruit, non-root/tuber vegetables, and meat. The authors found a negative association between food insecurity and the probability of daily consumption of fruits, vegetables and animal protein.

Other studies that have successfully validated the household food security scale, as a measure to identify the actual magnitude and severity of food security, include: Álvarez et al. (2006) that conducted a study in Antioquia, Colombia; and Gulliford, Mahabir, and Rocke (2004) that studied food security in a Caribbean community, among others.

Despite the demonstrated validity of the food security scale, there is no available study that has utilized the Mexican Food Security Scale (EMSA) to identify the factors that determine household food security for the particular case of Mexico. This study will bridge the gap in the literature regarding the identification of social-demographic factors that determine food (in)security in Mexico utilizing the EMSA and the Module of Socioeconomic Conditions (MSC) 2010 dataset.

One of the few studies on the subject that applied data from the ENIGH in Mexico is Carrasco, Peinador, and Aparicio (2010). Following the hypothesis that households with higher degree of food insecurity are expected to have less varied diets than food secure households they conducted a correspondence analysis, finding a slight association between food security and a more varied diet, measured through food expenditure in households. They note that in households with native language speakers and those households that are located in small isolated towns this association is clearer.

The problem of food security is multifactorial. In Mexican households, food insecurity should be understood as a problem of 1) food availability, 2) food access, and 3) food consumption (CONEVAL 2010). As for food availability, according to FAO data, between 2003 and 2005 there was adequate food availability in Mexico. The minimum requirements for the Mexican population was of 1,850 kilocalories per capita per day, while the food supply reached 3,270 kilocalories per capita per day (CONEVAL 2010). In terms of food access 18.2% of the Mexican population had income below the food poverty line in 2008, which means that they did not have enough income to buy a basic food basket (CONEVAL 2010). In terms of food consumption, in 2008 only a small proportion of rural households had a diversified diet, according to health recommendations. This problem is much more severe in indigenous households in rural communities (CONEVAL 2010).

Food security is not synonymous with a good nutritional status. Food security is a necessary but not a sufficient condition for nutrition security. Nutrition security requires not only that food is available and affordable, but it also should be consumed in an adequate quality and variety, be prepared properly in a hygienic environment, and consumed by a healthy body (CONEVAL 2010). In this research, the concept of nutrition security is not discussed further. Focus is on food security and its socioeconomic determinants.

IV.3. Data

The data used in this study come from the Module of Socioeconomic Conditions Module (MCS 2010) of the National Household Income and Expenditure Survey (ENIGH, Spanish acronym) collected from August 21 to November 28, 2010. This dataset incorporates data on income, health, education, social security, quality of living spaces, food security, among other variables. The MCS 2010 offers nationwide results, for urban and rural population in every State. The total sample consists of more than 60,000 households. The ENIGH is the only official source of data in Mexico that contains both data on food security as well as food expenditures at the household level in a nationally representative sample. The MCS is a joint effort between two Mexican Institutions: the National Institute of Statistics and Geography (INEGI) and the National Council for Evaluation of Social Development Policy (CONEVAL). The objective was to provide a statistical overview of variables needed for the multidimensional measurement of poverty, which was stipulated by the Law on Social Development.

It is worth noting that since 2008, the survey has undergone a series of changes. Among these is the inclusion of Mexican Food Security Scale (EMSA, Spanish acronym), an instrument which addresses the dimension of access to food, which is useful for the new poverty estimates in the country. The scale is constructed from a battery of twelve questions that consider the quality and adequacy of food through the reporting of experiences of the population. The EMSA measures the degree of household food insecurity and is the instrument to measure the lack of access to food. This newly implemented scale will be used in this research.

The set of food security questions included in the MSC survey can be combined –following the official methodology of CONEVAL (2011c) - into a single overall measure called the Mexican Food Security Scale (EMSA). This is a scale that measures, in a single numerical value, the level of food insecurity experienced by a household. The dependent variable in the model can have four different levels of food security that are defined following the criteria specified in the EMSA. As pointed out by Carrasco, Peinador, and Aparicio (2010), the conceptual and methodological basis of the EMCA is derived from the Latin America and Caribbean Scale Food Safety (ELCSA), which, comes from various studies and implementation experiences for the development and monitoring of public policy in the Latin American region. The ELCSA is rooted in nearly twenty years of research and analysis of a scale that USDA used for measuring the phenomenon. CONEVAL validated EMSA- at the national and state level in Mexico- as a reliable instrument to measure food security (Carrasco, Peinador, and Aparicio 2010).

The distinction between the levels of food insecurity is constructed after distinguishing between households with adults only and those with children under 18. In the first case, the scale uses values between zero and six, whereas in the second case, it uses values between zero and twelve. This is because for household with children six additional questions about the experience of food shortage or hunger are asked. Once this distinction is performed, the scale identifies four breakpoints: *food security* (no affirmative answers to any of the food insecurity/hunger questions); *very low food insecurity* (one or two positive answers in households without children and one to three affirmative answers in households with children); *moderate food insecurity* (three to four positive answers in households without children and four to seven in homes with minors); and *severe food insecurity* (five or six affirmative responses for households without children and eight to twelve positive answers in the case of households with children). This scale is summarized in table 4.1.

Table 4.1 Food Security Levels of the Mexican Food Security Scale (EMSA)

Food Security Status	Household w/o children	Household with children
Food Security	No affirmative answers	
Very Low Food Insecurity	1 to 2 affirmative answers	1 to 3 affirmative answers
Moderate Food Insecurity	3 to 4 affirmative answers	4 to 7 affirmative answers
Severe Food Insecurity	5 to 6 affirmative answers	8 to 12 affirmative answers

Source: CONEVAL, 2011c.

All of the food security questions in the EMSA have two common characteristics. Each question includes a phrase such as “due to lack of money or resources” to assure that the reported behavior or food availability condition occurred because of household financial limitations. It is important to notice that the term “resources” imply the possibility of obtaining or producing the food for the household without the need to use money. This opens up the possibility of obtaining food from own production and/or subsistence farming, something very common especially in rural communities across Mexico. Each question asks explicitly about circumstances that occurred during the past 3 months. The actual questionnaire can be found in Appendix F of this document.

IV.4. The Model

The model used to obtain the estimates is an ordered probit model, which can briefly be described, for each individual i, as:

$$y_i^* = \boldsymbol{x_i \beta} + \varepsilon_i \quad (4.1)$$

where y_i^* is a latent variable that can take on four values corresponding to four levels of food security in the EMSA. The vector $\boldsymbol{x}_i$ represents a set of demographic covariates discussed below, and ε_i is a random error. Following the notation used by Long and Freese (2006), the latent variable y^*, that ranges from $-\infty$ to ∞, is divided into J ordinal categories, such that:

$$y_i = m \text{ if } \tau_{m-1} \leq y_i^* < \tau_m \text{ for } m = 1 \text{ to } J = 4$$

The cutoff points τ_1 through τ_{J-1} are unknown parameters to be estimated. It is assumed that $\tau_0 = -\infty$ and $\tau_J = \infty$.

The four categories in the EMSA are: 1= Food Security (FS), 2= Very Low Food Insecurity, 3=Moderate Food Insecurity, and 4=Severe Food Insecurity. The observed food security categories are related to the latent variable as follows:

$$y_i = \begin{cases} 1 \text{ if } \tau_0 = -\infty \leq y_i^* < \tau_1 \\ 2 \text{ if } \tau_1 \leq y_i^* < \tau_2 \\ 3 \text{ if } \tau_2 \leq y_i^* < \tau_3 \\ 4 \text{ if } \tau_3 \leq y_i^* < \tau_4 = \infty \end{cases}$$

Estimation of cutoff points τ_1 through τ_{J-1}, along with estimation of the vector $\boldsymbol{\beta}$ in equation (4.1) is undertaken by maximum likelihood. According to Becker and Kennedy (1992) the probability of obtaining an observation with $y = 1$ is equal to:

$$prob\{ y^* = \boldsymbol{x}'\boldsymbol{\beta} + \varepsilon \leq \tau_1 \} = prob\{\varepsilon \leq \tau_1 - \boldsymbol{x}'\boldsymbol{\beta} \} = \int_{-\infty}^{\tau_1 - \boldsymbol{x}'\boldsymbol{\beta}} f(\varepsilon)d\varepsilon$$

where $f(\varepsilon)$ is the standard normal density function. Likewise, the probability of obtaining an observation such that $y = 2$ is given by the expression:

$$prob\{\tau_1 < y^* = \boldsymbol{x}'\boldsymbol{\beta} + \varepsilon \leq \tau_2 \} = prob\{ \tau_1 - \boldsymbol{x}'\boldsymbol{\beta} < \varepsilon \leq \tau_2 - \boldsymbol{x}'\boldsymbol{\beta} \}$$

$$= \int_{\tau_1 - \boldsymbol{x}'\boldsymbol{\beta}}^{\tau_2 - \boldsymbol{x}'\boldsymbol{\beta}} f(\varepsilon)d\varepsilon$$

The probabilities for the remaining categories of food security can be calculated with similar expressions. The likelihood of the function is the product of these expressions for each observation. By maximizing the likelihood function with respect to $\beta's$ and $\tau's$ generates the maximum likelihood estimates (Becker and Kennedy 1992). Stated alternatively, the probability of observing $y_i = m$ for given values of the covariates, $\boldsymbol{x}$, corresponds to the region of the distribution where $\tau_{m-1} < y^* \leq \tau_m$. That is:

$$prob\{y = m|\boldsymbol{x} \} = prob\{\tau_{m-1} < y^* \leq \tau_m|\boldsymbol{x} \} = F(\tau_m - \boldsymbol{x}'\boldsymbol{\beta}) - F(\tau_{m-1} - \boldsymbol{x}'\boldsymbol{\beta})$$

where F is the standard normal cdf for ε (Long and Freese 2006).

After the maximum likelihood estimates are obtained, marginal effects are calculated. A marginal effect is defined as the partial derivative of y with respect to x_k. For nonlinear models, such as ordered probit, the value of the marginal effect depends on the particular values of all the covariates (Long and Freese 2006). Marginal effects are obtained at the mean values of the explanatory variables and the estimation is performed using Stata.

As for the definition of the explanatory variables, the vector of covariates, $\boldsymbol{x}_i$, it is divided into three types of social-demographic characteristics: 1) household head characteristics, 2) household characteristics, and 3) community and regional variables.

Within the group of variables related to household head characteristics are: age, gender and level of formal education. Age is represented by a set of dummy variables for age ranges. Namely, variable *Age<=30* is a dummy variable equal to one if the household head is 30 years old or younger, zero otherwise. Variable *Age31-45* is a dummy variable equal to unity if the household head is 31 years old or older but not older than 45. Similar definitions apply for variables *Age46-60* and *Age>=61*. The purpose of this set of variables is to capture the effect of household head age, if any, on household food security status. Next, household gender is defined as a dummy variable named *male* equal to one if the household is male-headed, zero otherwise. It is hypothesized that gender may have a relevant effect of food security status. Furthermore, a group of dummy variables is included in the model to capture the effect of the level of formal education of the household head on household food security. In particular, five variables are considered: 1) *No formal education* is a dummy variable equal to one if the household head indicated that did not attend formally any school level, zero otherwise (notice that this does not necessarily imply that the household head is illiterate); 2) *Elementary* is a dichotomous variable that indicates if the household head attended elementary school (first to sixth grade), this variable includes those that have incomplete or complete elementary school as maximum level of formal education; 3) *Secondary* dummy variable identifies household heads with either incomplete or complete the level of education that goes from seventh to ninth grade (equivalent to Junior High School in the U.S.); 4) *High School* dichotomous variable indicates those household heads that have incomplete or complete High School (tenth to twelfth grade) as maximum level of education; and 5) *College* is a dummy variable that is equal to one if the household head went to College, graduated from College, attended Graduate School, or have a graduate degree, zero otherwise.

Variables associated with household characteristics include, among other variables, household composition, income levels, and number of kids in the household. In particular, *SDW- mother* is a dummy variable that identifies a female household head whose marital status is either single, divorced or widow. The objective of including the variable *SDW-mother* is to determine if this group of households is vulnerable in terms of food security. Next, *Disable person* is a dummy variable that takes on the value of one for those households that have at least one disable household member (unable to walk, move, use his/her arms or legs, is blind, deaf or mute, is mentally challenged, or any other cause).

Native language dichotomous variable identifies households in which at least one member speaks a native language (they may or may not speak also Spanish). It is important to highlight that indigenous people have their own customs; they have particular ways to dress, eat, and celebrate their festivities. In many cases, they also elect their authorities according to their own social structure. An important element that distinguishes these social groups and gives them identity is the language with which they communicate. This variable takes into account households with members that actually speak a native language, meaning that they have strong indigenous background. It is expected that *Native language* variable captures the effect of having indigenous background on food security status in a better way than a variable of self-reported household member an indigenous person would do.

As far as variables related to income are concerned, households are divided by income levels. A set of mutually exclusive dummy variables are included in the model taking into consideration official poverty lines in Mexico and higher levels of monthly per capita income. *Lower income* is a dichotomous variable that is equal to one for a household which income is below the food poverty line. As officially defined by CONEVAL, Mexican Institution in charge of this task, food poverty line for the fourth quarter of 2010 was MX$797.29 monthly per capita income for households living in rural communities (less than 2500 inhabitants) and MX$1,074.28 for urban households. *Low income* is a dummy variable that identifies households with monthly per capita income above the food poverty line but below the assets poverty line (MX$1,446.76 for rural households and MX$2,155.43 for urban households) defined by CONEVAL. *Middle income* dichotomous variable indicates if a household has monthly per capita income above the official assets poverty line, but below MX$2,893.52 for rural households, and MX$4,310.86 for urban households. Unlike the first two, the latter income level cutoff does not come from an official measure. It was created as the product of the assets poverty line times two. As a last category of income levels, *Higher income* is a variable that identifies households with monthly per capita income higher than twice the assets poverty line.

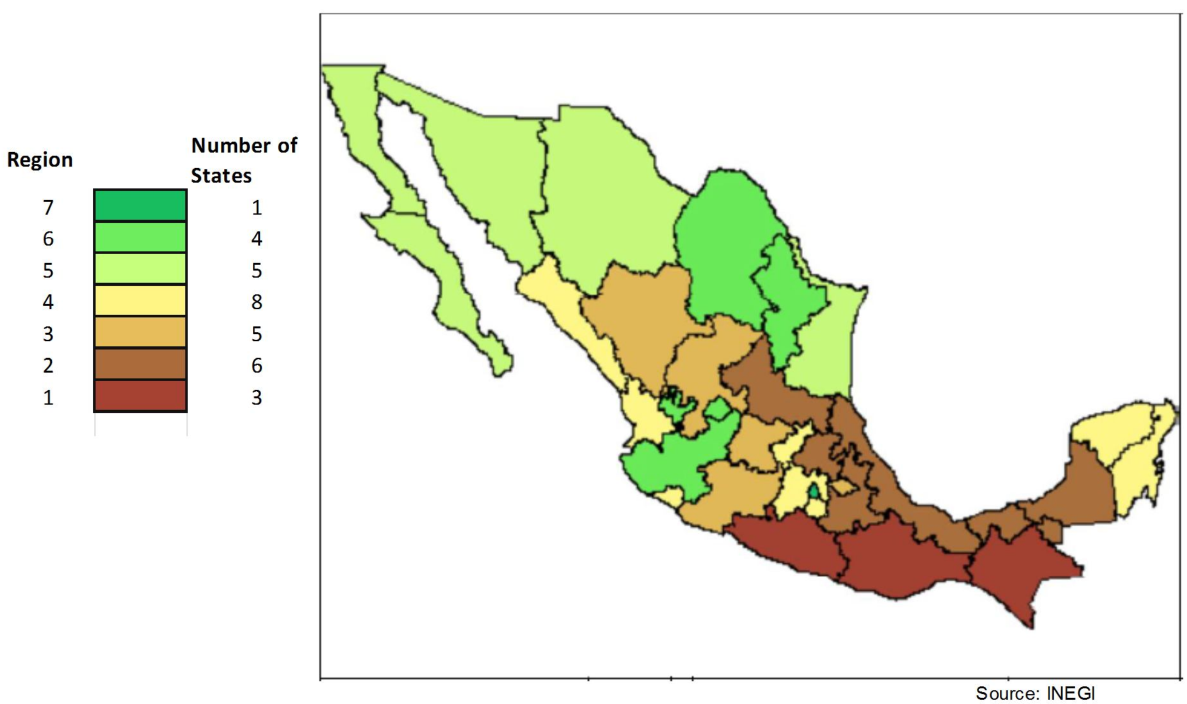
Source of income is also an important variable to consider. *Agricultural Household* is a dummy variable equal to one if the ratio of agricultural income to total income is grater or equal than ¼. The variable agricultural income is readily available in the dataset and it measures the household income from agricultural activities. This is a relevant variable for food security since food consumption from own production (not registered as food expenditure) is more likely to occur in this type of households than in non-agricultural households. The cutoff point, ¼, was arbitrarily selected and it is expected to represent those households in which agriculture is an important source of income.

Household type and household composition is capture next by a set of exhaustive and mutually exclusive dummy variables. *Unitary household* is that household in which the following characteristics hold: Household (HH) head=1 and spouse=0 and children=0 and relatives=0 and no relatives=0. It is considered a *Traditional household* if HH head=1 and {spouse>0 or children>0} and relatives=0 and no relatives=0. *Extended household* is defined as HH head=1 and {spouse>0 or children>0 or relatives>0} and no relatives=0. It is a *Composite household* if HH head=1 and {spouse>0 or children>0 or relatives>0} and no relatives>0. Finally, a *Co-resident household* is that in which the following composition holds: HH head=1 and spouse=0 and children=0 and relatives=0 and relatives=0 and no relatives>0. This household composition follows the classification defined by INEGI in the original dataset.

It has been stated in the literature that the number of children in a household is an important factor that affects food security. For that reason, a set of dummy variables related to the number of household members that are younger than 18 years of age (kids) is included in the model. The definitions of these variables is very intuitive and as they are named *Kids0*, *Kids1*, *Kids2*, *Kids3*, *Kids4*, and *Kids>4*, for households with no kids, one kid, two kids, three kids, four kids and more than four kids, respectively.

A group of dummy variables was included to identify the population size – number of inhabitants in city/town. The variable *Large City* identifies a household living in a city with more than 100,000 inhabitants. Variable *Medium City* indicates that the household lives in a city with population between 15,000 and 99,999 inhabitants. Likewise, *Small City* represents households in a city of more than 2,500 but less than 14,999 inhabitants, whereas the variable *Rural Community* identifies households living in rural areas or towns with less than 2,500 inhabitants.

Figure 4.1 Socioeconomic regions in Mexico



Finally, a group of dummy variables to identify the region –group of Mexican States with similar socioeconomic level- is included. The classification of socioeconomic regions in this model follows the stratification performed by INEGI (2012). The aim of this stratification is to present a comparative summary of the differences and similarities observed in economic and social conditions of the population across the country, using indicators on education, employment, and housing, among other welfare measures. In this ranking there are seven categories, from one to seven, where seven indicates the States with the most favorable relative position in terms of socioeconomic conditions, and one is assigned to States with the least favorable conditions (INEGI 2012). *Region1* includes the States of Chiapas, Guerrero, and Oaxaca. *Region2* comprises six States: Campeche, Hidalgo, Puebla, San Luis Potosi, Tabasco, and Veracruz. *Region3* is constituted by Durango, Guanajuato, Michoacán, Tlaxcala, and Zacatecas. *Region4* is formed by Colima, Estado de Mexico, Morelos, Nayarit, Queretaro, Quintana Roo, Sinaloa, and Yucatan. *Region5* includes Baja California, Baja California Sur, Chihuahua, Sonora, and Tamaulipas. *Region6* is Aguascalientes, Coahuila, Jalisco, and Nuevo Leon. *Region7* is Mexico City. The socioeconomic regions are illustrated in figure 4.1. The only region with ranking of 7 is Mexico City, while the States in northern Mexico have, in general, better socioeconomic conditions than the States in southern Mexico. This variable was included in the model to capture the effect that living in different regions may have on household food security.

IV.5. Results and Discussion

The final sample size after accounting for relevant demographic variables and the variables needed to calculate the household food security is 61,467 households. Less than 400 households with missing values in relevant variables were dropped from the sample. Every observation (household) in this nationally representative sample is weighted according to the complex sampling design (INEGI 2011). Sampling weights are provided in the dataset and used to obtain summary statistics and estimates.

Table 4.2 shows the weighted summary statistics of demographic variables for the whole sample, as well as for the four different levels of food security status. From the 2010 sample, 59.4% of the households are food secure, 18.5% have very low food insecurity, 12.1% of the Mexican households have moderate food insecurity, whereas 10.1% report severe food insecurity. Notice that proportions of food security status presented here slightly differ from proportions presented in the introductory section of this document. The reason is that in the introduction the proportion term refers to total population (sum of individuals), while in this section it refers to proportion of total number of households. As a consistency check, proportions of the Mexican population classified according to food security status were calculated from the weighted sample, obtaining the official figures provided by the Mexican government and reported at the beginning of this chapter.

Table 4.2. Summary Statistics Related to Food Security Levels.

			Food Insecurity		
Variable	All HH's	Food Security	Very Low	Moderate	Severe
Proportion of Households	1.00	0.59	0.18	0.12	0.10
Age<=30	0.14	0.13	0.15	0.15	0.14
Age 31-45	0.35	0.35	0.34	0.41	0.35
Age 46-60	0.29	0.30	0.28	0.27	0.29
Age >=61	0.21	0.22	0.22	0.17	0.21
Male	0.76	0.77	0.78	0.76	0.71
Female	0.24	0.23	0.22	0.24	0.29
No Formal education	0.09	0.06	0.11	0.12	0.18
Elementary	0.37	0.32	0.44	0.47	0.47
Secondary	0.27	0.27	0.29	0.28	0.26
High School	0.12	0.15	0.10	0.08	0.07
College	0.15	0.21	0.07	0.04	0.03
"SWD" Mother	0.20	0.19	0.18	0.19	0.24
Disable Person in Household	0.16	0.12	0.18	0.23	0.24
Native Language	0.09	0.06	0.11	0.14	0.15
Lower Income	0.16	0.09	0.22	0.30	0.34
Low Income	0.27	0.22	0.35	0.36	0.34
Middle Income	0.31	0.32	0.31	0.27	0.23
Higher Income	0.26	0.37	0.12	0.07	0.09
Social Program Participant	0.18	0.11	0.25	0.30	0.30
Income Social Prgm/1000	0.35	0.21	0.48	0.61	0.59
Prop. Social Prgm/Income	0.03	0.02	0.04	0.06	0.06
Agricultural Household	0.02	0.02	0.03	0.02	0.02
Unitary Household	0.10	0.11	0.06	0.06	0.13
Traditional Household	0.66	0.67	0.67	0.66	0.61
Extended Household	0.23	0.21	0.26	0.28	0.25
Composite Household	0.01	0.01	0.01	0.01	0.01
Co-resident Household	0.00	0.01	0.00	0.00	0.00
Kids 0	0.36	0.42	0.29	0.20	0.35
Kids 1	0.22	0.22	0.24	0.22	0.15
Kids 2	0.22	0.21	0.24	0.27	0.19
Kids 3	0.13	0.10	0.15	0.19	0.16
Kids 4	0.04	0.03	0.05	0.07	0.08
Kids >4	0.03	0.01	0.03	0.05	0.07

Table 4.2. Continued.

Variable	All HH's	Food Security	Food Insecurity Very Low	Moderate	Severe
Community and Regional Variables					
Large City	0.51	0.58	0.40	0.40	0.40
Medium City	0.15	0.15	0.15	0.14	0.14
Small City	0.14	0.12	0.16	0.16	0.16
Rural Community	0.21	0.16	0.28	0.29	0.31
Region 1	0.10	0.07	0.14	0.14	0.12
Region 2	0.19	0.17	0.22	0.22	0.23
Region 3	0.12	0.12	0.12	0.12	0.12
Region 4	0.23	0.22	0.25	0.27	0.24
Region 5	0.13	0.15	0.09	0.08	0.11
Region 6	0.14	0.15	0.13	0.11	0.12
Region 7	0.09	0.11	0.06	0.05	0.06

Weighted summary statistics reported.
Sample size: 61,467 households.

With respect to descriptive statistics of variables related to household head, the median age is 46 and the mean is 47.7 years of age. About 14% of the household heads are 30 years old or younger, 35% have ages between 31 and 45 years, 29% of total household heads are between 46 and 60 years old, while 21% are 61 years old or older. No clear relationship between age of household head and food security status is found in the data, as the proportions of households for all the levels of food security remain very close to the sample mean for all households. For example, 13% of the households that are food secure have a household head that is 30 years old or younger, this proportion is 0.15 for very low food insecure and moderate food insecure households and 0.14 for severe food insecure households. Recall that this proportion is 0.14 for all households.

Similar descriptive analysis can be performed for the three remaining household head age groups.

As for gender of the household head, the weighted sample shows that 76% of the households are male-headed, with the remaining 24% being female-headed. The percentage of households bearing severe food insecurity that are female-headed is 29%. This is the food insecurity level that differs the most with respect to the full sample proportion in terms of gender of household head. In alternative terms, the proportions of female-headed households that are food secure (0.23), very low food insecure (0.22), and moderate food insecure (0.24) are very similar to that proportion of the full sample (0.24).

Turning to formal education of the household head, 9% of the household heads in Mexico have no formal education, 37% went to elementary school as maximum level of formal education, 27% have secondary education, while 12% attended high school, and 15% have college education. As shown in table 4.2, there is a clear direct relationship between low levels of formal education and higher levels of household food insecurity. Households headed by a person that has no formal education represent 18% of the households under severe food insecurity. This is twice the proportion of such households in the full sample (0.09). Households headed by a person that has college education represent 21% of the households that are food secure and 15% of the full sample. The relationship between higher education and food security does not necessarily capture the marginal effect of education on food security. That is why it is important to conduct this analysis in an appropriate regression framework to control for relevant variables and be able to net out the effects of socioeconomic variables of interest.

Regarding variables at the household level, having a disabled person in the household or at least one member that speaks a native language (implying strong indigenous background) seem to affect the food security status towards food insecurity levels. It is shown in table 4.2 that 9% of the Mexican households have at least one member that speaks one of the almost hundred native dialects spoken across the country. This group accounts for 6% of the food secure households, 11% of the very low food insecure households, 14% and 15% of the moderate food insecure and severe food insecure households, respectively.

In terms of household income levels, 16% of the total households in the sample have income below the food poverty line (lower income), 27% have income above the food poverty line but below the assets poverty line (low income), 31% of households is classified as middle income (see definition in previous section), and the remaining 26% of households have higher income. Interestingly, 9% of the households that are food secure are households with incomes below the food poverty line (lower income), whereas 22% of the households that are food secure are low income households. It is clear that, even though they are correlated, food security and poverty are two different dimensions of welfare.

The variables related to social program participation refer to two specific conditional cash transfer programs: *Oportunidades*, previously known as *Progresa*, and *Apoyo Alimentario*. From the dataset it was calculated that 18% of the total number of households receive income from one of the afore-mentioned social programs. The average quarterly cash transfer by household was about MX$350, that represents in average 0.03% of the household income. This overall average is definitely affected by observations from higher income households that do not receive income from social programs. Social program participation is not included in the estimation for the whole sample, since the relevant population for this program includes only households that live under poverty conditions.

Household types are divided as follows: 10% are unitary households, 66% are traditional households, and 23% are extended households. Composite households and co-resident households represent a very small proportion (about 1% together).

As for number of kids in the household, 36% of the total households have no kids, 22% have one kid, 22% have two kids, 13% have three kids, 4% have four kids, and only 3% of the households have more than four kids. Food security status is, in general, inversely related to the number of kids in the household as can be observed in table 4.2.

The distribution in terms of size of city is: 51% of the households live in large cities, 15% live in medium cities, and 14% live in small cities, while the remaining 21% is classified as rural population. Among the households that are food secure, 58% of them live in large cities, 15% in medium cities, 12% in small cities, and 16% in rural communities. A positive relationship between food security and larger cities can be detected from these observations. Proportion of households living in different regions and their food security status are found in the second section of table 4.2.

Coefficient estimates and p-values from the ordered probit model, as well as marginal effects for the four levels of food security are reported in Table 4.3. Given the complex design of the sample, weighted data should be used for estimation (INEGI 2011). Discussion focuses on marginal effects (post-estimation) since coefficients from ordered probit do not have a direct interpretation.

Coefficients and marginal effects for variables *Age31-45* and *Age46-60* are not statistically significant. The marginal effects for variable *Age>=61* indicate that these households are 10.8 percentage points more likely to be food secure than those with household head younger than 30 years old, which is the omitted category in this case. The marginal effects for each of the food insecurity categories are negative, meaning that households in this category are less likely to be food insecure. This result may suggest that, in average, as age of household head increases she/he gets more experience in managing the resources in the household and, possible, more experience at work may represent higher income, reducing the probability of the household to be food insecure. Another possible interpretation is that as household head reaches an age over 60 he/she may get retirement funds. The probability of having children at this age is expected to be very low, which implies less family members.

Turning to gender of household head, once all other covariates are controlled for, a male-headed household is 2.5 percentage points more likely to be food secure than a female-headed household. The former household type is 0.6, .07, and 1.1 percentage points less likely to be very low food insecure, moderate food insecure and severe food insecure, respectively, compared to the latter household type.

Table 4.3. Regression Coefficients and Marginal Effects (Robust Estimation).

		Marginal Effects			
			Food Insecurity		
Variable	Coefficients	Food Security	Very Low	Moderate	Severe
Age 31-45	-0.056	0.019	-0.004	-0.006	-0.009
Age 46-60	-0.076	0.025	-0.006	-0.008	-0.012
Age >=61	-0.324***	0.108***	-0.024***	-0.033***	-0.051***
Male	-0.074**	0.025**	-0.006**	-0.007**	-0.011**
Elementary	-0.246***	0.082***	-0.019***	-0.025***	-0.038***
Secondary	-0.379***	0.126***	-0.029***	-0.038***	-0.059***
High School	-0.608***	0.202***	-0.046***	-0.062***	-0.095***
College	-0.853***	0.284***	-0.064***	-0.087***	-0.133***
"SWD" Mother	0.065*	-0.022*	0.005*	0.007*	0.010*
Disable Person	0.320***	-0.107***	0.024***	0.033***	0.050***
Native Language	0.110***	-0.037***	0.008***	0.011***	0.017***
Low Income	-0.255***	0.085***	-0.019***	-0.026***	-0.04***
Middle Income	-0.536***	0.178***	-0.040***	-0.054***	-0.083***
Higher Income	-1.062***	0.354***	-0.080***	-0.108***	-0.166***
Agricultural HH	-0.17***	0.057***	-0.013***	-0.017***	-0.027***
Traditional HH	-0.283***	0.094***	-0.021***	-0.029***	-0.044***
Extended HH	-0.318***	0.106***	-0.024***	-0.032***	-0.050***
Composite HH	-0.046	0.015	-0.003	-0.005	-0.007
Co-resident HH	-0.207	0.069	-0.016	-0.021	-0.032
Kids 1	0.041	-0.014	0.003	0.004	0.006
Kids 2	0.072**	-0.024**	0.005**	0.007**	0.011**
Kids 3	0.146***	-0.049***	0.011***	0.015***	0.023***
Kids 4	0.227***	-0.076***	0.017***	0.023***	0.035***
Kids >4	0.344***	-0.114***	0.026***	0.035***	0.054***
Large City	-0.075***	0.025***	-0.006***	-0.008***	-0.012***
Medium City	-0.125***	0.042***	-0.009***	-0.013***	-0.019***
Small City	-0.084***	0.028***	-0.006***	-0.008***	-0.013***
Region 1	0.126***	-0.042***	0.009***	0.013***	0.020***
Region 2	0.133***	-0.044***	0.010***	0.013***	0.021***
Region 3	-0.004	0.001	-0.0003	-0.0004	-0.001
Region 4	0.216***	-0.072***	0.016***	0.022***	0.034***
Region 5	-0.060	0.020	-0.005	-0.006	-0.009
Region 6	0.076**	-0.025**	0.006**	0.008**	0.012**

Sample size: 61,467 households. HH=Household. "SDW"=Single, Divorced or Widow.
*p<.1, **p<.05, ***p<.01

All variables related to a level of formal education have positive marginal effects for the food security category compared to the omitted category *No formal education*. A household headed by a person that has elementary school as maximum level of formal education is 8.2 percentage points more likely to be food secure than a household headed by a person with no formal education. This marginal effect is 12.6, 20.2, and 28.4 percentage points for the variables *Secondary*, *High School* and *College*, respectively. This result suggests that education is an important variable that affects the probability of a favorable food security status, controlling for other household head characteristics, household characteristics and community variables. Negative marginal effects were obtained for each of the three categories of food insecurity in terms of education levels. A household headed by a person with high school education is 9.5 percentage points less likely to be severe food insecure than a household headed by a person with no formal education.

A household headed by a *"SWD" mother* is 2.2 percentage points less likely to be food secure than other type of household, and 1.0 percentage points more likely to be under severe food insecurity. A household with a family member that is disabled is 10.7 percentage points less likely to be food secure, compared to a household that does not share this characteristic.

The probability of being food secure for a household where a native language is spoken is 3.7 percentage points lower than that for a non-indigenous household. This finding is consistent with conclusions in previous studies such as Oseguera-Parra (2010), who found that urban and mestizo –non-indigenous- women perceive less food insecurity compared to rural and indigenous women.

Findings so far suggest that *"SWD" mother* households, households that have a disabled family member (*Disabled person*), and households with a strong indigenous background (*Native language*) are vulnerable groups in terms of food security.

Regarding variables related to income the omitted variable was *Lower income*, thus the marginal effects of *Low income*, *Middle income*, and *Higher income* are compared to that category. All marginal effects are positive for food security and negative for each of the categories of food insecurity. As expected, income is an important determinant of food security. *Middle income* households are 17.8 percentage points more likely to be food secure than those household in the reference category (*Lower income*), and they are also 5.4 percentage points less likely to be moderate food insecure. *Low income* households are 4.0 percentage points less likely to be under severe food insecurity than those households in the reference category.

An *Agricultural household* is 5.7 percentage points more likely to be food secure than a type of household that is not considered under this definition. Recall that, for modeling purposes, it is considered an agricultural household if the income from agricultural activities is at least ¼ of total household income. An agricultural household is 2.7 percentage points less likely to suffer severe food insecurity. This result makes intuitive sense, since a household that receives income from agricultural activities may be more likely to also produce food for own consumption.

Marginal effects for household types are positive in the food security column. That is, *Traditional households* and *Extended households* are more likely to be food secure than *Unitary households*. This could be because in a non-unitary household there may be more persons receiving income and they can achieve some economies of scale in terms of food consumption. In a non-unitary household there may be a person in charge of preparing food, which may represent a way to take better advantage of the food resources at hand.

Variables related to number of kids in the household have negative marginal effects as for food security is concerned. When compared to the omitted category, *No kids*, households with two kids, three kids, four kids and more than four kids are 2.4, 4.9, 7.6, and 11.4 percentage points, respectively, less likely to be food secure. As expected the marginal effects are positive for each of the food insecurity categories, meaning that the probability of being food insecure is higher for households with kids. These probabilities increase monotonically with the number of kids in the household (See Table 4.3).

Households that live in rural communities appear to be more vulnerable than those living in larger communities/cities. Controlling for variables related to household head characteristics and household composition, households that live in large cities are 2.5 percentage points more likely to be food secure than those living in rural communities (omitted category). This marginal effect is even greater, 4.2 and 2.8 percentage points, for households living in medium and small cities, respectively. This result may be related to the level of isolation, since there are rural communities that do suffer from lack of access to development opportunities (jobs, education, health care, etc.).

Since poverty and food insecurity is a relevant problem in rural communities, a more detailed analysis is provided below. Determinants of food insecurity are analyzed for this particular population group.

In average households in *Region3* and *Region5* are, respectively, 0.1 and 2.0 percentage points more likely to be food secure than those in *Region7*. Conversely, households in *Region1*, *Region2*, *Region4* and *Region6* are more likely to be food insecure than the households in *Region7*, which is Mexico City.

Focusing on an important vulnerable population subgroup, which consists of rural households with incomes below the food poverty line (*Lower income*), the regression analysis is performed using a sample of 4,343 households that meet these two aspects (rural and *Lower income*).

Level of formal education of household head is an important determinant of food security in rural areas. As shown in table 4.4, the marginal effects of all levels of education are positive and highly significant for food security and for very low food insecurity, levels that represent the two best categories in the food security scale. Education may be important to food security not only because it is usually correlated with income, but also because it may have a positive impact on how the resources in the household are managed. Gundersen and Garasky (2012) found that households with greater financial management abilities are less likely to be food insecure. This finding holds even for households with incomes <200% of the poverty line in the United States.

These findings suggest that improving households' financial management skills has the potential to reduce food insecurity. It would be worth to explore if the same outcome holds for Mexican households and if that is the case, implementing training programs would help families to achieve food security.

Table 4.4. Regression Coefficients and Marginal Effects for Lower Income Households in Rural Communities

		Marginal Effects			
			Food Insecurity		
Variable	Coefficients	Food Security	Very Low	Moderate	Severe
Age 31-45	-0.038	0.013	0.002	-0.004	-0.011
Age 46-60	0.108	-0.036	-0.005	0.011	0.030
Age >=61	0.075	-0.025	-0.003	0.008	0.021
Male	-0.044	0.015	0.002	-0.004	-0.012
Elementary	-0.300***	0.101***	0.013***	-0.030***	-0.085***
Secondary	-0.347***	0.117***	0.015***	-0.035***	-0.098***
High School	-0.666***	0.225***	0.029***	-0.066***	-0.188***
College	-0.794*	0.268*	0.035*	-0.079*	-0.224*
Disable Person	0.262***	-0.089***	-0.011***	0.026***	0.074***
Native Language	0.166***	-0.056***	-0.007***	0.017***	0.047***
Social PP	-0.037	0.013	0.002	-0.004	-0.011
Agricultural HH	-0.246***	0.083***	0.011***	-0.025***	-0.069***
Traditional HH	0.199	-0.067	-0.009	0.020	0.056
Extended HH	-0.015	0.005	0.001	-0.001	-0.004
Composite HH	0.400	-0.135	-0.017	0.040	0.113
Co-resident HH	-1.032*	0.349*	0.045*	-0.103*	-0.291*
Kids 1	0.170**	-0.058**	-0.007**	0.017**	0.048**
Kids 2	0.256***	-0.086***	-0.011***	0.026***	0.072***
Kids 3	0.257***	-0.087***	-0.011***	0.026***	0.073***
Kids 4	0.361***	-0.122***	-0.016***	0.036***	0.102***
Kids >4	0.541***	-0.183***	-0.024***	0.054***	0.153***

Sample size: 4,343 households.
HH=Household. Social PP=Social Program participation.
*p<.1, **p<.05, ***p<.01

Households that have disabled persons have increased probability of being moderate food insecure (2.6 percentage points) and severe food insecure (7.4 percentage points) compared to households in the alternative category. This is not a surprising result since taking care of a disabled person increases household expenses.

Native language is a variable that have negative marginal effects for food security (-5.6 percentage points) and for very low food insecurity (-0.7 percentage points). This means that the probability of a household, where at least one member speaks a native language, to be food secure is significantly lower compared to households that do not share the native language characteristic. It is worth noticing that even in the rural-lower income subpopulation group the households with strong indigenous background are more likely (vulnerable) to be food insecure.

The marginal effects of participating in a social program, households that receive income from one of two government programs, *Oportunidades* or *Apoyo Alimentario*, are not statistically significant. This variable is only included in the estimation for the rural-lower income subpopulation group since the objective of the program is to reach households that live under poverty conditions. An alternative model specification (not reported) without including the variable for social program participation was estimated, finding that the estimates and marginal effects of the rest of the variables are practically unaffected when dropping such variable that could be considered as endogenous.

Estimation of a formal treatment effect of social program participation on food security is out of the scope of this research and it is left as an opportunity for future work. There is evidence in the literature that social program participation helps households to achieve better food security status. Ruiz-Arranz et al. (2002) analyze the impact on food security of two conditional cash transfer programs, *Oportunidades* (previously known as *Progresa*) and *Procampo*. Whereas *Oportunidades* is a transfer program aimed to help households through food consumption and the development of human capital, *Procampo* is an agricultural production program. The authors found that both programs boost total food consumption, and caloric intake in similar proportions. Moreover, both programs increase food diversity. Households that were *Procampo* recipients that also receive *Oportunidades*, were more likely to have a more varied diet than households that receive benefits from *Procampo* only. The authors conclude that access to information on nutrition and health that accompanies *Oportunidades* has a positive effect on food diversity. Education and training provided to women seem to affect positively the way resources in the household are spent. Nevertheless, Torres Salcido (2010) suggests that certain vulnerable population has not yet received benefits from social programs in Mexico. Among the reasons for this exclusion, the author cites adverse ethnic characteristics, isolation of rural communities and lack of information.

Back to the description of results, agricultural households have increased probabilities to have a positive food security status. An agricultural household in rural areas is 8.3 percentage points more likely to be food secure than a non-agricultural household. The definition of agricultural household is the same as in previous sections. Most agricultural households are eligible to receive benefits from *Procampo* and arguably are more likely to be better off than other households. Sadoulet, de Janvry, and Davis (2001) analyzed *Procampo* program in Mexico, finding that cash transfer programs can create multiplier effects, particularly when household recipients invest the money they receive to generate further incomes. The authors also find that these multipliers are higher for households with medium and large farms, low numbers of adults in the household, and households with nonindigenous backgrounds. They point out that opportunities are enhanced when recipient households have also access to technical assistance.

As for the number of kids in the household, the marginal effects on food security of having one, two, three, four and more than four kids are -5.8, -8.6, -8.7, -12.2 and -18.3 percentage points, respectively. Households with kids are less likely to be food secure than households without children. The probability of a household to have food security decreases as the number of kids in the household increase.

Common factors from the discussion above include: 1) education is an important determinant of food security, even in lower income households; 2) population with strong indigenous background, usually living in isolated communities, seem to be a vulnerable population segment in terms of food insecurity.

There is no straightforward solution to address the food insecurity problem, especially for households living in isolated communities. However, there are some alternatives that have been discussed in recent literature. Torres Salcido (2010) suggests not only implementing policies that will bring the benefits of cash transfer social programs to the residents of these localities but also implementing complementary policies to support sustainable local food production and development. In other words, the author specifies that it requires a holistic rural development perspective to enable sustainable productive capacities of these territories based on the recognition of their particular conditions to improve food security in isolated communities. Torres Salcido (2010) discusses that establishing public policies to promote the formation of Localized Agrifood Systems (LAS), an emerging paradigm in rural development, could be an option. The main objective of this approach is to exploit the interaction of people, culture, tradition in a given rural territory, such as the ability to sustainably produce value added products (ethnic handcrafts, organic coffee, honey, etc.), to provide services such as eco-tourism and rural tourism, among other economic activities. As a particular example, Juárez Sánchez and Ramírez Valverde (2007) observe that rural tourism is a complementary activity that can revitalize local rural economies. Investment in public goods (roads, infrastructure, etc.) and access to credits are relevant factors necessary to propel rural development, as discussed by the authors.

IV.6. Conclusions

The increase of food insecurity in Mexico has obvious policy implications and relevance. In this study an ordered probit model, along with nationally representative data and a newly developed food security scale was used to investigate how demographic variables are related to food security and to different degrees of food insecurity. The estimation was conducted for the general (total) population first, and then for a subpopulation group of rural lower income households. It was found, for the general population, that households with younger, less-educated household heads were more likely to suffer food insecurity. Other groups that were found to be vulnerable in terms of food insecurity include: households headed by a single, widow or divorced mother, households with disabled family members, households with strong indigenous background, rural households, low income families, non-agricultural households and households with kids.

Since households in rural areas and with income below the food poverty line were found to be a vulnerable group, estimation for this subgroup was conducted separately. Vulnerable groups in rural, lower income subgroup still include households with strong agricultural background (*Native language*), households with disabled family members and households with large number of children. It seems that is necessary not only implementing policies that will bring the benefits of cash transfer social programs to the residents of isolated rural communities but also implementing complementary public policies to support sustainable local food production and rural development.

It was found that the level of education is yet an important determinant of food security even among lower income families in rural areas. Education may be important to food security not only because it is usually correlated with income, but also because it may have a positive impact on how the resources in the household are managed. Gundersen and Garasky (2012) found that households with greater financial management abilities are less likely to be food insecure. These findings suggest that improving households' financial management skills has the potential to reduce food insecurity in the United States. If the same outcome holds for Mexican households, implementing training programs would help families to improve food security.

Within the rural and lower income subpopulation, other variable related to favorable food security status is *agricultural household*. Sadoulet, de Janvry, and Davis

(2001) analyzed *Procampo* program in Mexico, finding that cash transfer programs can create multiplier effects. They also point out that opportunities are enhanced when recipient households have also access to technical assistance. Education (technical training) seems to play an important role to achieve food security in agricultural households as well.

As for opportunities for further research, one way to expand the present work is to evaluate social program participation using food security as dependent variable. This could be done by using formal treatment effect methods and correcting for endogenous program participation. One possibility is to extend the model towards a bivariate ordered probit, as described in Jensen (2002). Other possibilities include program evaluation estimation through nonparametric or Bayesian methods.

Further research opportunities include the estimation of household food security determinants for particular geographic regions or demographic subgroups of interest, which may have the potential to identify relevant variables to help the design of development programs.

CHAPTER V

CONCLUSIONS

Higher and more volatile food prices, as reported in recent years, have consequences on household welfare and potentially on public policy. This dissertation provides information that could be useful in understanding food price dynamics and in designing agricultural and social public policies.

In the first essay the dynamic information flows among monthly prices of agricultural commodities in the U.S. and Mexico for the years 2000-2012 are analyzed. Error correction models and directed acyclical graphs are employed with observational data to sort-out the dynamic causal relationships among prices for important agricultural commodities in both countries. As for results, first, no structural change in commodity prices for the period under analysis was found for any of the commodity prices. Unlike in previous studies using VECM the results in this paper indicate the existence of long-run relationships among grain prices in the U.S. and Mexico. Analyses of impulse response simulations and forecast error variance decompositions indicate price dynamics in these markets. Results suggest that price discovery takes place in U.S. grain markets. Commodity prices in the U.S. market are highly influenced by their own historical innovations. U.S. grain prices have a consistently strong impact on price movements in Mexican agricultural markets in the long-run. Information flows among grain markets in Mexico and from grain to cattle markets are also identified and described. Contemporaneous price information flows from sorghum in the U.S. to sorghum in

Mexico, which in turn, influences price of yellow corn and price of beef in Mexico. This is a relevant finding on how price information in U.S. agricultural markets flows within the same period of time into agricultural markets in Mexico. Particularly interesting is the finding that the Mexican yellow corn market, along with domestic sorghum prices, passes information directly to the beef market. Historically, Mexican cattle were mainly grass-fed (Zahniser and Coyle 2004). As discussed in Peel, Mathews, and Johnson (2011), in much of Mexico market preferences for grain-fed beef are increasing rapidly, relative to traditionally produced grass-fed beef.

Given the recent increase in grain price volatility and the increased level of integration in agricultural markets between Mexico and the U.S., as found in this study, it makes more relevant the use of price risk management tools. Strengthening public policies in Mexico aimed to provide training for farmers and to facilitate the access to such tools seems to be a reasonable strategy.

In the second essay, a linearized EASI demand system was estimated in order to calculate the parameters needed to calculate the welfare effects due to food price increase for a specified reference household type in Mexico. The distribution of monetary measures of welfare effects from food price changes was estimated as well as equivalence scales that allow inter-household comparison of welfare changes. After accounting for substitution effects, poverty related impacts are estimated. Findings indicate that the increase in prices of five food groups from 2006 to 2010 has led to an increase of 1.8 percentage points in the proportion of households with income below the food poverty line. Welfare effects on poverty seem to be higher on households located in rural communities than in urban households. It is believed that the fact that it is feasible to estimate welfare effects in monetary terms, tailored for sub-population groups, has important implications and relevance for public policy in Mexico.

In the third essay, an ordered probit model was used, along with a nationally representative data and a newly developed food security scale for Mexico. The analysis was conducted for the general population first and then for a subpopulation group of rural lower-income households. It was found that households with younger, less-educated household heads were more likely to suffer food insecurity. Other groups that were found to be vulnerable in terms of food insecurity include: households headed by a single, widow or divorced mother, households with disabled family members, households with strong indigenous background, rural households, low income families, non-agricultural households and households with kids.

Education may be important to food security not only because it is usually correlated with income, but also because it may have a positive impact on how the resources in the household are managed. Gundersen and Garasky (2012) found that households with greater financial management abilities are less likely to be food insecure. These findings suggest that improving households' financial management skills has the potential to reduce food insecurity in the United States. If the same outcome holds for Mexican households, implementing training programs would help families to improve food security.

Having a strong indigenous background (native language) has negative effect on food security. This holds even among lower-income, rural subpopulation. It is possible that adverse ethnic characteristics, isolation of rural communities and lack of information limit the opportunities among these groups. One possible option would be implementing public policies to support sustainable local food production and rural development.

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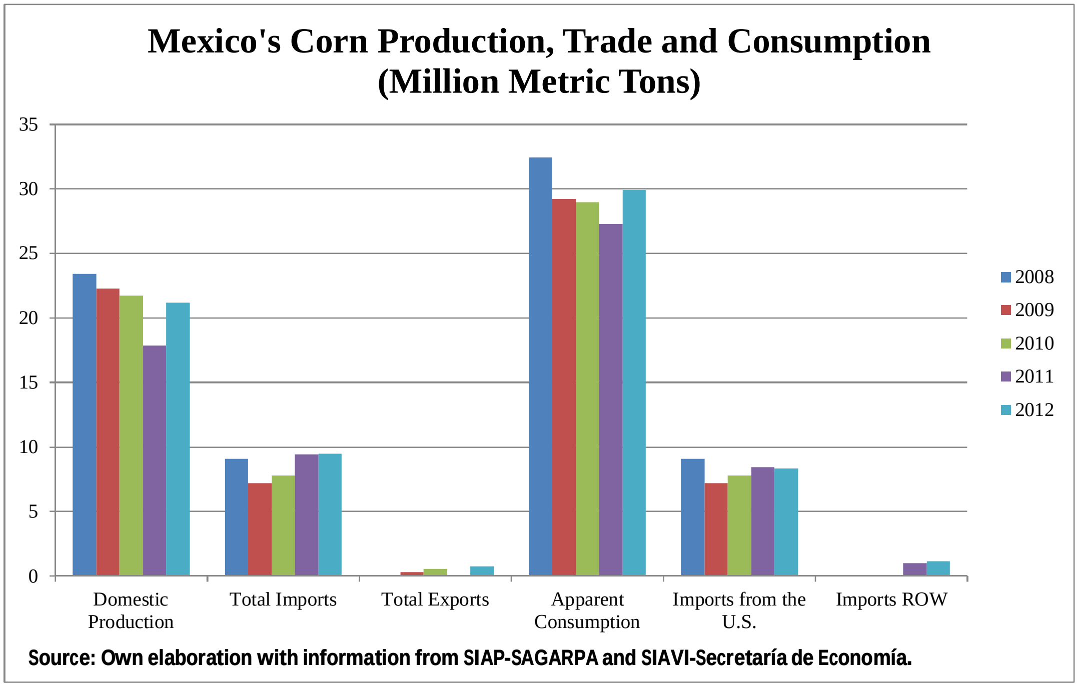
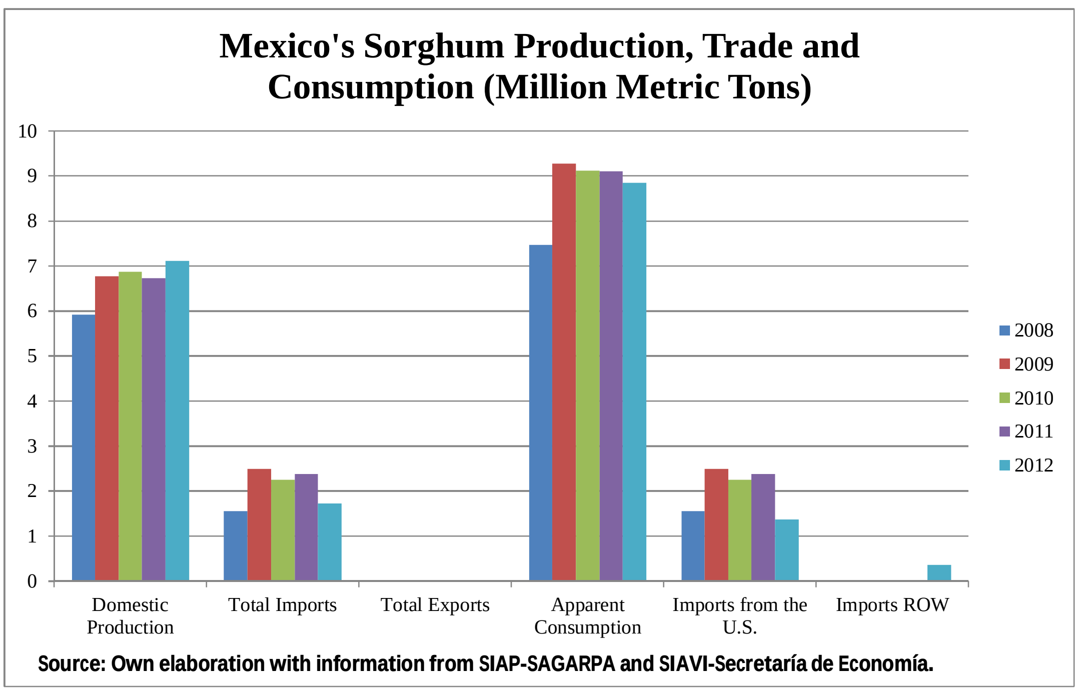
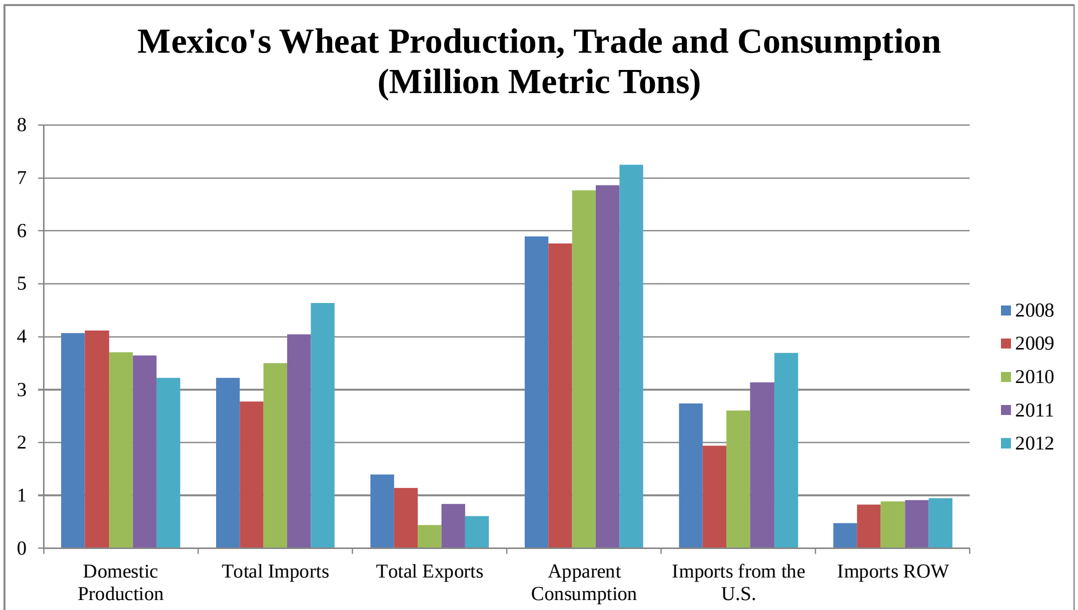
APPENDIX A

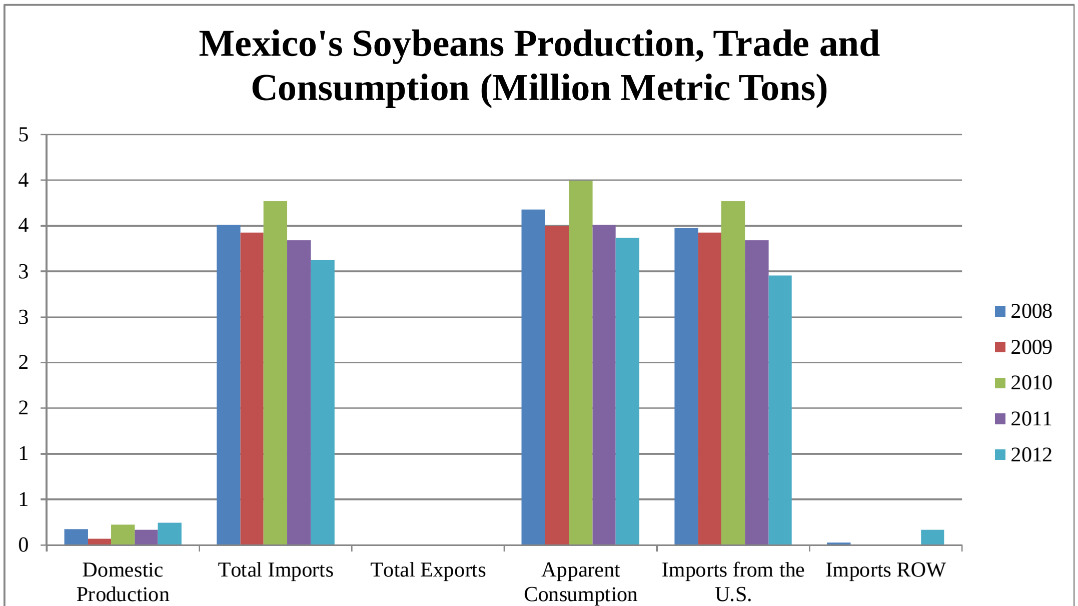
PRODUCTION, TRADE AND CONSUMPTION OF GRAINS AND SOYBEANS IN MEXICO







Source: Own elaboration with information from SIAP-SAGARPA and SIAVI-Secretaría de Economía.



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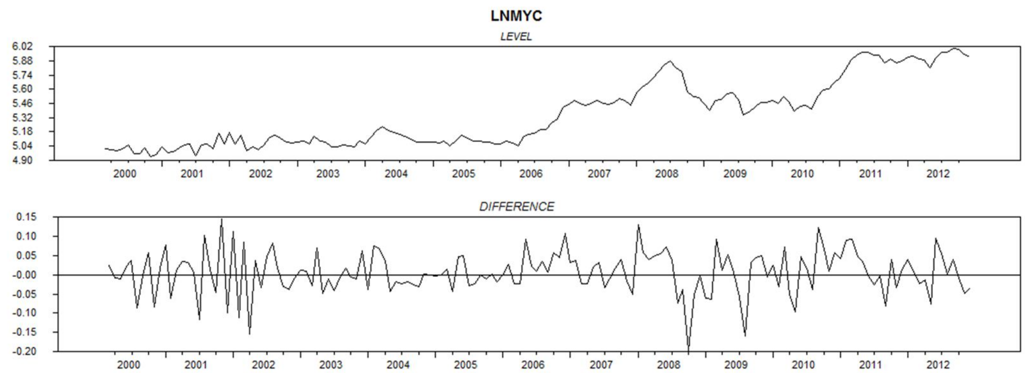
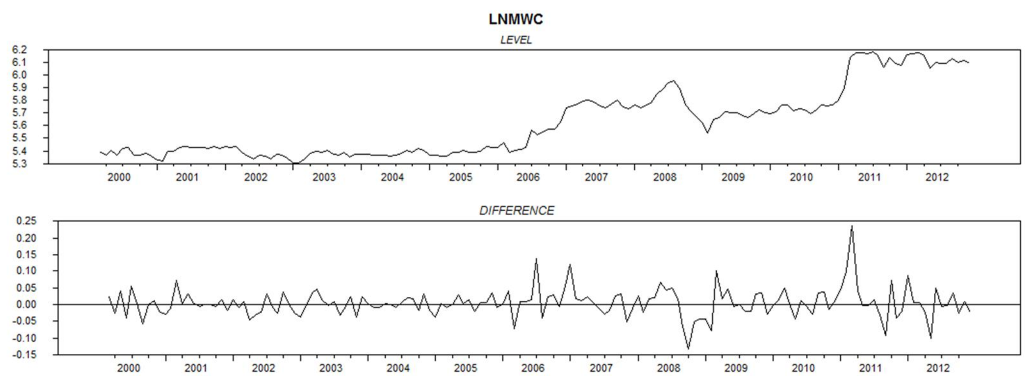
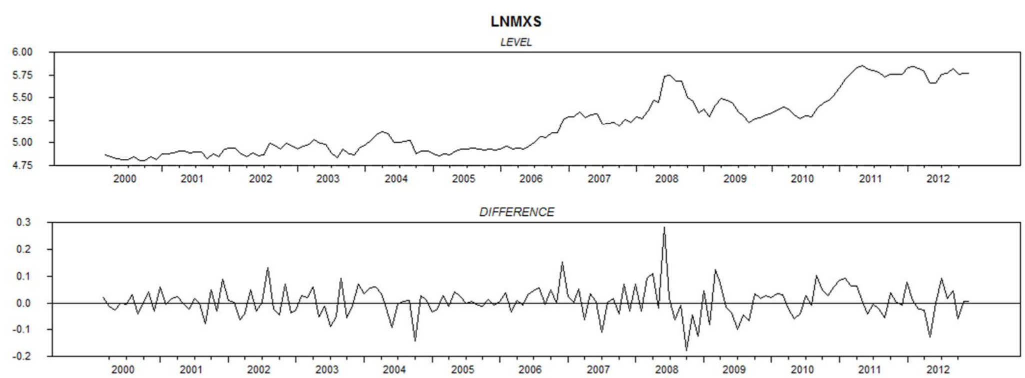
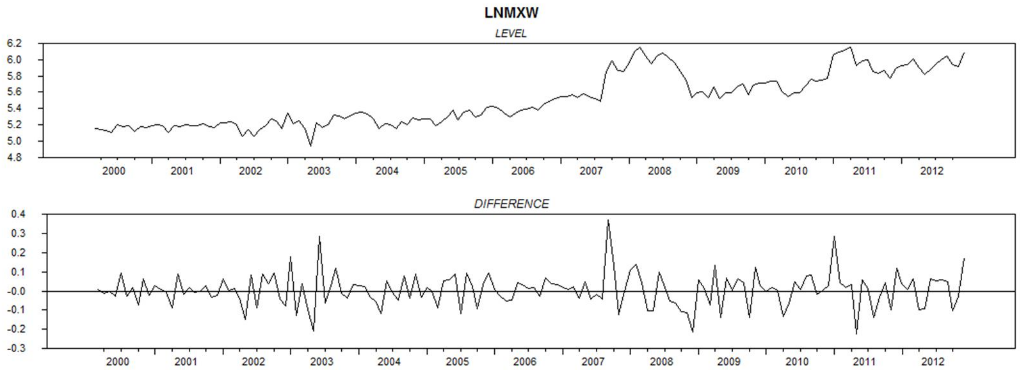
APPENDIX B

COMMODITY PRICE SERIES IN LOG LEVELS AND IN FIRST DIFFERENCES





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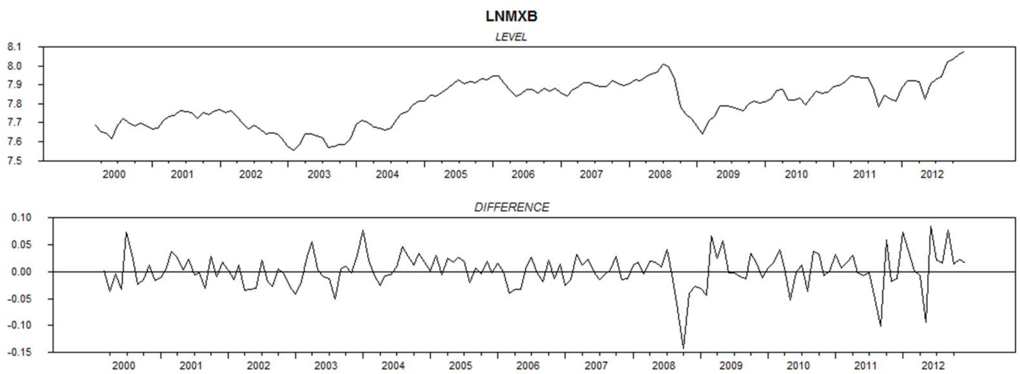
LEVEL
DIFFERENCE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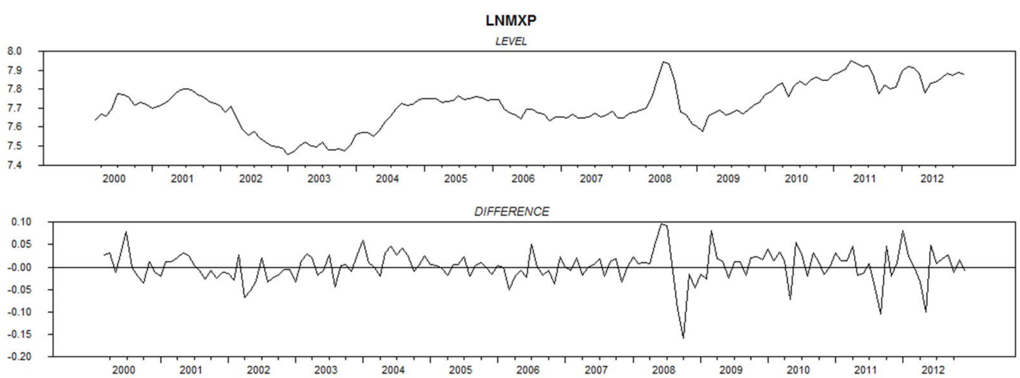
LEVEL
DIFFERENCE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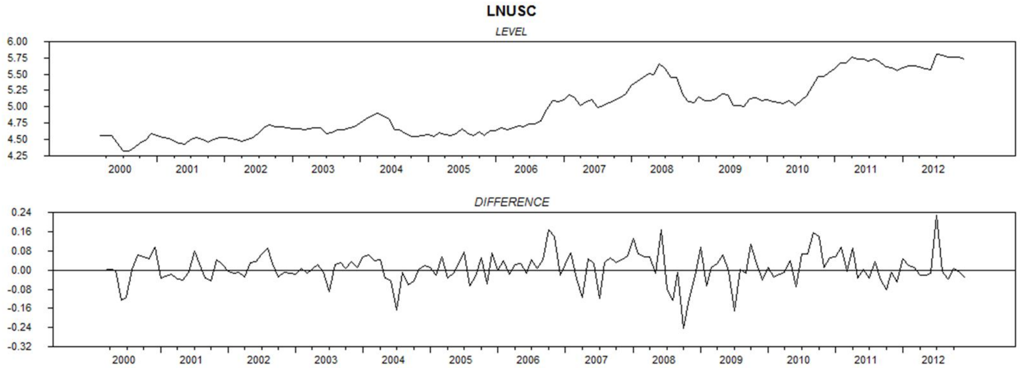
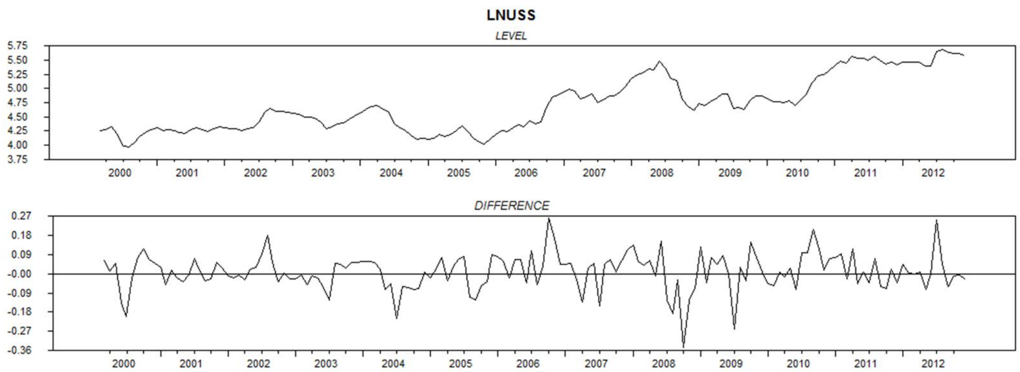

LNUSC
LEVEL
6.00 5.75 5.50 5.25 5.00 4.75 4.50 4.25
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012
DIFFERENCE
0.24 0.16 0.08 0.00 -0.08 -0.16 -0.24 -0.32
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012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2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012
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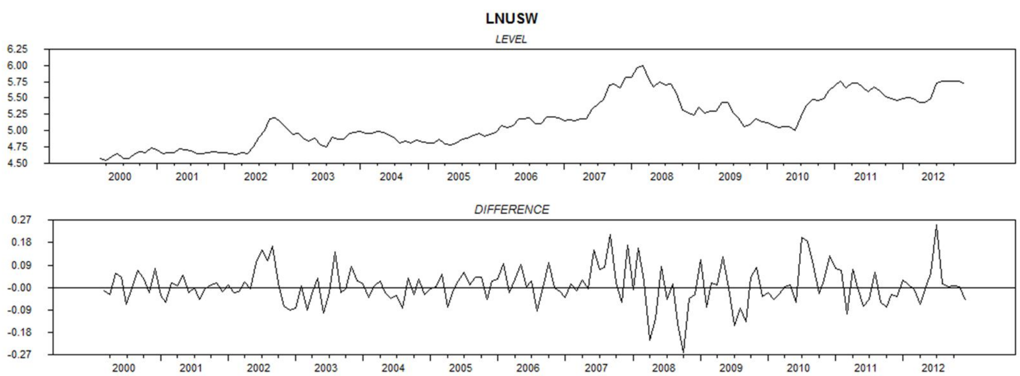
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012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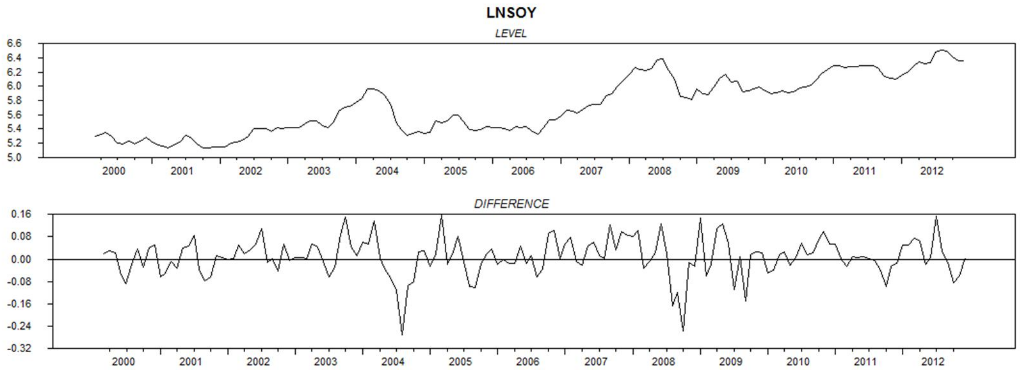
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012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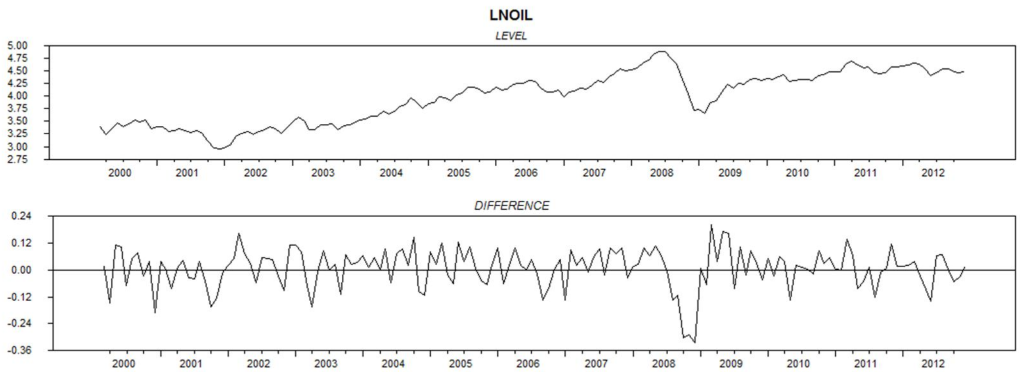
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LEVEL
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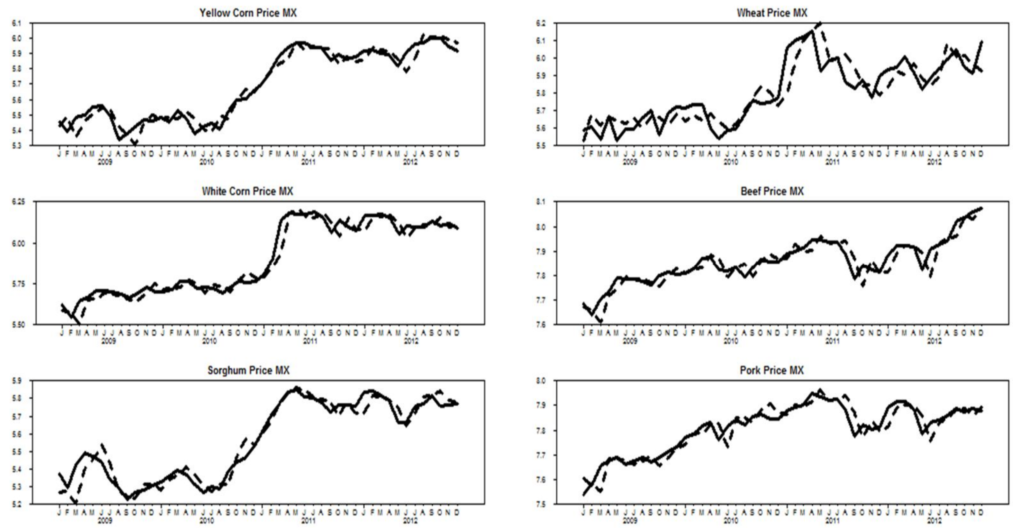
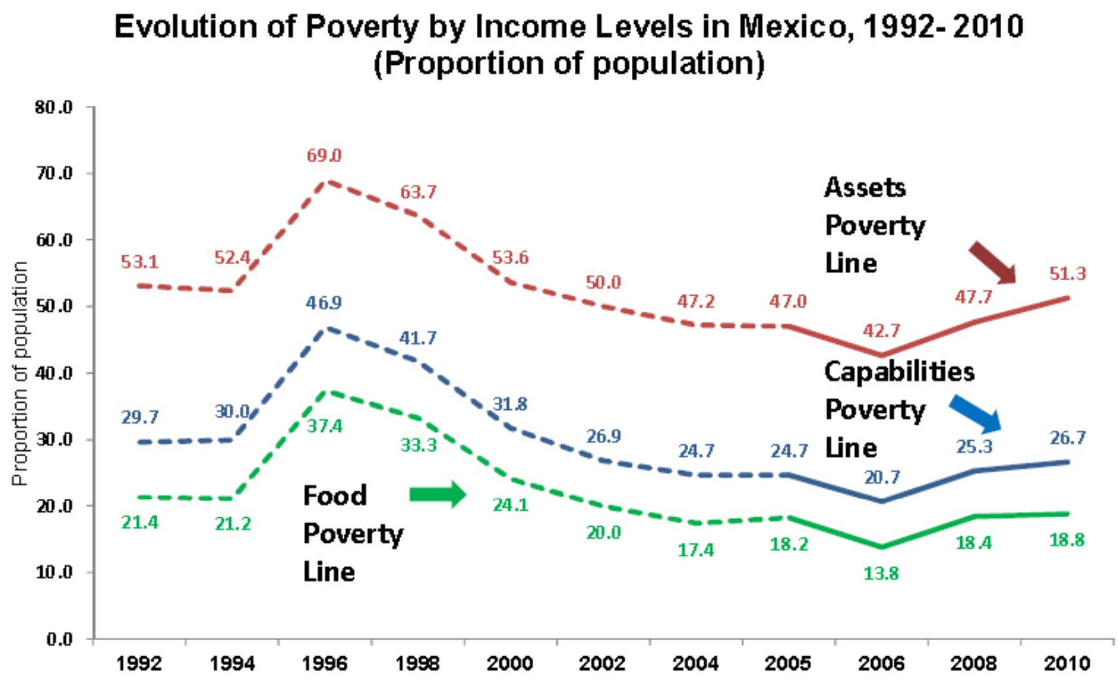
APPENDIX C

RECURSIVE FORECASTING OF LOG OF COMMODITY PRICES



APPENDIX D

EVOLUTION OF POVERTY BY INCOME LEVELS IN MEXICO, 1992-2010



Source: CONEVAL based on ENIGH from 1992 to 2010

APPENDIX E

PARAMETER ESTIMATES FROM THE DEMAND MODEL FOR THE REFERENCE HOUSEHOLD TYPE

EASI Parameter Estimates for the Reference Household

Variable	Tortilla	Cereal	Meat	Dairy	Fruit & Veg.
y1	-0.049***	-0.018***	0.028***	-0.02***	-0.013***
y2	0.001**	0.003***	-0.006***	-0.001**	-0.005***
Household Size	0.011***	0.004***	0.006***	0.004***	0.006***
HH Head's Age	0.0005***	-.0001***	0.001***	-.0002***	0.001***
Urban Setting	-0.005***	0.014***	-0.028***	-0.007***	0.048***
Tortilla Price	-0.007***	0.004***	0.002*	0.007***	0.015***
Cereal Price	0.004***	0.015***	-0.004***	-0.002***	-0.006***
Meat Price	0.002*	-0.004***	0.002	0.013***	0.003***
Dairy Price	0.007***	-0.002***	0.013***	-0.01***	0.007***
Fruit & Veg. Price	0.015***	-0.006***	0.003**	0.007***	-0.007***
Constant	0.078***	0.074***	0.17***	0.128***	0.13***

*** p<0.01, ** p<0.05, * p<0.1

EASI=Exact Affine Stone Index Model.

APPENDIX F

FOOD SECURITY QUESTIONNAIRE FOR THE MEXICAN FOOD SECURITY SCALE (EMSA)

1) In the last three months, due to lack of money or resources, did you or any adult in your household have a diet based on a limited variety of foods?

2) In the last three months, due to lack of money or resources, did you or any adult in your home skip a meal (breakfast, lunch or dinner)?

3) In the past three months, due to lack of money or resources have you or any adult in your household eaten less than you think you should eat?

4) In the last three months, due to lack of money or resources, did you ever run out food?

5) In the last three months, due to lack of money or resources, have you or any adult in your household been hungry but not eaten?

6) In the last three months, due to lack of money or resources, have you or any adult in your household eaten only once a day or eaten nothing in the whole day?

Following questions are asked only for households with members that are younger than 18 years old.

7) In the last three months, due to lack of money or resources, have anybody in the household under 18 had a diet based on a limited variety of foods?

8) In the last three months, due to lack of money or resources, have anybody in the household under 18 eaten less than you think they should?

9) In the last three months, due to lack of money or resources have you ever had to reduce
size of meals served to a minor (<18 years) in the household?

10) In the last three months, due to lack of money or resources, have anybody in the household under 18 been hungry but did not eat?

11) In the last three months, due to lack of money or resources, have anybody in the household under 18 gone to sleep at night hungry because there was not enough food?

12) In the last three months, due to lack of money or resources, have anybody in the household under 18 stopped eating all day or eaten only once?