WORLD PRICE, EXCHANGE RATE AND INVENTORY IMPACTS ON THE MEXICAN CORN SECTOR: A CASE STUDY OF MARKET VOLATILITY AND VULNERABILITY

JOSÉ ALBERTO GARCÍA-SALAZAR, RHONDA K. SKAGGS and TERRY L. CRAWFORD

SUMMARY

Two decades of trade liberalization and economic reform have led to a reduction in food self-sufficiency of corn, primary component of the Mexican food and feed supply. Due to the country's dependence on global markets, Mexican corn prices are sensitive to changes in international prices and inventory holding for speculative purposes. The impact of corn price volatility on Mexican social stability has prompted evaluation of the effects of changes in international prices, exchange rates and inventories on the corn price through the use of a spatial and intertemporal equilibrium model. Results indicate that if the world price increases by 20%, then the price increases by 15.6%, production increases by 4.0%, while corn imports decrease by 19.2%. Assuming that corn imports do not change, a three million metric tons inventory will increase corn price by 32.5%, and increase production by 8.7%. Higher corn prices are undesirable for society due to the negative effects on the low-income population. Thus it is recommended that the Mexican government apply policies that promote food self-sufficiency and reduce incentives for speculation.

Extreme price volatility throughout the year currently characterizes numerous food product markets in Mexico. Because the Mexican government has been gradually withdrawing from agricultural market interventions, price volatility in the local grain sector, particularly corn, has become more extreme. For example, in early 2007 the price of corn produced in Sinaloa and sold in the Central Wholesale Market of Ecatepec, Estado de México, increased 30% in less than a month (SNIIM, 2009).

From 1965 to 1999 corn price volatility was moderated by federal government intervention in the grain market through the Compañía Nacional de Subsistencias Populares (CONASUPO). On the consumption side of the market CONASUPO sold corn at lower than competitive prices and was responsible for moving grain from surplus to scarcity regions. On the production side, the government supported farmers with guaranteed output prices and subsidized input prices. CONASUPO was designed to promote Mexico's economic and social development by a) regulating the markets for staple or subsistence crops through the creation of more efficient and rational relationships between producers and consumers and the elimination of inefficient and dishonest intermediaries, and b) protecting low-income consumers by granting them access to basic foods and protecting low-income producers by allowing them to obtain a livelihood from their production activities. CONASUPO sought to increase both the purchasing power of low-income consumers and the incomes of small, staple-producing farmers while simultaneously promoting domestic and external trade in these commodities (Yunez-Naude, 2003). CONASUPO was liquidated in 1999 as part of Mexico's domestic economic reforms, general trade liberalization, and commitments made

KEYWORDS / Exchange Rate / International Price / Inventories / NAFTA / Spatial and Intertemporal Equilibrium Model / White and Yellow Corn /

Received: 05/11/2011. Modified: 06/04/2012. Accepted: 06/05/2012.

José Alberto García-Salazar. Agronomical Engineer, Universidad Autónoma de Chapingo, Mexico. M.Sc. and Doctor in Economy, Colegio de Posgraduados (COLPOS), Mexico. Professor-Researcher, COLPOS, Mexico. Address: Instituto de Socioeconomía, Estadística e Informática, COLPOS. Km. 36,5 Carretera México-Texcoco. CP 56230, Montecillo, Estado de México, México. e-mail: jsalazar@colpos.mx

Rhonda K. Skaggs. B.S. and M.S. in Agricultural and Natural Resource Economics, Colorado State University, USA. Ph.D. in Economics, Utah State University, USA. Professor, New Mexico State University (NMSU), USA. e-mail: rskaggs@nmsu.edu

Terry L. Crawford. B.S. in Agricultural Economics, NMSU, USA. M.s. and Ph.D. in Agricultural Economics, Cornell University, USA. Professor, NMSU, USA. e-mail: crawford@nmsu.edu

under the North American Free Trade Agreement (NAFTA) and the World Trade Organization (WTO).

Rising grain prices in 2007 led to 'tortilla riots' involving thousands of people throughout Mexico and resulted in attempts by the Mexican government to cap the price of corn flour (which rose by over 400% in a three-month period). As a result of global market forces, the millions of poor Mexicans who rely on corn as their primary source of calories found themselves competing for industrial corn demand and responded by taking to the streets. Mexico's corn-feeding livestock industries were also negatively impacted by recent corn market events, as were consumers of animal products, further compromising the nutritional status of the Mexican population.

Critics of the NAFTA blame policy reforms implemented as a result of agreement for reduced competitiveness of Mexican corn producers, exposure of the Mexican food and agricultural sector to greater price volatility, decreased food security, and increased risks of political and social instability. Mexico's official vision has been that free trade and economic reforms would transform the agricultural sector and increase national income. NAFTA opponents claim that the agreement has resulted in food dependence, led to massive rural-to-urban migration, and increased poverty; empirical findings suggest that the much-expected transformation of the Mexican agricultural sector did not occur in the first ten years of NAFTA (Yunez-Naude and Barceinas-Paredes, 2004). Due to the resulting negative distributional effects, some researchers, farmer groups, and members of opposition parties contend that the inclusion of corn into the NAFTA should be renegotiated.

Dramatic short-term corn price increases are problematic in Mexico for the following reasons: a) corn is the most important staple Mexican foodstuff, and is used as an input in many final products consumed by the population of 105 million people; currently more that 14 million metric tons are consumed by livestock, more than 10 million metric tons are used in tortillas and other food products, and more than three million metric tons are consumed by the industrial sector in the form of starch and other products (SAGARPA, 2007); b) higher corn prices disproportionately decrease corn consumption in the low-income population due to their greater dependence on corn as a basic foodstuff; and c) increasing corn prices decrease disposable income across the socio-economic spectrum, cause social discontent, and exacerbate Mexican economic crises.

Numerous factors can positively influence corn prices in Mexico. The most important are changes in the world price of corn, increases in the exchange rate, inventory accumulation, and supply curve shifts due to adverse climatic conditions. Because part of Mexican corn consumption is supplied by imports, an increase in the world price has a direct impact on price and on other market variables in Mexico. Clearly, abrupt changes in the USA market will cause sharp variations in Mexican domestic prices. Mexican domestic corn production has been insufficient to meet national consumption needs throughout the post-NAFTA period and Mexico has turned to the USA market to guarantee needed supplies. At the time NAFTA was implemented the annual average (1993-1995) Mexican imports of corn were 1,881,000 metric tons and represented 9.4% of national consumption. These numbers are contrasted with data for the post-NAFTA period 2005-2007 when 7,216,000 metric tons were imported and supplied 25.2% total consumption. Dependence on imports has resulted in decreased food self-sufficiency in Mexico.

Reduced self-sufficiency of a key staple crop has made the Mexican domestic market more vulnerable to changes in the global market, primarily changes in supply and demand emanating from the USA Mexican vulnerability to USA corn market events has been exacerbated by recent trends and regulations related to corn ethanol production and alternative fuel mandates. Rising oil prices and uncertainty in the world petroleum market underlie the rapid expansion of the ethanol industry in the USA.

The Energy Policy Act of 2005 established strong political support for the development of alternative fuel sources, and the Energy Independence and Security Act of 2007 established to move the United States toward greater energy independence and security, to increase the production of clean renewable fuels, to protect consumers, to increase the efficiency of products, buildings, and vehicles, to promote research on and deploy greenhouse gas capture and storage options, and to improve the energy performance of the Federal Government, and for other purposes. Ethanol, principally derived from corn, currently is the dominant biofuel used in the USA.

The Food and Agricultural Policy Research Institute projected in its March 2011 baseline that USA corn-derived ethanol production will increase from 13,387 million gallons in 2010/2011 to 15,994 million gallons by 2020/2021 (FAPRI 2011). To reach this level of ethanol production, FAPRI projected use of corn for fuel alcohol would increase from 4,902 million bushels in year 2010/2011 to 5,563 million bushels by 2020/2021.

Increased biomass demand by the ethanol industry is projected to considerably alter the USA corn market. FAPRI projects farm-level corn prices will increase from $3.89/bushel in 2008/2009 to $4.11/bushel in 2018/2019. Greater changes in corn prices will occur if projected production is not achieved. FAPRI projects corn production will increase from 13,740 million bushels in 2008/2009 to 16,215 million bushels in 2018/2019; these increases in corn production will come from an increase in harvested area (from 78.6 to 83.3 million acres) and a yield increase from 153.9 to 174.3 bushels per harvested acre.

Devaluation of the Mexican peso relative to the USA dollar would have effects on the Mexican corn market similar to changes in the world price. Inventory accumulation is another factor that could impact the Mexican corn market by increasing corn prices. Corn scarcity resulting from speculative storage activities produces a temporal demand surplus that can cause prices to rise, and it is probable that early 2007 increases in observed corn prices were caused by inventory accumulation. Data obtained from the *Sistema de Información Agroalimentaria y Pesquera de la Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación* (SIAP-SAGARPA, 2009b) support this hypothesis. Harvested production in December 2006 of 5,807,000 tons, plus inventories of 2,614,000 tons in this same month meant that by January 2007 available supply surpassed 8 million tons. Because exports were low in these months, it is very likely that the early 2007 rise in prices was a consequence of market speculation.

Given the importance of corn as a subsistence and market crop for producers and as a major ingredient in the diets of Mexican consumers, quantification of the impacts of key factors on the Mexican corn market and corn prices is needed. This paper examines world price, exchange rate and inventory effects on the Mexican corn sector. The objective of the research reported here is to provide policy recommendations for dealing with inter-temporal corn price variability and for increasing social welfare in Mexico.

The Model

A spatial and inter-temporal equilibrium model of the Mexican corn market was used to quantify world price, exchange rate and inventory effects on the Mexican corn sector. The model includes the spatial dimension because Mexico's tradable corn surplus is concentrated in the northwestern and southern regions of the country, while the majority of corn is consumed in the Mexico City metropolitan area. Large distances between the main producer-supplier regions and the main internal points of consumption emphasize the importance of transportation costs. The model includes a temporal dimension because almost 60% of Mexican-grown corn is harvested in November, December, and January; thus, storage costs are an important element in market dynamics.

The model separately considers production and consumption of white and yellow corn because each type responds differently to market stimuli. Corn consumption was broken into feed, food, and industrial uses. Because almost 100% of Mexican corn imports come from the USA, the model focuses on the connections between internal points of consumption, domestic supply regions, USA-Mexico border ports-of-entry and maritime ports-of-entry. Furthermore, the model includes the spatial and temporal allocation of both white and yellow corn imports.

Based on Takayama and Judge (1971), Bivings (1997) and García and Williams (2004), and assuming i(i=1,2…I=10) white corn production regions, s(s=1,2...S=10) yellow corn production regions, j(j=1,2…J=10) feed consumption regions, d(d=1,2,3…D=10) food consumption regions, f(f=1,2,3…F=10) industrial consumption regions, m(m=1,2…M=11) border and maritime ports-of-entry for white corn imports; n(n=1,2…N=11) border and maritime ports-of-entry for yellow corn imports and t(t=1,2...T=12) months, the model maximizes the 'net social payoff' (NSP) according to Eq. 1:

$$
\begin{aligned}
MaxNSP= & \sum_{t=1}^{T}\pi^{t-1}\sum_{j=1}^{J}\left[\lambda_{jt}y_{jt}+\tfrac{1}{2}\omega_{jt}y_{jt}^{2}\right]+\sum_{t=1}^{T}\pi^{t-1}\sum_{d=1}^{D}\left[\lambda_{dt}y_{dt}+\tfrac{1}{2}\omega_{dt}y_{dt}^{2}\right] \\
& +\sum_{t=1}^{T}\pi^{t-1}\sum_{f=1}^{F}\left[\lambda_{ft}y_{ft}+\tfrac{1}{2}\omega_{ft}y_{ft}^{2}\right]-\sum_{t=1}^{T}\pi^{t-1}\sum_{i=1}^{I}\left[\nu_{it}x_{it}+\tfrac{1}{2}\eta_{it}x_{it}^{2}\right] \\
& -\sum_{t=1}^{T}\pi^{t-1}\sum_{s=1}^{S}\left[\nu_{st}x_{st}+\tfrac{1}{2}\eta_{st}x_{st}^{2}\right]-\sum_{t=1}^{T}\pi^{t-1}\sum_{m=1}^{M}\left[p_{mt}x_{mt}\right]-\sum_{t=1}^{T}\pi^{t-1}\sum_{n=1}^{N}\left[p_{nt}x_{nt}\right] \\
& -\sum_{t=1}^{T}\pi^{t-1}\sum_{i=1}^{I}\sum_{j=1}^{J}\left[p_{ijt}^{c}x_{ijt}^{c}+p_{ijt}^{r}x_{ijt}^{r}\right]-\sum_{t=1}^{T}\pi^{t-1}\sum_{i=1}^{I}\sum_{d=1}^{D}\left[p_{idt}^{c}x_{idt}^{c}+p_{idt}^{r}x_{idt}^{r}\right] \\
& -\sum_{t=1}^{T}\pi^{t-1}\sum_{s=1}^{S}\sum_{j=1}^{J}\left[p_{sjt}^{c}x_{sjt}^{c}+p_{sjt}^{r}x_{sjt}^{r}\right]-\sum_{t=1}^{T}\pi^{t-1}\sum_{s=1}^{S}\sum_{f=1}^{F}\left[p_{sft}^{c}x_{sft}^{c}+p_{sft}^{r}x_{sft}^{r}\right] \\
& -\sum_{t=1}^{T}\pi^{t-1}\sum_{m=1}^{M}\sum_{j=1}^{J}\left[p_{mjt}^{c}x_{mjt}^{c}+p_{mjt}^{r}x_{mjt}^{r}\right]-\sum_{t=1}^{T}\pi^{t-1}\sum_{m=1}^{M}\sum_{d=1}^{D}\left[p_{mdt}^{c}x_{mdt}^{c}+p_{mdt}^{r}x_{mdt}^{r}\right] \\
& -\sum_{t=1}^{T}\pi^{t-1}\sum_{n=1}^{N}\sum_{j=1}^{J}\left[p_{njt}^{c}x_{njt}^{c}+p_{njt}^{r}x_{njt}^{r}\right]-\sum_{t=1}^{T}\pi^{t-1}\sum_{n=1}^{N}\sum_{f=1}^{F}\left[p_{nft}^{c}x_{nft}^{c}+p_{nft}^{r}x_{nft}^{r}\right] \\
& -\sum_{t=1}^{T}\pi^{t-1}\sum_{i=1}^{I}\left[p_{it,t+1}x_{it,t+1}\right]-\sum_{t=1}^{T}\pi^{t-1}\sum_{s=1}^{S}\left[p_{st,t+1}x_{st,t+1}\right] \\
& -\sum_{t=1}^{T}\pi^{t-1}\sum_{m=1}^{M}\left[p_{mt,t+1}x_{mt,t+1}\right]-\sum_{t=1}^{T}\pi^{t-1}\sum_{n=1}^{N}\left[p_{nt,t+1}x_{nt,t+1}\right] \qquad (1)
\end{aligned}
$$

subject to the following restrictions:

$$x_{it}+x_{it-1,t}-x_{it,t+1}\geq\sum_{j=1}^{J}\left[x_{ijt}^{c}+x_{ijt}^{r}\right]+\sum_{d=1}^{D}\left[x_{idt}^{c}+x_{idt}^{r}\right] \qquad (2)$$

$$x_{st}+x_{st-1,t}-x_{st,t+1}\geq\sum_{j=1}^{J}\left[x_{sjt}^{c}+x_{sjt}^{r}\right]+\sum_{f=1}^{F}\left[x_{sft}^{c}+x_{sft}^{r}\right] \qquad (3)$$

$$x_{mt}+x_{mt-1,t}-x_{mt,t+1}\geq\sum_{j=1}^{J}\left[x_{mjt}^{c}+x_{mjt}^{r}\right]+\sum_{d=1}^{D}\left[x_{mdt}^{c}+x_{mdt}^{r}\right] \qquad (4)$$

$$x_{nt}+x_{nt-1,t}-x_{nt,t+1}\geq\sum_{j=1}^{J}\left[x_{njt}^{c}+x_{njt}^{r}\right]+\sum_{f=1}^{F}\left[x_{nft}^{c}+x_{nft}^{r}\right] \qquad (5)$$

$$\sum_{i=1}^{I}\left[x_{ijt}^{c}+x_{ijt}^{r}\right]+\sum_{s=1}^{S}\left[x_{sjt}^{c}+x_{sjt}^{r}\right]+\sum_{m=1}^{M}\left[x_{mjt}^{c}+x_{mjt}^{r}\right]+\sum_{n=1}^{N}\left[x_{njt}^{c}+x_{njt}^{r}\right]\geq y_{jt} \qquad (6)$$

$$\sum_{i=1}^{I}\left[x_{idt}^{c}+x_{idt}^{r}\right]+\sum_{m=1}^{M}\left[x_{mdt}^{c}+x_{mdt}^{r}\right]\geq y_{dt} \qquad (7)$$

$$\sum_{s=1}^{S}\left[x_{sft}^{c}+x_{sft}^{r}\right]+\sum_{n=1}^{N}\left[x_{nft}^{c}+x_{nft}^{r}\right]\geq y_{ft} \qquad (8)$$

$$x_{i12,13}=x_{i0,1} \qquad (9)$$

$$x_{s12,13}=x_{s0,1} \qquad (10)$$

$$x_{t}=\sum_{m=1}^{M}x_{mt} \qquad (11)$$

$$\sum_{t=1}^{T}\sum_{m=9}^{M}\left[x_{mt}\right]+\sum_{t=1}^{T}\sum_{n=9}^{N}\left[x_{nt}\right]=\delta\left[\sum_{t=1}^{T}\sum_{m=1}^{M}\left[x_{mt}\right]+\sum_{t=1}^{T}\sum_{n=1}^{N}\left[x_{nt}\right]\right] \qquad (12)$$

and

$$y_{jt},\ y_{dt},\ y_{ft},\ x_{it},\ x_{st},\ x_{mt},\ x_{nt},......x_{it,t+1},\ x_{st,t+1},\ x_{mt,t+1},x_{nt,t+1}\geq 0 \qquad (13)$$

where, for month t, $\pi^{t-1}=(1/1+i_t)^{t-1}$: discount factor with i_t equal to the rate of inflation; λ_{jt}, λ_{dt} and λ_{ft} : intercepts of corn demand functions in j, d and f; y_{jt}, y_{dt} and y_{ft} : quantities of corn consumed (feed, food, and industrial consumption) in j, d and f; ω_{jt}, ω_{dt} and ω_{ft} : slopes of demand functions in j, d and f; ν_{it} and ν_{st} : intercepts of corn supply functions in i and s; x_{it} and x_{st} : quantities of white and yellow corn produced in i and s; η_{it} and η_{st} : slopes of supply functions in i and s; p_{mt} and p_{nt} : prices prevailing at ports-of-entry m and n; x_{mt} and x_{nt} : quantities of white and yellow corn imported through ports-of-entry m and n; p^{c}_{ijt} and p^{r}_{ijt} : costs of transporting white corn by truck and train from i to j; x^{c}_{ijt} and x^{r}_{ijt} : quantities of white corn shipped by truck and train from i to j; p^{c}_{idt} and p^{r}_{idt} are the costs of transporting white corn by truck and train from i to d; x^{c}_{idt} and x^{r}_{idt} : quantities of white corn shipped by truck and train from i to d; p^{c}_{sjt} and p^{r}_{sjt} : costs of transporting yellow corn by truck and train from s to j; x^{c}_{sjt} and x^{r}_{sjt} : quantities of yellow corn shipped by truck and train from s to j; p^{c}_{sft} and p^{r}_{sft} : costs of transporting yellow corn by truck and train from s to f; x^{c}_{sft} and x^{r}_{sft} : quantities of yellow corn shipped from s to f; p^{c}_{mjt} and p^{r}_{mjt} : costs of transporting white corn by truck and train from m to j; x^{c}_{mjt} and x^{r}_{mjt} : quantities of white corn shipped by truck and train from m to j; p^{c}_{mdt} and p^{r}_{mdt} : costs of transporting white corn by truck and train from m to d; x^{c}_{mdt} and x^{r}_{mdt} :e quantities of yellow corn shipped by truck and train from m to d; p^{c}_{njt} and p^{r}_{njt} : costs of transporting yellow corn by truck and train from n to j; x^{c}_{njt} and x^{r}_{njt} : quantities of yellow corn shipped by truck and train from n to j; p^{c}_{nft} and p^{r}_{nft} : costs of transporting yellow corn by truck and train from n to f; x^{c}_{nft} and x^{r}_{nft} : quantities of yellow corn shipped by truck and train from n to f; $p_{it,t+1}$ and $p_{st,t+1}$: costs of storage per unit of white and yellow corn in i and s from t to t+1; $x_{it,t+1}$, $x_{st,t+1}$: quantities of white and yellow corn stored in i and s from t to t+1; $p_{mt,t+1}$, $p_{nt,t+1}$: storage costs per unit of white and yellow corn stored in m and n from t to t+1; and $x_{mt,t+1}$, $x_{nt,t+1}$: quantities of white and yellow corn stored in m and n from t to t+1.

The target function in Eq. 1 maximizes the 'net social payoff' (NSP) which is equal to the areas under the demand curves minus the areas under the supply curves, less the value of the imports less transportation and storage costs. Restriction (2) establishes how white corn production in i is distributed to j and d, and restriction (3) defines how yellow corn production in s is distributed to j and f. Restriction (4) establishes how white corn imports through m are distributed to regions j and d, and restriction (5) indicates how yellow corn imports through n are distributed to j and f. Restriction (6) establishes how feed consumption in j is supplied with corn originating in i, s, m and n. Restriction (7) indicates that food consumption in d is supplied with grain coming from i and m; in similar form, restriction (8) establishes that industrial consumption in f is supplied with grain coming from s and n.

Restrictions (9) and (10) indicate that ending inventories in i and s are equal to initial inventories. Shortages of white corn in the USA market were incorporated into the model by restriction (11), which indicates that imports entering through different ports in a given month must be equal to the data observed in the average year over the period 2005-2007. Actual Gulf of Mexico region port storage and transportation infrastructure capacity was established by restriction (12), which indicates that white and yellow corn imports through the USA-Mexico border ports-of-entry of Nuevo Laredo, Piedras Negras and Ciudad Juárez must represent 60.1% (δ) of total imports, or the average annual amount for the period 2005-2007. Finally, restriction (13) establishes the non-negativity conditions.

The model included ten white corn production regions: Chiapas, Jalisco, Central, Guanajuato-Michoacán, Sinaloa, Gulf, Guerrero-Oaxaca, North, Northeast and Peninsula. The same regions also were defined for yellow corn production and feed, food, and industrial corn consumption. Eleven ports-of-entry were included for white and yellow corn: Mexicali, Nogales, Cd. Juárez, Piedras Negras, Nuevo Laredo, Tampico, Veracruz, Progreso, Guaymas, Mazatlán, and Manzanillo. The model was optimized over a 12 month period, beginning in October of one year through September of the following year.

The model includes production, consumption, and prices by region and month, monthly imports by port-of-entry, trade flows by month, and quantities of storage by region and month. To determine factors affecting corn prices the model was first estimated and validated for the average year for the period 2005-2007. The model was validated by comparing the observed values of production (white and yellow corn), consumption (feed, food, and industrial) and average consumer prices in the average year 2005-2007, with the values obtained using the base period model. The following scenarios were then examined and compared with the results of the base model: a) increases in the international price of yellow corn by 10% and 20%, b) increases in the exchange rate by 15% and 30%, and c) increases in ending inventories by three million and five million tons.

Data

For each region, averages of the three yearly corn consumption cycles were used, beginning in October 2004 and ending in September 2007; thus, the data used in the model refer to an average of three years. All values for October to December are averages of the corresponding data in 2004, 2005, and 2006. From January to September, all values are annual averages for the years 2005, 2006, and 2007. The year that runs from October of the first year to September of the following year is referred to as average year 2005-2007.

Supply and demand functions were estimated using domestically-produced and consumed quantities, grower and consumer prices, and supply and demand price elasticities. The price elasticities of food and feed demand were from FAPRI (2009). The industrial demand price elasticity was assumed to be the same as the food demand price elasticity. The domestic corn supply price elasticity also came from FAPRI (2009). Corn production by region and month was obtained from SIAP-SAGARPA (2009c).

Mexican corn consumption by region and month was calculated as follows: a) Annual national consumption was calculated as the sum of domestic production (white and yellow corn) plus imports (white and yellow) minus exports per year, and was separated into food, feed, industrial, seed, and shrinkage. b) Seed corn usage by region and month was obtained by multiplying surface by planting density ($kg \cdot ha^{-1}$). c) It was assumed that 4.14% of corn production is lost in storage and marketing processes to estimate post-harvest shrinkage. d) Annual national feed consumption was proportionally weighted using data on grain consumption by region to obtain animal consumption by region. e) Annual national food (industrial) consumption was proportionally weighted using data on industrial production of hominy paste and milled starch to obtain food and industrial consumption by region. f) It was assumed that feed, food, and industrial consumption were equally distributed across 12 months of the year. Data and information used to calculate total consumption were obtained from INEGI (1995), SAGARPA (2007), SIAP-SAGARPA (2009c) and USITC (2009).

The regional price paid by consumers and received by producers was calculated using the international price of corn at Mexican ports-of-entry. Transportation costs from each port-of-entry to internal points of consumption were added to the international price to obtain consumer prices. Producer prices in each region were assumed to be equal to consumer prices less a marketing margin for transportation of the grain from the farm to the points of consumption. Marketing margins for each region were calculated using the difference between corn price in the wholesale markets and the average price received by producers. Data for the average producer price were obtained from the SIAP-SAGARPA (2009a); corn price data for the wholesale market are from SNIIM (2009).

International prices of yellow corn at the Mexican border were calculated using the Des Moines, Iowa price plus transportation costs to Laredo, Texas and Eagle Pass, Texas. International prices of corn at Mexican Gulf and Pacific ports were calculated using New Orleans prices plus shipping costs to Mexican ports. The international price of corn was calculated by taking into account the exchange rate, insurance, ocean freight, costs of international financing, and entry costs. Based on data from SAGARPA (2007) it was assumed that the white corn international price was equal to the yellow corn international price plus a 13% premium. Data for Des Moines and New Orleans corn prices and transportation costs from Des Moines to Laredo and Eagle Pass, and insurance and freight costs were obtained from AMS-USDA (2009). Mexican port-of-entry costs were obtained from Apoyos y Servicios a la Comercialización Agropecuaria (ASERCA). The peso/dollar exchange rate was obtained from INEGI (2008a); the London interbank offer rate (LIBOR) used to calculate the costs of international financing was obtained from INEGI (2008c).

Rail transportation costs from Mexican production regions and ports-of-entry to internal points of consumption were estimated using a distance matrix and an average tariff which includes both fixed and variable cost factors. Data for the average tariff were obtained from SCT (2009). The cities used as reference points for calculating the transportation matrix costs were Tapachula, Guadalajara, Ciudad de México, Morelia, Culiacán, Jalapa, Oaxaca, Chihuahua, Monterrey and Mérida. Mexican trucking costs from production regions and ports-of-entry to internal consumption points were similarly estimated using a distance matrix and data from DGTTFM (2000). The 2000 data were used to calculate that for 2005-2007 using the national consumer price index for the transport sector obtained from INEGI (2008b). The cities taken as reference points were Tapachula, Guadalajara, Ciudad de México, Morelia, Culiacán, Jalapa, Oaxaca, Chihuahua, Monterrey, and Mérida. Finally, storage costs for imports (including handling at entry and exit points) and Mexican-produced corn were obtained from SAGARPA (2002) and INEGI (2008b).

TABLE I
VALIDATION OF THE CORN MODEL, 2005-2007

Region	Observed data	Base model	Dif.	Dif.	Observed data	Base model	Dif.	Dif.
	Thousand metric tons			%	Thousand metric tons			%
	Feed consumption (white and yellow corn)				Food consumption (white corn)			
Chiapas	453	466	13	2.8	344	354	10	2.9
Jalisco	2,692	2,765	73	2.7	1,153	1,184	32	2.8
Central	2,350	2,372	23	1.0	4,137	4,175	38	0.9
Gto. - Mich.	1,442	1,487	45	3.1	976	1,005	29	2.9
Sinaloa	1,384	1,418	34	2.5	1,121	1,151	31	2.7
Gulf	1,803	1,807	3	0.2	797	801	4	0.5
Oax. - Gro.	592	611	19	3.2	647	668	20	3.1
North	2,076	2,113	37	1.8	982	995	13	1.3
Northeast	770	784	13	1.7	701	698	-2	-0.3
Peninsula	746	750	3	0.5	387	386	-1	-0.3
Total	14,309	14,572	263	1.8	11,244	11,417	173	1.5
	Industrial consumption (yellow corn)				White corn production			
Chiapas	5	5	0	1.8	1,266	1,270	3	0.3
Jalisco	834	834	1	0.1	2,746	2,742	-4	-0.2
Central	1,382	1,380	-2	-0.2	3,515	3,680	164	4.7
Gto. - Mich.	25	26	0	1.2	2,595	2,581	-14	-0.5
Sinaloa	321	321	0	0.0	4,913	4,891	-23	-0.5
Gulf	3	3	0	-1.1	1,134	1,223	89	7.9
Oax. - Gro.	2	2	0	-0.2	1,845	1,830	-15	-0.8
North	282	284	2	0.8	1,066	1,120	54	5.1
Northeast	186	187	1	0.8	372	411	39	10.6
Peninsula	13	13	0	-0.4	493	535	42	8.5
Total	3,052	3,054	2	0.1	19,946	20,281	335	1.7
	Yellow corn production				Corn average prices (Pesos/metric ton)			
Chiapas	168	177	8	4.8	1,669	1,371	-298	-17.8
Jalisco	325	356	30	9.3	2,033	1,748	-285	-14.0
Central	21	23	2	9.7	1,894	1,812	-81	-4.3
Gto. - Mich.	23	24	1	4.7	2,055	1,678	-378	-18.4
Sinaloa	43	48	5	10.5	2,033	1,780	-253	-12.4
Gulf	18	21	2	13.0	1,724	1,736	12	0.7
Oax.-Gro.	0	0	0	-	1,933	1,594	-339	-17.5
North	493	530	37	7.5	1,819	1,641	-178	-9.8
Northeast	345	375	29	8.5	1,731	1,649	-83	-4.8
Peninsula	6	7	1	12.1	1,755	1,770	14	0.8
Total	1,444	1,559	115	8.0	1,865	1,678	-187	-10.0
	White corn imports				Yellow corn imports			
Total	124	124	0	0.0	7,092	7,079	-12	-0.2

Results and Discussion

The model was validated for consumption (feed, food, and industrial), production (white and yellow corn), and prices. Table I presents results obtained from the model compared to actual values for the average of years 2005-2007. The model solution was very close to the actual levels for the corresponding variables in the year of analysis except in a few cases. At the national level the model overestimated feed, food and industrial consumption, and white and yellow corn production by 1.8, 1.5 and 0.1%, and by 1.7 and 8.0%, respectively. The base model underestimated yellow corn imports by 0.2% and consumer prices by 10.0%. At the regional level, the model overestimated Northeast white corn production by 10.6%; however, the effect on total white corn production is small. Likewise, the model underestimated consumer price in the regions of Chiapas, Guanajuato-Michoacán and Oaxaca-Guerrero by 17.8, 18.4 and 17.5%. This is a consequence of the fact that corn consumption in these regions is lower than in other parts of Mexico because the livestock population and consumer industries are smaller, and corn grown there is consumed primarily by the households that produce it.

In the average year 2005-2007, feed, food and industrial corn consumption were 14,309,000; 11,244,000 and 3,052,000 metric tons, respectively; 61.7% of feed consumption was supplied with white corn and 30.3% was supplied with yellow corn, 100% of food consumption was white corn, and 100% of industrial consumption was yellow corn. White and yellow corn production was 19,946,000 and 1,444,000 metric tons, and white and yellow imports were 124,000 and 7,092,000 metric tons. In the average year 2005-2007, 25.2% of the Mexican corn demand was supplied with imports from the USA (Table I).

The factors affecting corn price are shown in Table II. If the international price of yellow corn increases by 20%, then total Mexican production increases by 4.0% and total consumption decreases by 1.8% relative to the observed base model values. Because Mexican production is higher and consumption is lower, total corn imports decrease by 19.2%. As a result of a higher international price, the Mexican corn price is 15.6% higher with respect to the base model, which indicates a strong relationship (1 to 0.78) between domestic and foreign markets. Similar impacts, although of lower magnitude, would occur if international white and yellow corn prices were to increase by 10% (Table II).

All factors affecting the international corn price do impact the Mexican corn price, and for this reason an increase in the exchange rate has similar effects on the Mexican corn market. If the peso/dollar exchange rate increases by 30%, then Mexican corn production increases 5.5% and total consumption decreases 2.5% relative to the observed base model values. Likewise, because production is higher and consumption is lower, total corn imports decrease by 27%. In this case, corn price would increase by 22.3% as a result of the peso devaluation. If a duty is imposed on corn imports from the USA, similar effects would be observed in the Mexican market.

TABLE II
IMPACTS OF INTERNATIONAL CORN PRICE, EXCHANGE RATE AND INVENTORY HOLDING ON THE MEXICAN CORN SECTOR

Variable	Base model	Scenario Tons	Dif.	Dif. %	Scenario Tons	Dif.	Dif. %
		10% increase in international corn price			20% increase in international corn price		
Consumption	29,044	28,800	-244	-0.8	28,524	-520	-1.8
Feed	14,572	14,431	-141	-1.0	14,273	-299	-2.0
Food	11,417	11,344	-74	-0.6	11,253	-164	-1.4
Industrial	3,054	3,026	-29	-0.9	2,997	-57	-1.9
Production	21,840	22,228	388	1.8	22,704	864	4.0
White	20,281	20,634	353	1.7	21,071	790	3.9
Yellow	1,559	1,594	35	2.2	1,633	74	4.7
Imports	7,204	6,572	-632	-8.8	5,819	-1,384	-19.2
White	124	124	0	0.0	124	0	0.0
Yellow	7,079	6,448	-632	-8.9	5,695	-1,384	-19.6
Consumer price[1]	1,678	1,803	125	7.4	1,940	262	15.6
		Exchange rate (Mexican pesos/USD) increases by 15%			Exchange rate (Mexican pesos/USD) increases by 30%		
Consumption	29,044	28,660	-384	-1.3	28,308	-736	-2.5
Feed	14,572	14,351	-221	-1.5	14,148	-424	-2.9
Food	11,417	11,298	-120	-1.0	11,190	-228	-2.0
Industrial	3,054	3,011	-43	-1.4	2,970	-84	-2.8
Production	21,840	22,468	628	2.9	23,050	1,210	5.5
White	20,281	20,856	574	2.8	21,377	1,096	5.4
Yellow	1,559	1,613	53	3.4	1,673	114	7.3
Imports	7,204	6,192	-1,012	-14.0	5,257	-1,946	-27.0
White	124	124	0	0.0	124	0	0.0
Yellow	7,079	6,068	-1,012	-14.3	5,133	-1,946	-27.5
Consumer price[a]	1,678	1,872	194	11.6	2,053	375	22.3
		Ending inventories increase by 3 million metric tons[b]			Ending inventories increase by 5 million metric tons[b]		
Consumption	29,044	27,950	-1,094	-3.8	27,220	-1,824	-6.3
Feed	14,572	13,951	-621	-4.3	13,538	-1,034	-7.1
Food	11,417	11,054	-363	-3.2	10,812	-606	-5.3
Industrial	3,054	2,945	-110	-3.6	2,870	-184	-6.0
Production	21,840	23,746	1,906	8.7	25,016	3,176	14.5
White	20,281	22,038	1,757	8.7	23,206	2,925	14.4
Yellow	1,559	1,708	149	9.6	1,810	251	16.1
Imports	7,204	7,204	0	0.0	7,204	0	0.0
White	124	124	0	0.0	124	0	0.0
Yellow	7,079	7,079	0	0.0	7,079	0	0.0
Consumer price[a]	1,678	2,223	545	32.5	2,592	914	54.5
Beginning inventories	2,042	2,042	0	0.0	2,042	0	0.0
White	1,305	1,305	0	0.0	1,305	0	0.0
Yellow	737	737	0	0.0	737	0	0.0
Ending inventories	2,042	5,042	3,000	146.9	7,042	5,000	244.9
White	1,305	3,222	1,917	146.9	4,500	3,195	244.9
Yellow	737	1,820	1,083	146.9	2,542	1,805	244.9

[a] Average consumer price.
[b] These scenarios assume that total imports of yellow corn are equal to the level observed in the base model.

How can international and domestic corn prices be de-linked in the Mexican market? The strong relationship between the prices is a consequence of the high import levels required to meet domestic consumption needs. With domestic consumption dependent on imports, Mexico loses food self-sufficiency and the international price has a large effect on domestic prices. Imports supplied 9.7% of Mexican annual corn consumption needs at the time when NAFTA was implemented, with the share of imports in total national consumption increasing to an annual average of 25.2% for the period 2005-2007. The dramatic absolute and relative increases in Mexican corn imports in a short period of time have led many Mexicans to question what policy responses are needed and feasible in order to improve domestic food security and reduce price volatility. Trade liberalization and broad economic reforms limit the federal government's policy options, although the present study provides insight into possible policy responses.

While the range of options is limited, policy instruments designed to encourage domestic corn production could help reverse recent increases in Mexican corn imports. The competitiveness and viability of Mexican corn production could be improved through input subsidies to decrease farm-level production costs, subsidies to reduce post-harvest transportation and storage costs, as well as publicly-funded investments designed to increase yields.

Increased inventory holding is another factor that may cause an increase in Mexican corn prices. Corn storage causes a temporary scarcity of grain and drives corn prices higher. The effect on the Mexican corn market of ending inventories which are higher than those observed in the base model are shown in Table II. If it is assumed within the model that total yellow corn imports are similar to those observed in the base model and ending inventories are 5,042,000 metric tons (equal to the base model level plus 3,000,000 metric tons), corn price would be 32.5% higher relative to the observed model base values. Higher inventories would have the following effects on the Mexican corn market: total corn production would increase by 8.7% and total corn consumption would decrease by 3.8%. A 5,000,000 metric ton change in the ending inventory would result in a 14.5% increase in corn production and a 6.3% decrease in corn consumption. These changes are relative to base model levels. Because the scenario assumes that imports cannot change, this implies that domestic consumers cannot turn to external suppliers to meet their consumption needs and corn price would increase by a dramatic 54.5% (Table II).

Inventory accumulation may be associated with the existence of an imperfect structure in the Mexican corn market and imply monopolistic or oligopolistic control of the market. If such structural problems do exist, the government should take the necessary steps to strengthen the market and encourage greater competition. Government loans could also be made available to individual growers or through cooperatives to support shipping and storage processes and enable them to efficiently market the corn they produce.

The government should to support the establishment of 'farm marketing enterprises'. Locally, or by region or zone, each enterprise should consolidated its associates' supplies to favor operation savings, provide specialized services, reduce costs and increase producer's efficiency, competitiveness and negotiating capacity when confronting the market and governmental institutions. It is believed that the stocking and marketing projects of farm marketing enterprises could be successful if they included inventory programs, which can be an effective way to prevent a seasonal fall in prices. Producers would store part of their harvest during the high production months, and withdraw their inventories when production is scarce. In the long term the inventory programs would decrease prices and reduce price volatility, although prices would rise in the short term when inventories are increased.

Development of storage infrastructure in México's regions should to be supported by the government. Roofed storage infrastructure surpassed storage demand in the North and Center regions of México. These maize-producing regions can, without difficulty, implement inventory programs to avoid intermediaries and price seasonal drops. In contrast, the West and South regions do not have enough storage capacity for surpluses during months of highest harvest production.

Conclusions

Due to a growing dependency on imports the Mexican domestic corn market is increasingly vulnerable to international markets and price changes. Corn prices in Mexico are highly sensitive to changes in international prices and exchange rates. Because corn is the most important staple food product in Mexico, high and volatile prices are undesirable, as this has a strong negative effect on low-income consumers and can lead to potential social unrest. Application of government policies that may help Mexico achieve or re-capture a greater degree of food self-sufficiency should therefore be considered. Inventory accumulation has strong positive effects on corn prices in Mexico, and for the reasons listed above it is recommended that the federal government implement the necessary measures to reduce opportunities for undue market manipulation as a result of speculative inventory building. Although policy options are limited as a result of trade agreements and the national objectives of economic reform and restructuring, reduced corn import dependency should be viewed as means to improve food security and enhance social and political stability. If Mexico does not implement policies that lead to greater domestic corn production, the tortilla riots of 2007 may be the first stage of a long period of social and political unrest driven largely by food market factors.

REFERENCES

AMS-USDA (2009) *Agricultural Transportation, Grain Transportation Report*. Agricultural Marketing Service, United States Department of Agriculture. www.ams.usda.gov.

BANXICO (2009) *Informe sobre la Inflación Octubre-Diciembre 2009 y Programa Monetario para 2009*. Banco de México. www.banxico.org.mx.

Bivings EL (1997) The seasonal and spatial dimensions of sorghum market liberalization in Mexico. *Am. J. Agric. Econ. 79*: 383-393.

DGTTFM (2000) *Competitividad de lo Servicios de Transporte para Maíz en México*. Dirección General de Tarifas, Transporte Ferroviario y Multimodal En Foro Cadenas Productivas: Maíz. Colegio de Postgraduados. Montecillo, Estado de México. 32 pp.

FAPRI (2009) *Elasticities Database*. Food and Agricultural Policy Research Institute. www.fapri.org/tools/elasticity.aspx.

FAPRI (2011) *US Baseline Briefing Book, Projections for Agricultural and Biofuel Markets*. FAPRI-MU Report #02-11. Columbia, MI, USA. www.fapri.missouri.edu/outreach/publications/2011/FAPRI_MU_Report_02_11.pdf

García-Salazar JA, Williams GW (2004). Evaluación de la política comercial respecto al mercado de maíz. *Trimestre Econ. 281*: 169-213.

INEGI (1995) *XIV Censo Industrial, XI Censo Comercial y XI Censo de Servicios*. Instituto Nacional de Estadística Geografía e Informática. Aguascalientes, Mexico. Several issues.

INEGI (2008a) *Finanzas Públicas e Indicadores Monetarios Bursátiles*. Instituto Nacional de Estadística Geografía e Informática. dgcnesyp.inegi.org.mx/cgi-win/bdieintsi.exe.

INEGI (2008b) *Precios e Inflación*. Instituto Nacional de Estadística Geografía e Informática. dgcnesyp.inegi.org.mx/cgi-win/bdieintsi.exe.

INEGI (2008c) *Cuaderno de Información Oportuna Nº 432*. Instituto Nacional de Estadística, Geografía e Informática. www.inegi.gob.mx.

SAGARPA (2002) *Lineamientos y Mecanismos Específicos de Operación del Subprograma de Apoyo a la Pignoración de la Cosecha de Maíz Blanco del Ciclo Otoño-Invierno 2001-2002 del Estado de Sinaloa*. Diario Oficial de la Federación, 23 de mayo de 2002. www.diariooficial.gob.mx.

SAGARPA (2007) *Situación Actual y Perspectivas del Maíz en México 1996-2012*. Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación. México, D.F. 208 pp.

SCT (2009) *Tarifa de Transporte Ferroviario*. Dirección General de Transporte Ferroviario y Multimodal. Secretaría de Comunicaciones y Transportes. dgtfm. sct.gob.mx/index.php?id=439.

SIAP-SAGARPA (2009a) *Agricultura, Producción Anual, Cierre de la Producción Agrícola por Estado*. Sistema de Información Agroalimentaria y Pesquera. Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación. www.siap.sagarpa.gob.mx.

SIAP-SAGARPA (2009b) *Agricultura, Balanza Disponibilidad-Consumo, Maíz*. Sistema de Información Agroalimentaria y Pesquera. Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación. www.siap.sagarpa.gob.mx.

SIAP-SAGARPA (2009c) *Agricultura, Producción Mensual, Resumen de la Producción Agrícola por Cultivo, Avances de Siembras y Cosechas*. Sistema de Información Agroalimentaria y Pesquera-Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación. www.siap.sagarpa.gob.mx.

SNIIM (2009) *Mercados Nacionales, Precios de Mercado, Mercados Agrícolas, Granos Básicos*. Sistema Nacional de Información e Integración de Mercados. www.secofi-sniim.gob.mx/nuevo/.

USITC (2009) *Interactive Tariff and Trade DataWeb. Corn: FAS General Customs Value/General First Unit of Quantity by HTS Number for Mexico*. Unites States International Trade Commission. dataweb.usitc.gov.

Takayama T, Judge GG (1971) *Spatial and Temporal Price and Allocation Models*. North-Holland. Amsterdam, Holland. 528 pp.

Yunez-Naude A (2003) The dismantling of CONASUPO, a Mexican state trader in agriculture. *World Econ. 26*: 97-122.

Yunez-Naude A, Barceinas-Paredes F (2004) *The Agriculture of Mexico after Ten Years of NAFTA Implementation*. Central Bank of Chile. Working Paper Nº 277. Santiago, Chile. 44 pp.

IMPACTOS DEL PRECIO INTERNACIONAL, TASA DE CAMBIO E INVENTARIOS SOBRE EL SECTOR MAICERO MEXICANO: UN ESTUDIO DE CASO SOBRE VOLATIVIDAD Y VULNERABILIDAD DEL MERCADO

José Alberto García-Salazar, Rhonda K. Skaggs y Terry L.Crawford

RESUMEN

Dos décadas de liberalización comercial y reformas económicas han llevado a la pérdida de autosuficiencia alimentaria en maíz, componente principal de la oferta de alimentos y forrajes en México. Debido a la dependencia del país de los mercados globales, el precio del maíz mexicano es sensible a los cambios en el precio internacional y a los inventarios con propósitos especulativos. El impacto de la volatilidad del precio del maíz mexicano sobre la estabilidad social de México motivó la evaluación de los efectos de cambios en el precio internacional, tasa de cambio e inventarios sobre el precio de maíz a través del uso de un modelo de equilibrio espacial e inter-temporal. Los resultados indican que si el precio mundial aumentara en 20%, entonces el precio se incrementaría en 15,6%, la producción aumentaría en 4,0%, mientras que las importaciones disminuirían en 19,2%. Asumiendo que las importaciones de maíz no cambian, un inventario de tres millones de toneladas métricas incrementaría el precio del maíz en 32,5%, y aumentaría la producción en 8,7%. Altos precios al maíz son indeseables para la sociedad debido a los efectos negativos sobre la población de bajos ingresos. Por lo tanto, es recomendable que el gobierno de México aplique políticas que promuevan la autosuficiencia alimentaria y reduzcan los incentivos para la especulación.

IMPACTOS DO PREÇO INTERNACIONAL, TAXA DE CÂMBIO E INVENTÁRIOS SOBRE O SETOR DOS PRODUTORES DE MILHO MEXICANO: UM ESTUDO DE CASO SOBRE VOLATILIDADE E VULNERABILIDADE DO MERCADO

José Alberto García-Salazar, Rhonda K. Skaggs e Terry L.Crawford

RESUMO

Duas décadas de liberalização comercial e reformas econômicas têm levado à perda de autosuficiência alimentária em milho branco e amarelo, componentes principais da oferta de alimentos e forragens no México. Devido à dependência do país dos mercados globais, o preço do milho mexicano é sensível a mudanças no preço internacional e aos inventários com propósitos especulativos. O impacto da volatilidade do preço do milho mexicano sobre a estabilidade social do México motivou a avaliação dos efeitos de mudanças no preço internacional, taxa de câmbio e inventários sobre o preço do milho através do uso de um modelo de equilíbrio espacial e intertemporal. Os resultados indicam que se o preço mundial aumentara em 20%, então o preço se incrementaria em 15,6%, a produção aumentaria em 4,0%, enquanto que as importações diminuiriam em 19,2%. Assumindo que as importações de milho não mudam, um inventário de três milhões de toneladas métricas incrementaria o preço do milho em 32,5%, e aumentaria a produção em 8,7%. Altos preços do milho são indesejáveis para a sociedade devido aos efeitos negativos sobre a população de baixos ingressos. Portanto, é recomendável que o governo do México aplique políticas que promovam a autossuficiência alimentária e reduza os incentivos para a especulação.