EXCHANGE RATE SENSITIVITY OF MEXICAN MAIZE IMPORTS FROM THE UNITED STATES: A COINTEGRATION ANALYSIS

Rakhal Sarker*
Associate Professor
Department of Food, Agricultural and Resource Economics
University of Guelph
Guelph, Ontario
Email: rsarker@ouguelph.ca

and

Jose Luis Jaramillo-Villanueva
Assistant Professor
Colegio de Postgraduados – Campus Puebla
Km. 125.5 Carretera Mexico-Puebla, Momoxpan, San Pedro Cholula,
Puebla, C.P. 72760, Maxico
Email: jjaramil301@yahoo.es

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* The corresponding author.

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## ABSTRACT

Since the implementation of the NAFTA in 1994, agri-food trade between Mexico and the United States grew substantially. While some analysts argue that NAFTA has contributed the most to the dramatic expansion of this trade, others emphasized the role played by exchange rate in this process. An attempt is made in this paper to address this issue by determining the extent to which NAFTA, expansion of the livestock sector, changes in exchange rate and exchange rate variability have contributed to the expansion of Mexican maize imports from the United States from January 1989 to December 2004. The results from cointegration analysis demonstrate that changes in exchange rate, per capita income in Mexico and livestock inventory all have significant positive effects on Mexican maize imports from the United States in the long-run. In the short-run, however, NAFTA has been the most important driver of maize imports by Mexico from the United States.



Key words: Maize trade, NAFTA, exchange rate, cointegration analysis, error-correction model.

## INTRODUCTION

Mexico is an important partner in the North American Free Trade Agreement. Unlike Canada and the United States, however, agriculture in Mexico is less developed and domestic production of major staples such as maize is dominated by small and mid-sized farms. The United States is the most important agri-food trade partner of Mexico. Since the implementation of NAFTA in 1994, Mexican exports dominated by fruits and vegetables grew by 75-100 percent while Mexican imports dominated by maize, wheat soybeans and sorghum increased by 80 percent (Yunez and Barceinas, 2002). Some analysts have argued that NAFTA has been a major contributor to the dramatic expansion of the U.S.-Mexico agri-food trade (Rosenzweig, 1996; USDA, 1999). Others, however, emphasized the role played by exchange rate variations in enhancing Mexican agri-food trade with the United States (Mora-Flores et al., 2002). No formal attempt has been made to determine empirically the extent to which NAFTA and the variations in peso-dollar exchange rates have influenced the growth in agri-food trade flows between these two countries.

While the borders between Mexico and the United States became increasingly open due to NAFTA, Mexican agri-food trade has also been influenced by changes in exchange rate and exchange rate volatility. To the best of our knowledge, a rigorous analysis has not been performed to determine the relative contributions of these factors to the growth of Mexican agri-food trade with the United States. An attempt is made in this paper to bridge this gap in the literature by determining the extent to which NAFTA, the continuous devaluation of peso against the U.S. dollar and the exchange rate volatility have contributed to the growth in maize imports by Mexico from the United States during the last two decades. The choice of maize has been influenced by two considerations: (i) maize (white corn) is the most important staple in Mexico and has been treated as one of the sensitive commodities under the NAFTA. Thus, Mexican maize was subject to a gradual process of year-to-year liberalization and all NAFTA provisions for trade liberalization have been phased-in by January 2008, and, (ii) while Mexico could impose tariff rate quotas (at the rate of 215 percent or 206.40 US$/Mt. tariff) for imports of more than 2.5 million metric tons of maize and/or seasonal tariffs to protect domestic maize producers, it did not impose any TRQ on maize imported above the quota limit from the United States.

Exchange rates determine which agri-food **c**ommodities are traded, and where they are shipped to or sourced from. The trade literature related to the effects of exchange rate movements on agri-food trade primarily focused on whether exchange rate matters for agricultural trade and if it does, what is the magnitude of this effect. On the first issue, the results have been mixed (Chambers and Just, 1979; Fuller et al., 1992; Cho et al., 2002). The results also suggest that for major commodities traded internationally, exchange rate has a significant positive effect on trade flows. However, the magnitudes vary considerably across countries and commodities.

While there is a general agreement that flexible exchange rate period has been characterized by a high level of exchange rate volatility, the literature does not provide conclusive evidence regarding the effects of exchange rate volatility on agri-food trade flows. A growing number studies such as Anderson and Garcia, 1989, Cushman, 1988, Cho et al. 2002, Lastrapes and Koray, 1990 and Thursby and Thursby, 1987 documented significant negative effects of exchange rate volatility on trade flows. But a few studies such as Asseery and Peel (1991) and Kroner and Lastrapes (1993) suggest that a positive relationship exists between exchange rate volatility and trade flows. The inconsistent empirical findings may be attributed to the specification of the volatility measure, data used and the estimation method employed in various studies.

Only a few studies attempted to determine the effects of exchange rate on agri-food trade in Mexico and found either a positive effect or no effect on trade (Diaz-Garces, 2002; Mora-Flores et al., 2002). None of these studies, however, investigated the effect of exchange rate volatility on trade flows and none focused on maize. This paper focuses on maize trade between Mexico and the United States from January 1989 to December 2004. Unit root tests are used to determine time series properties of data and Johansen's maximum likelihood cointegration analysis is employed to determine the long-run effects of all relevant variables. Finally, the vector error-correction model is estimated to determine the short-run effects of exchange rate, exchange rate volatility and NAFTA on Mexican imports of maize from the United States.

Section two provides a brief overview of the maize sector and agricultural policies in Mexico. Section three focuses on the analytical framework used in this study to guide the empirical estimation. Section four concentrates on empirical issues, data and the estimation method. The next section discusses the estimated results and highlights their implications. The final section summarizes the main findings and concludes the paper.

## MAIZE SECTOR AND AGRICULTURAL POLICY IN MEXICO[1]

Maize and dry beans are two important staples in Mexico. Both of these crops are characterized by highly heterogeneous production conditions in Mexico. While some maize farmers in Mexico own large farms and have access to irrigation and modern

[1] This section relies heavily on Zahniser and Coyle (2004).

technology, the vast majority of farms (61%) growing maize own less than 5 hectares and produce maize under rain fed condition. About one-third of the maize growers have access to high yielding varieties of seeds and tractors but only about 10 percent has access to irrigation (INEGI; Nadal and Wise, 2004). Efforts to improve corn production in Mexico have increased both acres under irrigation which almost doubled between 1996 and 2007and raised yields to about 6 metric tons per hectare in irrigated areas. The yield has also increased marginally to 2.0 metric tons per hectare in rain-fed areas during last 15 years (SAGARPA/SIAP, 2009).

The growing integration of local economies, import pressures and the implementation of structural adjustment programs are the principal events that have influenced the consumption and production of maize and other grains in Mexico during the last two decades. The overall development strategy in Mexico focused on: (i) a reduction or elimination of tariffs and other controls on international trade, (ii) a reduction or elimination of subsidies to consumers and an equalization payment to domestic producers, and (iii) a devaluation of real exchange rate (Byerlee and Sain). These policies may have contributed to sustained increase in domestic production maize in Mexico which reached about 24 million metric tons in 2007 and significant increase in maize imports from the United States.

While the process of phasing-out government interventions in Mexican agriculture started at the end of the 1980s, it went into a full gear during the early 1990's with the implementation of NAFTA. La Compañia Nacional de Subsistencias Populares (CONASUPO) was the main institution through which government interventions in the Mexican agriculture took place before the reforms in the 1980s. CONASUPO supported the prices of major grains and oilseeds, provided processing, storage and distribution services and regulated trade through direct imports. Thus, CONASUPO exerted significant control over production, marketing and distribution of grains and oilseeds in Mexico before deregulation. By 1996, most of the agencies and the financial activities of CONASUPO were dismantled or privatized, and by 2000, the long standing institution, CONASUPO, was fully liquidated (Yunez-Naude, 2003; Taylor et al., 2005).

To replace some of the CONASUPO's activities in the early 1990's, a new marketing agency called Apoyosy Servicios a la Comercializacion Agropecuaria (ASERCA) was created. This agency facilitates the marketing of basic crops, but it does not buy or store these commodities, as CONASUPO did. It also operates the PROCAMPO program through which the Mexican Government transfers direct cash subsidy to eligible farmers in Mexico (Sadoulet et al., 2001). PROCAMPO is the only income support program available to maize farmers in Mexico. While the initial purpose of this program was to facilitate the transition from the old price support system to a more competitive market, PROCAMPO as a farm safety net program may outlive the full liberalization of agri-food production and trade in Mexico under the NAFTA.

In addition to decoupled income support and less acrimonious provision of marketing services under ASERCA, the Mexican Government has initiated an "Alliance for the Countryside" in 1995 to increase agricultural productivity by making additional capitals available to farmers for investments in agriculture. This initiative also promotes farming efficiency through crop substitution (mainly from basic crops to fruits and vegetables) for farmers who have demonstrated comparative advantage in producing such crops in the context of an open economy (Yunez-Naude, 2003).

Under NAFTA, some agricultural commodities were liberalized in January 1994. Others such as maize and dry beans (considered politically more sensitive than other commodities) were subjected to a process of gradual year-to-year liberalization. Eventually, the full trade liberalization took place in January 2008. For this group of commodities, tariff rate quotas (TRQs) and/or seasonal tariffs could be used to protect domestic producers. Quota levels were established based on 1989-91 trade flows between Mexico and its two North American partners, Canada and the United States. In 1994, the TRQs were set at 2,500,000 metric tons (Mts.) for United States maize and 1,000 Mts. for Canadian maize and the above-quota consolidated tariff on maize from both countries was fixed at 215 percent (or 206.40 US$/Mt.). While Mexico could impose TRQs on the imports of maize, this right was never exercised.

Mexican consumes two types of maize. White maize which comes predominantly from domestic production is used for making tortillas and other maize-based foods and is used for direct human consumption. On the other hand, yellow corn is mostly used for pork and poultry production in Mexico. As the production of hogs and poultry increased substantially since the 1990s due to higher domestic demand for pork and poultry meats, the demand for yellow corn in Mexico grew sharply. Since Mexican production of feed corn is insufficient to meet growing domestic demand from hog and poultry producers, large quantities of yellow corn have been imported by Mexico from the United States.

While more than 80 percent of Mexican imports of corn from the United States consist of yellow corn, Mexico also imported significant quantities of white corn between 1998 and 2000. However, the share of white corn imported from the U.S. did not exceed 15% of total maize imports during this period. After 2000, the import of white corn from the United States declined steadily. The United States supplied about 95 percent of total maize imported by Mexico during the study period. As mentioned earlier, Mexico has pursued an import policy towards the United States corn which is more liberal than that required under the NAFTA. As a result, U.S. corn exports to Mexico have increased dramatically to about 9.2 million metric tons in 2008 (USDA/FAS, 2009). It appears that due to growth in per capita income in Mexico, the annual per capita consumption of tortillas declined from almost 120 kilogram to about 80 kilograms between 1995 and 2008 (Arreola). As income continues to grow in the near future, Mexicans will incorporate more meats into their diets. As a consequence, the demand for yellow corn imported from the United States is expected to increase despite higher prices (Zahniser and Coyle).

## AN ANALYTICAL FRAMEWORK:

The estimation of import demand functions for various commodities have received a great deal of attention in the agricultural trade literature in recent years. The demand for traded goods is usually written as a linear or log-linear function of real income and the price of the traded goods relative to the price of domestic substitutes and other relevant factors. The relevant import demand functions can be derived from a production or utility theory depending on whether the commodity in question is considered as an intermediate good or a finished product. In this model, production theory is used to derive the import demand function for maize by treating imports as inputs to the domestic production of a final product. It is assumed that import decisions are made by profit maximizing firms operating under competitive conditions. Firms choose their optimal output mix and their input requirements subject to a vector of output and input prices. All domestic factors are assumed to be mobile between firms and their rental rates are determined by their marginal products. Imports are used together with domestic inputs and services to produce output that can be consumed at home. Using the framework developed by Appelbaum and Kohli (1997), an attempt is made to model import demand under exchange rate uncertainty.

Let $q = f(X_L, X_M, K)$ be a standard neoclassical production function. Assume that $f(\cdot)$ is continuous, non-decreasing, linearly homogeneous and strictly quasi-concave or concave. Where $X_L$ is the labor input, $X_M$ represents the quantity of the imported input needed to produce output q and K is capital. It is assumed that the only source of risk is the uncertain exchange rate. Therefore, the exchange rate is a random variable and so are the foreign price and profits. The profit maximization problem can be represented as:

$$Max_{X_L, X_K, X_M} \left\{ E\left\{ U\left[ (\bar{R}+\theta_1)P \cdot f(X_L, X_M, K) - w_L X_L - (\bar{R}+\theta_M) w_M X_M - w_K K \right] \right\} \right\}$$

where $R = \bar{R} + \theta_i$ the currency price of imports (foreign currency) and θ is a random variable distributed according to the density function $g(\theta)$, with $E(\theta) = 0$, (so that $E(R) = \bar{R}$) and $Var(R) = Var(\theta) = \sigma^2$. It is assumed that $U'(\cdot)$ is a Von-Newman-Morgestern utility function with $U'(\cdot) > 0$. The solution to the firm's problem defines the (dual) indirect (expected) utility function $V$, which is

$$(1)......................Max_{y,x} E\{U[(\overline{R}+\theta_1)P\cdot y - w_L X_L - (\overline{R}+\theta_M)w_M X_M - w_K K]: y \le F(x)\}$$

$$\equiv V(w_i, P, \overline{R}, \theta_i, \rho).$$

Where ρ represents higher moments of *g(θ)* and the random variable *θ* is continuous and convex to the moments (Appelbaum, 1993). The following input demand and output supply functions can be obtained from the above indirect expected utility function by applying the envelope theorem.

$$(2)......................x_i = \frac{\partial V}{\partial w_i} / \frac{\partial V}{\partial w_K}, \text{ and}$$

$$(3)........................y = \frac{\partial V}{\partial \overline{P}} / \frac{\partial V}{\partial w_K} \ .$$

The first order conditions for maximizing the expected utility of profits can be rearranged to obtain the following conditions.

$$\left(\overline{R}+\theta_1\right)P\cdot f_L(\mathrm{X_L}, \mathrm{X_M}, \mathrm{K}) = \mathrm{w_L}, \text{ and}$$

$$(\overline{R}+\theta_1)P\cdot f_M(\mathrm{X_L}, \mathrm{X_M}, \mathrm{K}) = (\overline{\mathrm{R}} + \theta_M)\cdot w_M \quad ,$$

where *θ = Cov [U'(π),v]/E[U'(π)]*. *θ* is positive, zero or negative as U´´(·) is positive, zero or negative (i.e as the agent is risk-averse, risk neutral, or risk lover). The term $(\overline{R}+\theta_M)\cdot w_M$ is the full marginal cost of imports and $\theta_M$ represents the marginal cost of uncertainty. It follows that the presence of uncertainty will generally lead the value of the marginal product of imports to deviate from the expected marginal cost of imported products. Particularly under risk-aversion, θ is positive so the value of the marginal product of imports will exceed their expected market price. This implies that the quantity of imports will be smaller under uncertainty. The first order conditions can be solved to obtain,

$$(4)\ldots\ldots\ldots\ldots\ldots\ldots\ldots X_L^* = X_L^*(w_L, w_M, p, \overline{R}, \theta_1),$$

$$(5)\ldots\ldots\ldots\ldots\ldots\ldots\ldots X_M^* = X_M^*(w_L, w_M, p, \overline{R}, \theta_M).$$

These relations indicate the amount of each factor to be hired depends on the factor prices, the product price, exchange rate and exchange rate uncertainty. We used the second function in this paper. Assuming that the agents are risk-averse and the production function is well-behaved, the following comparative static results can be derived from this model.

$$(6)\ldots\ldots\ldots\ldots\ldots\ldots \frac{\partial X_L^*}{\partial w_L} = \frac{f_{MM}}{(\overline{R}+\theta_1)P(f_{LL}f_{MM} - f_{LM}^2)} < 0$$

This expression is evidently negative under the hypothesis of risk-aversion and a well behaved production function since denominator is positive. In other words, demand of labor responds negatively to changes in its price. Similarly, the following expression indicates that demand of imported inputs responds negatively to changes in its price.

$$(7)\ldots\ldots\ldots\ldots\ldots\ldots \frac{\partial X_M^*}{\partial w_M}\frac{\partial w_M}{\partial R} = \frac{(\overline{R}+\theta_1)f_{LL}}{(\overline{R}+\theta_1)P(f_{LL}f_{MM} - f_{LM}^2)} < 0$$

This expression is indicates that demand of domestic input responds positively to changes in output price and the exchange rate.

$$(8)\ldots\ldots\ldots\ldots\ldots\ldots \frac{\partial X_L^*}{\partial P}\frac{\partial P}{\partial R} = \frac{-(\overline{R}+\theta_1)\left[f_L f_{MM} + f_M f_{LM}\right]}{(\overline{R}+\theta_1)P(f_{LL} f_{MM} - f_{LM}^2)} > 0.$$

Similarly, under the hypothesis of risk-aversion and assuming negative sign for the cross partial derivative, the demand for imports respond positively to changes in output price and the exchange rate.

$$(9)\ldots\ldots\ldots\ldots\ldots\ldots \frac{\partial X_M^*}{\partial P}\frac{\partial P}{\partial R} = \frac{-(\overline{R}+\theta_1)\left[f_M f_{MM} + f_L f_{LM}\right]}{(\overline{R}+\theta_1)P(f_{LL} f_{MM} - f_{LM}^2)} > 0.$$

These comparative static results are used to guide the empirical analysis in this paper.

**ECONOMETRIC ISSUES, DATA AND ESTIMATION METHOD:**

The simplest and most widely used procedure for estimating an import demand function is to relate total quantity of imports by a country to the level of its real expenditure or real income, the price of imports and the prices of domestic substitutes measured in the same currency. To determine the effects of exchange rate and its variability on import volumes, the exchange rate variable and the volatility of the exchange rate variable are introduced directly into the import demand functions to be estimated. Since white maize and yellow maize serve two different end uses and more than 85% of total maize imported from the United States is yellow maize, the assumption of differentiated products is maintained in the empirical analysis.

While it is generally recognized in the literature that exchange rate volatility influences trade, no consensus exists on how to measure it. In this article the exchange rate is assumed to be a random variable with the density function *g(θ),* where *E(θ)* = 0, so that

$E(R) = \bar{R}$ and $Var(R) = Var(\theta) = \sigma^2$. Since the moments of the distribution $g(\theta)$ are unknown, they need to be estimated prior to the estimation of the import demand function. It is widely recognized that exchange rates are generated through a stochastic process and that exchange rate data exhibit certain features that violate the assumptions of a constant variance of the disturbance term maintained in standard regression analysis. Exchange rates are typically heteroskedastic, leptokurtic and exhibit volatility clustering. These features could be handled adequately by modeling the volatility of the time series as conditional on its past behaviour (Bollerslev et al. (1992). Since the introduction of ARCH models by Engle (1982) and their subsequent generalizations as GARCH, they have very useful techniques to measure exchange rate volatility (Engle, 2001). Both ARCH and GARCH models have been recently used in different studies of exchange rate volatility using monthly data (McKenzie and Melbourne, 1999; Lastrapes and Koray, 1990; and Qian and Varangis, 1994). Due to the growing popularity of this approach, the exchange rate variability is measured by employing the GARCH procedure in this paper.

As for the appropriate specification of the import demand, economic theory does not provide any specific direction to identify the best functional form. Thursby and Thursby (1984) explored nine most commonly used specifications of aggregate import demand functions for the United States and found the log-linear functional form to be better than others. Thus, for maize imports from the United States by Mexico the following equation is estimated in log-linear form.

$$(10)\ldots\ldots\ldots\ldots Qc^* = \beta_0 + \beta_1 MXY + \beta_2 Pc + \beta_3 Pcd + \beta_4 INV + \beta_5 D_i + \beta_6 ER + \beta_7 VG + \varepsilon_i$$

where:

$$\frac{\partial Q^*}{\partial MXY} > 0 \quad \frac{\partial Q^*}{\partial Pc} < 0 \quad \frac{\partial Q^*}{\partial Pcd} > 0 \quad \frac{\partial Q^*}{\partial INV} > 0 \quad \frac{\partial Q^*}{\partial ER} > 0 \quad \frac{\partial Q^*}{\partial V_i} < 0 \quad \frac{\partial Q^*}{\partial D_i} > 0$$

The volume of maize imported from the Unites States, Qc*, is measured in metric tons. The importer's income is represented by MXY in constant 1993 pesos per person. Pc is the border price (in US$/kg) of maize obtained by dividing the total value (in US dollars) of Mexican imports from Unites States by the volume of Mexican imports. The border piece was converted to real dollar by using the US CPI. Pcd is the price of a substitute. The wholesale price of domestic maize has been used as a substitute in this study. The variable INV represents the inventory of hogs on feed while $D_i$' are NAFTA or monthly dummy variables to indicate the effects of trade liberalization or seasonality on maize imports. ER is the Mexican peso per US dollar and VG is the measure of exchange rate volatility. The expected signs for all these variables are given immediate after the import demand function. Table 1 provides a full description of the data along with their sources and the summary statistics. To avoid issues related to food vs. fuel uses of corn since 2005, we limited our data set to December 2004.

In empirical work using economic time series, it is important to determine if the data are level or difference-stationary. To test the existence of difference stationarity formally, a number of unit root tests (parametric, non-parametric and Bayesian) have been developed in the econometric literature. While each of the unit root test has its strengths and limitations, the Augmented Dickey-Fuller (ADF) test is employed in this study because it generates more consistent results compared to the other tests in small samples (Harris and Soilis, 2003). To formally test for the presence of a unit root in a series $y_t$, an augmented Dickey-Fuller (ADF) test can be computed by running the following regression:

$$(11)..................(1-L)y_t = \alpha_0 + a_1 y_{t-1} + \sum_{i=1}^{p} \gamma_i (1-L) y_{t-i} + \varepsilon_t \,.$$

A negative and significant estimate of $a_1$ is inconsistent with the null hypothesis of a unit root in $y_t$. The t-ratio on the estimated parameter, $a_1$, however, does not have a standard t-distribution. The critical value provided by Dickey and Fuller (1979) needs to be used.

If the unit root test on the data reveals that all variables are difference-stationary then a precondition for the existence of a stable steady-state relationship in the system is cointegration among the variables. A vector of variables is said to be cointegrated if each variable in the vector has a unit in its univariate representation, but some linear combination of these variables is stationary (Engle and Granger 1987). A number of alternatives approaches for testing cointegration have been developed in the literature. These include the two-step procedure developed by Engle and Granger (1987), the dynamic ordinary leas squares (OLS) procedure developed by Stock and Watson (1988), the system approach developed by Johansen (1988, 1991) and the canonical correlation of Bossaerts (1988). The Engle-Granger procedure is a single-equation, regression residual-based test. Although it is a simple and attractive test for bivariate models, it does not perform well in a multivariate situation.

The approach developed by Johansen derives maximum likelihood estimators of the cointegrating vectors for a VAR system. It extends the Engle-Granger procedure to a multivariate context where there may exist more than one cointegrating relationship among a set of n variables. Moreover, it provides a likelihood ratio test and a maximum eigenvalue test for determining the exact number of cointegrating vectors in a particular model. This approach also provides a flexible format for investigating the properties of the estimators under various assumptions about the underlying data-generating process (DGP) and allows for testing policy relevant economic hypothesis. Using Monte Carlo simulations, both Gonzalo (1994) and Hubrich et al., (2001) demonstrate that the maximum likelihood procedure performs better than all other cointegration methods. Because of these attractive features, Johansen's approach is used in this research. A brief description of Johansen maximum likelihood cointegration analysis is presented below.

Following Johansen (1995) and Johansen and Juselius (1990), this approach starts with a $k_{th}$ order unrestricted VAR representation of $X_t$ such that:

(12)……$X_t = c + \pi_1 X_{t-1} + \pi_2 X_{t-2} + \ldots . \pi_k X_{t-k} + \mu + \psi\ TD + \Phi D_t + \varepsilon_t$ (t = 1,…, T)

Where: $X_t$ = a vector of p I(1) variables; $D_t$ = eleven seasonal dummies;

$\pi_i$ = a (p x p) matrix of parameters; c = a (p x 1) vector of constant terms;

TD = trade dummy variables, and $\varepsilon \sim NID(0, \Omega)$.

Using $\nabla = 1 - L$, where L is the lag operator, the above model can be re-parameterized as:

(13)………$\nabla X_t = C + \Gamma_1 \nabla X_{t-1} + \Gamma_2 \nabla X_{t-2} + \ldots . + \Gamma_{K-1} \nabla X_{t-k+1} - \Pi X_{t-k} + \Phi D_t + \varepsilon_t$

where: $\Gamma_i = - I + \pi_1 + \ldots\ldots + \pi i$, and $- \Pi = I - \pi_1 - \pi_2 - \ldots . - \pi_k; \forall i = 1,2,\ldots . , k-1$.

It is interesting to note that the re-parameterized model is a traditional first-differenced VAR model except for the term $\Pi X_{t-k}$. The coefficient matrix of $X_{t-k}$, $\Pi$, contains information about the long-run relationships among variables in the model. If $\Pi$ has a full rank, then X is a stationary process. In this case, a non-differenced VAR model is appropriate. If $\Pi$ has a zero rank, then $\Pi$ is a null matrix and $X_t$ is an integrated process. Only in this case, a traditional first-differenced VAR model is appropriate (Hamilton). If, however, 0 < (rank (Π) = r) < p, cointegration holds and Π can be represented as the product of two p x r matrices α and β, such that Π = $\alpha\beta'$. The $\beta'$s are the cointegrating vectors and $\alpha'$s are the weights. In this case, $\beta' X_t$ is stationary. Further details on the maximum likelihood estimation of Π can be found in Johansen (1995, pp. 70-131).

Johansen's approach provides a convenient framework for testing linear hypotheses expressed in terms of μ, α and β. Likelihood ratio tests can be formulated to test a variety of linear restrictions on α and β. Theoretical and empirical economic knowledge can be used to formulate these restrictions. These restrictions essentially limit the space spanned by the r cointegrating vectors to lie in the s-dimensional space. If $s = r$, then the cointegration space is said to be fully specified (Johansen 1995). Let $H_3$: $\beta$ = $H_\delta$ represents a formulation of a linear restriction on the cointegrating vectors, where $H$ is a p .x matrix of restrictions designed to restrict the space spanned by $\beta$ to lie in s-dimensional space and δ is a set of cointegrating vectors (see Johansen 1995 for details).

After obtaining the long-run cointegration relationship, it is possible to reformulate the above model and estimate the VECM with the error-correction term explicitly included in it. It also has the advantage of not requiring *a priori* assumptions of endogenity or exogenity of the variables. Consider the following VECM:

$$(14)\ldots\ldots\ldots\ldots\ldots\ldots\Delta Y_t = \sum_{j=1}^{k-1} \Gamma_j \, \Delta Y_{t-j} + \alpha\beta' \, Y_{t-k} + \mu + \varepsilon_t$$

where $_t = \sum_{j=1}^{k-1} \Gamma_j \, \Delta Y_{t-j}$ and $\alpha\beta' \, Y_{t-k}$ are the vector autoregressive (VAR) component in first differences and error-correction components, respectively, in levels of the VECM, $Y_t$

is a p x 1 vector of variables and is integrated of order one. $\mu$ is a p x 1 vector of constants, k is a lag structure, while $\varepsilon_t$ is a p x 1 vector of white noise error term. $\Gamma_j$ is a p x p matrix that represents short-term adjustments among variables across p equations at the *j*th lag. $\beta'$ is a p x r matrix of cointegrating vectors, and Δ denotes first differences. $\alpha$ is a p x r matrix of speed of adjustment parameters representing the speed of error correction mechanism. The VECM can be estimated using OLS and all standard statistical tests can be employed.

**RESULTS AND DISCUSSION:**

Since the cointegration analysis is meaningful when relevant data are characterized by nonstationarity, an attempt is made first to determine if the variables used in Mexico's import demand function for maize are characterized by unit root nonstationarity. We employed the ADF test and the results are presented in Table 2. Akaike's final prediction error (FPE) criterion is used to determine the optimum lag-length for each series. Since the critical value of ADF at 5% level of error probability for a sample size of 250 is -3.43 (see Hamilton, page 763), the null hypothesis of a unit root cannot be rejected for all variables in their level form. However, the null hypothesis is soundly rejected for each variable when the series is first-differenced. Thus, all variables become stationary after first-differencing. Hence, we conclude that the univariate representation of each of the seven variables is characterized by unit root nonstationarity and each series is integrated of order one.

An appropriate econometric technique to be used in this situation is cointegration analysis. The estimated cointegrated relationship represents the stable long-run relationship to which the variables in the system have a tendency to return in the long-run (Engle and Granger, 1987). We employed the Johansen's maximum likelihood procedure to determine if cointegration relationship exists among these variables and if so, the nature of this relationship. Since an unrestricted VAR formulation used in Johansen's approach is sensitive to the number of appropriate lags of each of the variable in the system, it is important determine the appropriate lag-length for the system. We employed Sims' modified likelihood ratio test to determine the appropriate lag-length in this article. The results presented in Table 3 suggest an appropriate lag-length to be 10. In view of monthly maize imports by Mexico from the United States, the results seem reasonable.

Table 4 reports the results of cointegration analysis. The trace statistic tests the null hypothesis that the cointegration rank is equal to *r* against the alternative that the cointegration rank is *k* while the maximum eigenvalue statistic tests the null hypothesis that the cointegration rank is equal to *r* against the alternative that the cointegration rank is equal to *r*+1. Both the trace (0.95) and the maximum eigenvalue (0.90) test reject the null hypothesis of no cointegration and suggest the existence of one cointegrating vector in this system. This cointegrating vector represents the long-run relationship among the variables in this system and can be written as,

$$(15)\ldots\ldots Qc = -0.804Pc + 1.268Pmx + 0.582MXY + 0.631ER - 0.422VG + 0.420INV.$$

This represents the long-run import demand function for maize in Mexico. In this equation the estimated coefficients of all variables have theoretically expected signs. Since all variables were log-transformed prior to estimation, the estimated coefficients are elasticities. The import demand for maize is price inelastic. As per capita income in Mexico increases, Mexican will include more meats in their diets and higher will be import of maize form the United States. The sign of the exchange rate volatility indicates a negative relationship between maize imports and exchange rate uncertainty.

The estimated weights ($\alpha's$) for imports of maize suggest that in the event of any disturbance affecting the long run equilibrium, the quantity of maize imports and the import price will respond faster than any other variable to bring this system back to the equilibrium path.

The short-run results of Mexican import demand for maize from the United States along with a set of diagnostic statistics are presented in Table 5. The goodness of fit measured by $R^2$ is 0.32 and the F statistics is significant. The DW-h statistic rejects the presence of autocorrelation. With regard to the J-B normality test, the null hypothesis of normality of the disturbances cannot be rejected at the five percent level. Finally, the Lagrange Multiplier (LM) statistic indicates that the null hypothesis of no autocorrelation cannot be rejected at the five percent significant level. Thus, the short-run import demand function for maize is fully satisfactory.

The coefficient of the own price of maize exhibits an expected negative sign at the five percent level. The coefficient of the price of the related commodity (maize produced in Mexico) exhibits an expected positive sign and is statistically significant. The above results are consistent with the results obtained from the long-run analysis. Maize produced in Mexico is a substitute for maize imports from the Unites States. Both short-run own price and cross price elasticity values are smaller than their long-run counterparts. The small value of the price elasticity reflects the fact that few possibilities of substitution exist for maize imported from the United States. Other sources of imports of maize into Mexico are nonviable as long as Mexico enjoys trade preferences because of the NAFTA agreement and lower transportation costs because of the proximity to the United States. The coefficient of the income variable is positive and significant suggesting a direct relationship between income and quantity of maize imported into Mexico from the Unites States. Avalos-Sartorio (1998) reported that Mexico's apparent utilization of maize has risen sharply because demand for meat and meat products have increased in recent years. Since the domestic production of maize has been remarkably stable, as income rises in Mexico, the import of maize will continue to grow. The increasing share of maize demand has been fulfilled by imports, which have risen significantly after the implementation of NAFTA 1994.

The result related to the exchange rate variable is consistent with the hypothesis that a depreciation of the Unites States currency relative to the Mexican peso makes imports into Mexico less expensive resulting in an increase of maize imports. The results in Table 5 also suggest that in the short-run volatility has a negative influence on Mexican imports of maize from the United States. Thus, risk-averse importers are discouraged by higher volatility episodes of the Mexico-US exchange rate which leads to lower volumes of maize imports by Mexico from the United States.

The results suggest that NAFTA is having a very large and statistically significant effect on the US-Mexico maize trade. While this has been discussed in many circles since NAFTA took effect (see Zahniser and Coyle), the precise magnitude of this effect was not known prior to our analysis. In regards to seasonality, only two monthly dummy variables, M3 and M9, are found to be statistically significant. Maize imports increase during the winter season and before the harvest season since the main region devoted to hog and cattle production in Mexico (the state of Sonora located in the border with the Unites States) is affected by winter weather and require manufactured feed for livestok.

The coefficient of the lagged dependent variable is positive and significant. Even though the responsiveness appears to be small, this result illustrates the influence of previous trade on current volumes of maize imports by Mexico. The results suggest that it takes about six months for Mexican maize importers to adjust to changing market conditions. With regard to the inventory of hog's (INV), the error-correction model yields a positive and significant coefficient. Previous research in Mexico did not reveal a strong link between imports of maize and the domestic feed industry. Results from a regression analysis with data from 1990 to 998 did not produce a strong link between imports of whole maize and animal feed production. However, results indicated a strong link between imports of broken maize and animal feed produced commercially, and between imports of maize gluten and feed produced by commercial operations (Avalos-Sartorio).

Finally, the coefficient of the error-correction term (ECT) is negative and significant which reconfirms the presence of a cointegration in this system. The small coefficient of the ECT, however, suggests a slow adjustment towards the long-run equilibrium, if the system is disturbed by an exogenous shock.

**CONCLUDING REMARKS:**

As the border between Mexico and the United States became increasingly open due to NAFTA, Mexican agri-food trade may also have been influenced simultaneously by changes in exchange rate and exchange rate volatility. A rigorous analysis has not been performed to determine the relative contributions of these factors to the growth of

Mexican agri-food trade with the United States. An attempt is made in this article to bridge this gap by determining the extent to which NAFTA, the continuous devaluation of peso against the U.S. dollar and the exchange rate volatility have contributed to the growth in maize imports by Mexico from the United States during the last two decades.

We employed unit root test, the maximum likelihood cointegration analysis and error-correction models to determine the long-run as well as short-run effects of exchange rate, volatility of exchange rate, NAFTA and other relevant factors on maize imports by Mexico from the United States. The results show that growth in per capita income, changes in exchange rate, volatility of exchange rate and the growth in livestock production all have significant influence on maize imports in the long-run. However, in the short-run, NAFTA is the most important driver of maize imported by Mexico from the United States.

While the error-correction model estimated in this paper is theoretically consistent and econometrically satisfactory, a large portion of the total variations in maize trade remains unexplained. Although the explanatory power of an ECM is typically low, future research should attempt to improve the performance of such error-correction models. Finally, appropriate impulse response and variance decomposition analysis may also shed additional lights on short-run dynamics of Mexican maize imports from the United States.

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Table 1: Description of Variables Used in the Maize Import Demand Function

| Variable | Description | Units | Mean | St Dev. |
|---|---|---|---|---|
| Qc* | Quantity of maize imported by Mexico from US. | Metric Ton | 328953 | 248973.7 |
| MXY | Importer's income is the MX per-capita GDP. | MX$/person | 2977.21 | 1367.36 |
| Pc | The border price of Mexican maize imports from the US. | US$/kg | 0.13667 | 0.05485 |
| Ps | Ps is the price of a substitute, the price of domestic maize in Mexico | US$/kg | 0.228 | 0.04125 |
| INV | INV is the inventory of hogs on feed in Mexico. | Million Heads | 6.74318 | 1.0968 |
| R | ER is the Mexican peso per US dollar exchange rate. | MX$/US$ | 6.84389 | 3.19897 |
| Di | Dummy variables to represent trade liberalization (NAFTA) and Seasonal Effects on trade | Zero / one | --- | --- |

Table 2. Unit Root Test Results for Variables used in the Maize Model

| Variables in Level Form | Estimated Coefficient | Lag Length (Months) | ADF Statistic* |
|---|---|---|---|
| MX Domestic Corn Price | - 0.1325 | 8 | - 3.164 |
| Corn Import Volume | - 0.3334 | 5 | - 3.160 |
| Corn Border Price | - 0.3185 | 12 | - 2. 681 |
| US-Mexico real ER | -0.0149 | 5 | -1.092 |
| Volatility of ER (VG) | -0.5029 | 5 | 2.028 |
| MX per-capita GDP (real) | -0.3261 | 12 | -2.710 |
| INV of Hogs on Feed in MX | -0.2174 | 10 | -2.653 |
| Variables in First Differenced Form | | | |
| MX Domestic Corn Price | - 1.2311 | 8 | - 4.941 |
| Corn Import Volume | - 3.1122 | 5 | - 11.53 |
| Corn Border Price | - 4.5644 | 12 | - 5.912 |
| US-Mexico real ER | -0.9724 | 5 | -7.162 |
| Volatility of ER (VG) | -1.2385 | 5 | -8.089 |
| MX per-capita GDP (real) | -4.5318 | 12 | -5.860 |
| INV of Hogs on Feed in MX | -2.963 | 10 | -6.383 |

*The critical value at five percent significance level is -3.43.

Table 3. Optimal Lag Length Selection for the Maize Model

| Lag-Lengths Compared | No. of LAGS | Log Likelihood | No. of parameters | N* | LR Test | $\chi^2_d$ (df=7) 5% | Decision |
|---|---|---|---|---|---|---|---|
| Two-Three | 2 | -6.083 | | 158 | 51.105 | 14.02 | Reject Lag 2 |
| | 3 | -6.496 | 34.000 | | | | |
| Three-Four | 3 | -6.496 | | 151 | 88.675 | 14.02 | Reject lag 3 |
| | 4 | -7.302 | 41.000 | | | | |
| Four-Five | 4 | -7.302 | | 144 | 52.975 | 14.02 | Reject lag 4 |
| | 5 | -7.854 | 48.000 | | | | |
| Five-Six | 5 | -7.854 | | 137 | 29.184 | 14.02 | Reject lag 5 |
| | 6 | -8.209 | 55.000 | | | | |
| Six-Seven | 6 | -8.209 | | 130 | 23.319 | 14.02 | Reject lag 6 |
| | 7 | 8.310 | 62.000 | | | | |
| Seven-Eigth | 7 | 8.310 | | 123 | 21.060 | 14.02 | Reject lag 7 |
| | 8 | 8.700 | 69.000 | | | | |
| Eigth-Nine | 8 | 8.700 | | 116 | 17.200 | 14.02 | Reject lag 8 |
| | 9 | 9.130 | 76.000 | | | | |
| Nine-ten | 9 | 9.130 | | 109 | 14.560 | 14.02 | Reject Lag 9 |
| | 10 | 9.690 | 83.000 | | | | |
| Ten-Eleven | 10 | 9.690 | | 102 | 6.960** | 14.02 | Accept Lag 10 |
| | 11 | 10.270 | 90.000 | | | | |
| Eleven-Twelve | 11 | 10.270 | | 95 | -1.360 | 14.02 | --- |
| | 12 | 10.950 | 97 | | | | |

N* indicates the Net Number of Observations
** Once an optimal lag is achieved, no further test is conducted.

Table 4. Long-Run Cointegration Results of Mexico's Import Demand for Maize

**A Seven Variables Ten Lags System Using VG**

| Eigenvalues | 0.234248 | 0.2032 | 0.1512 | 0.1297 | 0.0872 | 0.0220 | 0.0035 |
|---|---|---|---|---|---|---|---|
| | | | | Eigenvector ($\beta_s$) | | | |
| MXY | -0.8473 | 0.9547 | -0.1644 | -0.5860 | -2.3805 | 3.3061 | -11.589 |
| ER | -0.5168 | 2.6810 | -0.1812 | 1.2912 | -1.2714 | 1.6409 | 20.1984 |
| VG | 0.8517 | -1.3779 | -0.2251 | -0.2471 | -0.3561 | -0.6658 | 6.9855 |
| INV | -0.3170 | 2.8230 | 0.1311 | -3.2038 | 2.6480 | 0.6237 | 6.9953 |
| Pc | 0.3760 | -0.4428 | 0.3568 | -1.4004 | -5.7391 | -1.0850 | 3.9987 |
| Pcd | -0.6790 | 7.9606 | 0.0258 | 0.6383 | -0.6188 | -1.3585 | -6.4744 |
| Qc | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| | | | | Weights ($\alpha_s$) | | | |
| MXY | 0.0007 | 0.0000 | -0.0004 | 0.0011 | -0.0001 | -0.0005 | 0.0003 |
| ER | 0.0004 | -0.0010 | -0.0003 | 0.0018 | 0.0014 | -0.0007 | -0.0003 |
| VG | 0.0042 | -0.0017 | -0.0002 | -0.0015 | 0.0002 | 0.0010 | -0.0001 |
| INV | 0.0857 | -0.0242 | 0.0890 | 0.0926 | -0.0807 | -0.0008 | 0.0002 |
| Pc | 0.0013 | 0.0143 | 0.0036 | 0.0080 | 0.0054 | 0.0015 | -0.0010 |
| Pcd | -0.0043 | -0.0044 | 0.0083 | 0.0033 | 0.0090 | 0.0022 | 0.0002 |
| Qc | 0.1340 | 0.0961 | 0.1315 | -0.0662 | 0.0492 | -0.0428 | -0.0061 |

Testing the Number of Cointegrating Vectors

| Null Hypothesis | Trace Statistic | Trace (0.95) | Max $\lambda$ | Max $\lambda$ (0.95) |
|---|---|---|---|---|
| $r = 0$ | 165.420* | 150.4 | 48.308 | 50.51 |
| $r \leq 1$ | 117.110 | 117.49 | 41.113 | 44.37 |
| $r \leq 2$ | 76.003 | 88.59 | 29.681 | 38.22 |
| $r \leq 3$ | 46.321 | 63.66 | 25.141 | 31.99 |
| $r \leq 4$ | 21.179 | 42.7 | 16.521 | 25.68 |
| $r \leq 5$ | 46.581 | 25.64 | 4.027 | 19.21 |
| $r \leq 6$ | 0.631 | 12.34 | 0.631 | 12.34 |

* Significance at 5 percent level (MacKinnon, 1999)

Table 5. Results from the Error Correction Model: Mexico's Import Demand for Maize

| Variables | Estimated Coefficient | T-Ratio |
|---|---|---|
| QC t-6 | 0.081 | 1.702 |
| MXY t-9 | 0.125 | 8.376 |
| ER t-3 | 0.244 | 2.646 |
| VG t-1 | -0.057 | -3.326 |
| DINV t-12 | 0.144 | 1.993 |
| $P_{c(t-4)}$ | -0.138 | -2.202 |
| $P_{cd(t-1)}$ | 0.153 | 2.628 |
| ECT t-1 | -0.018 | -5.002 |
| NAFTA | 1.161 | 2.556 |
| M3 | 0.427 | 1.835 |
| M9 | 0.308 | 1.988 |
| CONSTANT | 0.883 | 4.258 |
| $R^2$ | 0.319 | |
| $R^2$ Adjusted | 0.284 | |
| F-Value | 5.010 | |
| DW-H Statistic | - 1.482 | |
| Skewness | - 0.732 | 0.000 |
| Kurtosis | 1.815 | 3.000 |
| J-B Normal | 8.861 | 9.210[b] |
| Instability Test: | | |
| Variance | 0.233 | 0.353 |
| Joint | 4.082 | 3.690 |
| L.M Statistic | 29.059 | 35.172[a] |

[a] Denotes the critical value of chi-squared with 23 degrees of freedom.
[b] Denotes the critical value of chi-squared with two degrees of freedom.