EXCHANGE RATE SENSITIVITY OF MEXICAN MAIZE IMPORTS FROM
THE UNITED STATES

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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 have 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, 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 show 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 is the most important driver of maize imports into Mexico from the United States.

Key words: Maize trade, exchange rate, volatility of exchange rate, livestock inventory, cointegration analysis, error-correction model.

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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 and beans are dominated by small and mid-sized farms. Historically, the United States has been the most important agri-food trade partner of Mexico. Since the successful 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 contributed the most to the dramatic expansion of the U.S.-Mexico agri-food trade (Rosenzweig, 1996; USDA, 1999). However, others have emphasized the role played by exchange rate changes in enhancing Mexican agri-food trade with the United States (Mora-Flores et al., 2002). To the best of our knowledge, no formal attempt has been made to determine empirically the extent to which NAFTA and the continuous devaluation of Mexican peso relative to the U.S. dollar contributed to the growth in Mexico-U.S. agri-food trade.

The Government of Mexico initiated a fundamental change in the direction of its development policy from a strategy of import substitution to gradual outward orientation with declining state intervention in the economy after the economic crisis in 1982. To maximize the benefits of outward orientation, Mexico joined the GATT in 1986 and the importance of trade in the Mexican economy has been growing ever since. The trade sector received an unprecedented boost in 1994 with the successful implementation of

NAFTA. The share of agri-food trade relative to total supply of agri-food products in Mexico almost doubled from about 19% during 1990-93 to 35% during 1994-2002. While this is great news, growing dependence on trade also makes the agri-food sector in Mexico more vulnerable to changes in exchange rate of Mexican peso relative to the U.S. dollar than in the past. Moreover, since the switch from a peg to a floating exchange rate system in 1995, the Mexico-U.S. exchange rate has been characterized by periods of calm followed by episodes of high volatility (Bazdrech, 2002).

While the borders between Mexico and its important trade partners, the United States and Canada, 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 is yet to be performed to determine the relative contributions of these factors to the growth of Mexican agri-food trade. 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 into Mexico from the United States during the last two decades. The choice of maize has been influenced by three considerations: (i) maize (white corn) is the most important staple in Mexico and has been treated as one of the sensitive commodities under NAFTA. Thus, Mexican maize was subject to a gradual process of year-to-year liberalization and all NAFTA provisions for trade liberalization will be phased-in by January 2008; (ii) while Mexico could impose tariff rate quotas (at 215% tariff for imports of more than 2.5 million metric tons) and/or seasonal tariffs to protect domestic maize producers, it did not impose any TRQ on maize imported from the United States; and, finally, (iii) other things being equal, the

significant push for renewable energy and ethanol production from corn in the United States can have significant implications for Mexico-United States trade in maize.

Exchange rates or the relative currency prices determine which agri-food commodities are traded, and where they are shipped or sourced. The trade literature related to the effects of exchange rate movements on agri-food trade primarily focused on whether exchange rate matter for agricultural trade and if it matters, 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 matters as it has a significant positive effect on trade flows. However, the magnitudes vary considerably across countries and commodities or commodity aggregates. 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 related to 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 revealed 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 controversial empirical findings may be related to the specification of the volatility measure used and the estimation method employed in these 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 investigated the effect of exchange rate

volatility on trade flows and none focused on maize or any other grains produced, consumed and traded in Mexico. 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 the nonstationarity in 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 2 provides a brief overview of the maize sector and agricultural policies in Mexico. Section 3 focused on the analytical framework used in this article to guide the empirical estimation. Section 4 concentrates on empirical issues, data and 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:

While some grain producers in Mexico hold large farms, modern technology and production practices, a more representative Mexican producer has access to roughly 10 hectares of farmland. According to Mexico's 1991 National Agricultural and Livestock Census, 61 percent of the farms where corn was the principal crop were smaller than 5 hectares (INEGI). Census data also reveal that only 31 percent of all corn farms used improved varieties of corn, 35 percent had tractors and 9 percent had access to irrigation, a critical input to the Mexican corn sector (Nadal 2004). Efforts to improve corn production in Mexico have raised yields to about 6 metric tons per hectare on irrigated

land and 2.0 metric tons per hectare on rain-fed land during the 1990s.

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 outward orientation emphasized three types of policies: (i) a decrease or elimination of tariffs and controls on international trade; (ii) a decrease or elimination of subsidies to consumers, along with an equalization of domestic producer prices with their world equivalents; and (iii) a devaluation of real exchange rate (Byerlee and Sain, 1991).

While the process of phasing-out government interventions in Mexican agriculture started at the end of the 1980s and it went into a full gear during the early 1990's with the implementation of NAFTA in 1994. La Compañia Nacional de Subsistencias Populares (CONASUPO) was the main institution through which government interventions in the Mexican agriculture took place. Before the reforms of the 1980s, the programs of CONASUPO covered most of the grain and oilseed crops produced and consumed in Mexico. By supporting the prices of these crops, by processing, storing, and distributing the crops and by regulating trade through direct imports, CONASUPO exerted significant control over agri-food production, marketing and distribution in Mexico.

By 1996, most of the agencies and financial activities of CONASUPO were dismantled or privatized, and by 2000, the liquidation of CONASUPO was complete (Taylor et al., 2004). To replace some of the CONASUPO's activities in the early 1990's, a 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. This agency also operates the Procampo program through which Mexican Government transfers direct cash income to Mexican farmers (Sadoulet et al., 2001).

A major reform in staple production was the elimination of guaranteed prices that CONASUPO traditionally awarded to the producers of basic crops such as maize and beans in Mexico. In 1995, the government took further steps towards a more liberalized food chain and decided to liquidate CONASUPO in 2000. Thus, a decoupled income support program called PROCAMPO is the only income support program available for maize farmers in Mexico. While the purpose of this program is to facilitate the transition of farmers from the old price support system to a more open international market, PROCAMPO as a farm safety net program may outlive the full liberalization agri-food production and trade in Mexico under NAFTA.

In addition to ASERCA and PROCAMPO, the Mexican Government has initiated an "Alliance for the Countryside" in 1995. The main objective of this initiative is to increase agricultural productivity by making additional capitals available to farmers for investments in sanitary and other desirable projects.   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.

Under NAFTA, some agricultural commodities were liberalized in January 1994. Others such as maize and beans (considered politically more sensitive) were subject to a process of year-to-year liberalization, so that full trade liberalization will take place in

January 2008. For this group of commodities, tariff rate quotas (TRQs) and/or seasonal tariffs are used to protect domestic producers. While Mexico can impose TRQs on the imports of maize, this right was never exercised. Quota levels were established based on 1989-91 trade flows between Mexico and its two North American partners. 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.).

With the second phase of the structural adjustment programs, subsidies on maize production were eliminated and a system of price bands was adopted. Under this system, the government sets minimum and maximum internal prices and regulates imports to manage the band. Since prices in the domestic market are linked to the price trends in the international market, it may have contributed to improvements in resource use efficiency and productivity in the maize sector (Sainz and Lopez-Pereyra, 1999). Growth in productivity rose considerably over the last decade. Together with moderate growth in cultivated area, yield growth contributed to Mexico's high growth rate in maize production. Maize production in central and southern Mexico (the states of Jalisco, Mexico, Oaxaca, Veracruz, Tabasco, Chiapas, Campeche, Yucatán and Quintana Roo) represents approximately 60 percent of the country's total production. While the growth rates vary among the states of central and southern Mexico, maize production in these states rose by about 4 percent per year during last ten years (SAGARPA, 2004).

Maize consumption in Mexico consists of two major components: direct human consumption (white maize) and animal feed (yellow corn mostly used for pork and poultry production). Growth in total maize consumption results from growth in both

components. While yellow corn accounts for the bulk of U.S. corn production, white corn dominates production in Mexico. In the feed market, yellow corn from the United States is supplementing Mexican production, which is clearly insufficient to meet growing domestic demand from hog and poultry producers.

The majority of Mexican imports of corn consist of yellow corn (more than 80 percent), which is primarily used as an ingredient in animal feed. Between 1998 and 2002, Mexico also imported significant quantities of white corn, which have been processed to make traditional food. However, the share of white corn imported from the U.S. never exceeded 15% of total maize imports during the period considered in this study. The United States supplied about 95 percent of total maize imported into Mexico during the study period and 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 7.7 million metric tons in 2003 (USDA 2004). In the near future, the demand for feed corn is expected to increase rapidly with the growth in per capita income in Mexico and as Mexicans incorporate more meat into their diets (Zahniser and Coyle, 2004).

AN ANALYTICAL FRAMEWORK:

The estimation of import demand functions for various commodities have received a great deal of attention in the empirical literature of agricultural trade 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. Depending upon whether the commodity in question is considered as an intermediated good or a finished product, such demand functions for imports can be derived from conventional production or utility theory. 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 import 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. Exchange rate uncertainty enters the model affecting both firm's revenue and firm's expenditure on imported inputs.

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 input labour, 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 $R = \overline{R} + \theta_i$ 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 $E(R) = \overline{R}$) 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

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

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

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

$$x_i = \frac{\partial V}{\partial w_i} / \frac{\partial V}{\partial w_K} \quad \text{and}$$

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

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

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

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$$(\bar{R}+\theta_1)P \cdot f_M(X_L, X_M, K) = (\bar{R} + \theta_M) \cdot w_M \qquad ,$$

where $\theta = Cov\ [U'(\pi),v]/E[U'(\pi)]$. θ is positive, zero or negative as $U''(\cdot)$ is positive, zero or negative (i.e as the agent is risk-averse, risk neutral, or risk lover). The term $(\bar{R}+\theta_M) \cdot w_M$ is the full marginal cost of imports and θ_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,

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

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

These relations indicate the amount of each factor that will 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.

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

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.

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

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

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

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.

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

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

ECONOMETRIC ISSUES, DATA AND ESTIMATION METHOD:

The issues related to empirical specification of the import demand function need to be addressed before estimation. 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 above 85% of the 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 $g(\theta)$, where $E(\theta) = 0$, 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 in order to proceed with the estimation of the import demand. 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 past behaviour (Bollerslev et al. (1992). Since the introduction of ARCH models by Engle (1982) and their subsequent generalizations as GARCH have proved to be a very useful technique to measure exchange rate volatility. Both ARCH and GARCH models have been recently used in different studies of exchange rate volatility using monthly data (McKenzie, 1998; Lastrapes and Koray, 1990; and Qian and Varangis, 1994). Due to the growing popularity of this approach, the exchange rate variability is measured

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by employing the Generalized Autoregressive Conditional Heteroskedasticity (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 into Mexico the following equation is estimated in log-linear form.

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

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 is 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 exchange rate and VG is the measure of exchange rate volatility. The expected signs for all relevant variables are given immediate after specified import demand function. Table 1 provides a full description of the data along with the sources and summary statistics.

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 in small samples compared to 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:

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

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). At least five alternatives approaches for testing cointegration have been developed in the literature. These are 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), the non-linear least squares of Watson (1987) 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 maximum eigenvalue test for determining the exact number of cointegrating vectors in a particular model. This approach also provides a very 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 that 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

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with a k_{th} order unrestricted VAR representation of X_t such that:

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

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

π_i = a (p x p) matrices 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:

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

where: $\Gamma_i = -I + \pi_1 + \ldots + \pi_i$, 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}, Π, contains information about the long-run relationships among variables in the model. If Π has a full rank, then X is a stationary process. In this case, a non-differenced VAR model is appropriate. If Π has a zero rank, then Π 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, $0 < (\text{rank } (\Pi) = r) < p$, cointegration holds and Π can be represented as the product of two p x r matrices α and β, such that $\Pi = \alpha\beta'$. The β's are the cointegrating vectors and α's are the weights. In this case, $\beta'X_t$ is stationary. The 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 the coefficients μ, α and β. In particular, it is possible to test for the presence or absence of linear trends in the stochastic part of the model. It is important to choose the appropriate model formulation (i.e., with or without a trend variable), because

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the asymptotic distributions of the test statistic and estimators depend on which assumption is maintained (West 1988).

Likelihood ratio tests can also 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: $\beta = H_\delta$ represent 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 β to lie in s-dimensional space and δ is a set of cointegrating vectors (see Johansen 1995 for details).

The importance of the ECM in the cointegration literature derives from a demonstration by Engle and Granger that if two variables are integrated of order one and are conintegrated, they can be modeled as having been generated by an ECM. The resulting error-correction models should produce better short-run and long-run forecasts and the results can be interpreted in economically meaningful ways (Granger and Newbold, 1986). The importance of the ECM in the cointegration literature derives from a demonstration by Engle and Granger that if two variables are integrated of order one and are conintegrated, they can be modeled as having been generated by an ECM. The resulting error-correction models should produce better short-run and long-run forecasts and the results can be interpreted in economically meaningful ways (Granger and Newbold, 1986).

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 a VECM that is of the form:

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

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. μ is a p x 1 vector of constants. k is a lag structure, while ε_t is a p x 1 vector of white noise error term. Γ_j is a p x p matrix that represents short-term adjustments among variables across p equations at the *j*th lag. β' is a p x r matrix of cointegrating vectors, and Δ denotes first differences. α 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 cointegration analysis is meaningful when relevant data used in an empirical analysis are characterized by nonstationarity, an attempt is made in this paper 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, the variables in the maize model 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.

Since all relevant variables in Mexico's maize import demand function are integrated of order one, the use of OLS to estimate this function would lead to spurious results. 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 is used in Johansen's system approach of cointegration which 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 paper. The results presented in Table 3 suggest an appropriate lag-length to be 10. In view of monthly maize imports into 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,

$$Qc = -0.804Pc + 1.268Pmx + 0.582MXY + 0.631ER - 0.422VG + 0.420INV \quad .$$

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, in fact, easliticities. 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 variable will responds faster than any other variable to bring this system back to the long run equilibrium

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 it 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 normality test, while the null hypothesis

of normality of the disturbances is marginally rejected at the five percent level. 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 appears 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 exchange rate variable has an expected positive sign and is statistically

significant. This result 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 into Mexico.

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, 2004), the precise magnitude of this effect was not known prior to our analysis. In regards to seasonality, two seasonal 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 into Mexico. The lagged dependent variable becomes significant at six lags which implies 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

that considered the period of 1990 to 998 did not produced 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. This result reconfirms the presence of cointegrating vector in the system. The small coefficient of the ECT, however, suggests a slow adjustment towards the long-run equilibrium.

CONCLUDING REMARKS:

Mexico is an important NAFTA partner. The importance of trade in the Mexican economy has been growing since Mexico joined the GATT in 1986. The agri-food trade sector received an unprecedented boost in 1994 with the successful implementation of NAFTA. Fruits and vegetables exports to the United States and imports of grains from the US grew substantially. While this is great news, growing dependence on trade also makes the agri-food sector in Mexico more vulnerable to changes in exchange rate of Mexican peso relative to the U.S. dollar than in the past.

While the borders between Mexico and its important trade partners, the United States and Canada, 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 is yet to be performed to determine the relative contributions of these factors to the growth of Mexican agri-food trade. 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 into 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 drivers of maize imports into Mexico from the United States. The results show that growth in per capita income, changes in exchange rate, volatility of exchange rate and livestock sector all influence maize imports in the long-run. However, in the short-run, NAFTA is the most important driver of maize imported in Mexico from the United States.

While this article makes an important empirical contribution, two of its limitations need to be highlighted. While the error-correction model presented in this paper is satisfactory, it can only explain about 30% of the month-to-month variations in maize imports into Mexico. Clearly, a large portion of the total variation remains unexplained. Future research should attempt to improve the performance of such error-correction models. Finally, appropriate impulse response and variance decomposition analysis may shed additional lights to short-run dynamics of Mexican maize imports from the United States. This remains a fruitful area for future research.

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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
Pcd	Ps is the price of a substitute, the price of domestic maize in Mexico	Units	11971	10083
INV	INV is the inventory of hogs on feed in Mexico.	Million Units	6.74318	1.0968
ER	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	-0.2145	6	-2.325
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	-1.3456	6	-5.275

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

Table 3. Optimal Lag Length Selection for the Maize Model

Pair of Lag-Lengths Compared	NLAGS	Log Likelihood Value	Number of parameters	N*	Ml Test	LRm χ_d^2 (df=7) 5%	Test Result
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
** Denotes that once an optimal lag is achieved, no further testing 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 (β_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 (α_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 λ	Max λ (0.95)		
r = 0		165.420*	150.4	48.308	50.51		
r ≤ 1		117.110	117.49	41.113	44.37		
r ≤ 2		76.003	88.59	29.681	38.22		
r ≤ 3		46.321	63.66	25.141	31.99		
r ≤ 4		21.179	42.7	16.521	25.68		
r ≤ 5		46.581	25.64	4.027	19.21		
r ≤ 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
PCO t-4	-0.138	-2.202
PMX 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
R2	0.319	
R2 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**
Instability Test:		
Variance	0.233	0.353
Joint	4.082	3.690
L.M Statistic	29.059	35.172*

* Denotes the critical value of chi-squared with 23 degrees of freedom.
** Denotes the critical value of chi-squared with two degrees of freedom.