SPATIAL INTEGRATION OF MEXICO AND UNITED STATES IN GRAIN MARKET: THE CASE OF MAIZE, WHEAT AND SORGHUM

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ABSTRACT

Based on agricultural trade liberalization that the Mexican governments began to implement in early 1990s and increasing agricultural trade flows in North America, in this paper we show empirically that trade liberalization between Mexico and United States (U.S.) under the North American Free Trade Agreement (NAFTA) has implied structural change in prices received by Mexican producers of maize, sorghum and wheat, and that this has been accompanied by price convergence with U.S. prices of these crops.

Using data on Mexico and U.S. prices from 1981 to 2010, the study provides evidence that trade liberalization has led to greater integration of Mexico-U.S. agricultural markets, specifically of the three major food-crops produced in Mexico, evidenced by the existence of a long-term relationship between the price series analyzed, greater flows of trade, and an increase in the speed of adjustment of domestic prices in response to changes in international prices.

Key words: markets, price convergence, structural change, grains.

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I. INTRODUCTION

Trade liberalization undertaken by Mexico began in 1986 with the accession of the country to the General Agreement on Tariffs and Trade (GATT), and deepened with the signing with Canada and the United States (U.S.) the North American Free Trade Agreement (NAFTA). NAFTA implementation began in January 1994, and complete agricultural trade liberalization was reached in 2008. NAFTA has promoted trade integration of markets in North America, reflected in a greater exchange of products. With respect to agriculture, imports of Mexico have raised continuously particularly that of grains and oilseeds since the 1990's. Mexico's agri-food exports have also increased, but at a lower phase, producing an agri-food trade deficit of 2.7 billion US dollars (USD) in 2009 (National Institute of Statistics, Geography and Informatics, INEGI website).

In Mexico, maize has remained as the most important agricultural products. In 2010 represented 51.3% of agricultural planted land and, from a total of about four million Mexican farmers, 80% of them produced during 2006-2009 between 20 and 24 million tons of the grain. In addition to maize, other major staple crops produced in the country are sorghum and wheat. Maize and these two grains accounted in 2010 for 68% of agricultural planted land and 46% of the value of total agricultural production in Mexico (Agricultural and Fisheries Information Services (SIAP) of the Mexican Ministry of Agriculture (SAGARPA), website). Maize, sorghum and wheat also stand out in agricultural imports by Mexico. In 2009, these three goods accounted for 30.2% of the value of Mexican agriculture imports. Maize is the most drastic case, whose imports increased from 1.7 million tons on average for 1990-1995, to 7.9 million tons for the period 2006-2010 (Economic Research Service (ERS), U.S. Department of Agriculture website).

An argument for signing the North American Free Trade Agreement (NAFTA) was that greater market integration would bring economic benefits, especially for consumers. In this point, economic theory predicts that market integration generates welfare gains for trade partners, because in addition to promote economic growth, it affects relative prices altering the distribution and location of economic activities towards the most efficient ones. However, in view of structural, functional and policy asymmetries between Mexican agricultural sector and those of the U.S, some authors have expressed serious concerns about the distribution of benefits from market integration under NAFTA (see for example Romero and Puyana, 2004).

Economic theory establishes that the continuous trade flows between two regions is a sufficient condition to speak of trade integration (Krugman and Osdtfeld, 2008). In this sense, Vollrath (2001) shows that the availability of goods and services has effectively increased among the NAFTA partners and that the movement toward a greater integration has formed a major agri-food market in the three countries, and even has improved the signal transmission of markets among countries, contributing to the efficiency of these markets.

The present study is related to Vollrath 's arguments, by studying if NAFTA has conducted to greater trade integration between Mexico and the U.S. in maize, sorghum and wheat markets, as expressed by increases in trade flows of these grains and better transmission of market signals.

In addition to the introduction this study was divided into five sections. The following one is a brief review of theoretical literature on the link between efficiency and market integration, as well as of the empirical evidence for the case of NAFTA. In section three the evolution of grain production and marketing in Mexico is analyzed, with emphasis on maize, sorghum and wheat. Section four is dedicated to present the methodology and data used for the empirical analysis of integration, and section five presents the econometric results about structural change and cointegration. We finish in section 6 with the main conclusions.

II. MARKET INTEGRATION AND EFFICIENCY

The definition, delimitation and functioning of a market has implications for the efficient allocation of goods and services, and for public policies. Therefore, the study of agricultural markets spatially separated has been a topic of great interest for decades to understand their implications for economic welfare (see, for example: Ardeni (1989); Baffes (1991); Barrett and Li (2002); McNew (1996); and Ravallion (1986)).

The theory used in studies of the integration of spatially separated markets of an homogeneous product is the equilibrium condition known as the Law of One Price (LOP), which guarantees the absence of arbitrage opportunities, and is needed for spatial efficiency (McNew, 1996). If this equilibrium condition is satisfied, it is possible to say that markets are integrated and price transmission is perfect. In this situation, the difference between prices is given purely for transaction costs between markets, which rarely occur due to the presence of market power, other type of transaction costs and strong government intervention, among others.

The response in the variation of a price to the change of another, whether of the same good or just an input to produce it, can be symmetrical or asymmetrical. The first type of price transmission occurs when the only difference between two markets (e.g. the world market and the domestic market) is in transfer costs. Instead, the asymmetry in price transmission often occurs from distortions introduced by the government, adjustment costs and type of market structure.

McNew distinguishes the concept of market integration from the concept of the Law of One Price (LOP), allowing him to establish that when two or more markets located in different places are integrated, the price transmission between them will be perfect. The lack of integration means that there is no mechanism by which the changes in the excess of demand can be transferred spatially and therefore the price changes are not transmitted.

Market integration and efficiency are two concepts often used together in empirical studies, but rarely have been defined and differentiated properly. Barrett (2001) argues that spatial integration can be studied and better reflected using trade data, while the efficiency is directly related to an equilibrium situation where price data are the most appropriate. In international trade, market integration necessarily implies the removal of trade barriers, so if there is a trade flow of a product between two regions, it is said that these are integrated as a single market. According to Barrett (2001), market integration represents the Walrasian transfer of excess demand from one market to another, for which prices do not necessarily have to be balanced. However, the existence of trade is a condition that does not involves equilibrium in the sense of trade theory as proposed by Enke-Samuelson-Takayama-Judge (ESTJ from now on). In this theory, prices, traded quantities, and transaction costs play an equally important role in evaluating the efficiency in the operation of international or regional markets (Barret, 2001).In this sense, continuous trade flows constitute an evidence of trade integration between two or more spatially separated regions (Doan et al., 2005). For the specific case of the products covered by this study, it is observed that Mexico's imports from the U.S. grew at an average annual rate of 17%, 12% and 11% for maize, wheat and sorghum respectively for the period 1995-2010 (Food and Agricultural Organization (FAO) website).

Mohantly and Langley (2003) examined the integration of grain markets between Canada and the U.S. using Cointegration and a Vector Error Correction Model (VECM). The relationship between prices was analyzed for four different subperiods in order to capture when trade agreements between these two countries affected trade flows, as well as the corresponding

prices. The influence of domestic policies was incorporated as a variable that influences the behavior of agricultural markets and prices of grains. Cointegration was found in the four subperiods, and the Canadian Free Trade Agreement improved integration of grain markets between Canada and the U.S. In addition, the authors found that the speed of adjustment to price exogenous changes was higher for the fourth subperiod.

Araujo (2009) estimated the cointegration between U.S. and Mexico maize prices using prices in supply centers. The methodology used allows the authors to estimate asymmetric price transmission, finding that prices in Mexico share a common long-term relationship with prices in the U.S.

Base on the LOP Dutoit, Hernandez and Urrutia (2009) studied the transmission of prices in international markets to domestic markets of Latin American countries for the period 1985-2008, trying to find out how international price movements are reflected in local producer prices, and how fast this phenomenon takes place. The results show that in the case of rice, the Central American market of the crop is related to the international market, a situation that can be explained by the influence this latter market have on Central America's main trading partner: the U.S. In Brazil, the producer and wholesale rice market is integrated with the markets of Argentina and Uruguay. This is consistent with the fact that imports from Brazil come mostly from these two countries.

III. CHARACTERISTICS OF THE GRAIN INDUSTRY IN MEXICO

The framework: reforms and new public institutions for the countryside

In 1986, Mexico joined the General Agreement of Trade and Tariffs (GATT) as a member, but continued protecting producers through its price support program to farmers producing "basic crops" (maize, wheat, sorghum, among other field crops) granted by the State Enterprise: The National Company of Popular Subsistence (CONASUPO, Spanish acronym), as well as by import licenses. Until the early 90s the Mexican government began to liberalize the agricultural sector of Mexico. Between 1990 and 1991, import controls and direct support to producers of basic crops, except for maize and beans, were eliminated. In addition, subsides for inputs, credit and agricultural insurance were drastically reduced (details in Yunez-Naude, 2003).

In 1991 the Agricultural Marketing Board (ASERCA) was created to replace the direct government intervention through CONASUPO. In order to avoid unfair external competition

caused, amongst others, by agricultural subsidies in the U.S. and by costs differences to transport basic crops produced in Mexico, ASERCA has been applying a system of ‘’indifference prices" for buyers of some of the domestically produced basic crops, including maize, sorghum and wheat. So, when the international (U.S.) price of a certain basic crop is lower than its domestic price at the domestic market of destination, an indifference price is set by ASERCA at a level that buyers of basic crops in Mexico would be indifferent between buying them to Mexican producers with surplus or import them. The subsidy is an income transfer that was granted first to buyers and from 2003 to date to producers. The scheme is called Target Income and is similar to deficiency payments applied, for example in the U.S. Due to the recent world-wide price increases of commodities, ASERCA has substituted its supports to domestic basic crop production from Target Income to risk management, mainly through supports for price coverage.

Three years after the creation of ASERCA, the government created the PROCAMPO, a major program of broad coverage of income supports to producers of basic crops. PROCAMPO is part of ASERCA, and started in 1993, just a few months before NAFTA came into operation. As opposed to Target Income, the program is decoupled from production. PROCAMPO is a pure income transfer program whose purpose was to support all farmers producing basic crop in three consecutive years before the beginning of NAFTA implementation. PROCAMPO was designed to operate from 1993 to 2008, i.e. during the transition period for reaching full liberalization under NAFTA. However, the administration of President Calderon has decided to extend it indefinitely.

Besides creating PROCAMPO and ASERCA, the administration of President Zedillo (1995-2000) created Alliance for the Countryside (*Alianza para el Campo* in Spanish) whose main goal was to increase agricultural productivity and capitalize producers by federal investment in rural and agricultural infrastructure (SAGARPA, 2004).

Notwithstanding that the administrations of Presidents Fox and Calderon (2001-2006 and 2007-2012 respectively) have done some modifications of agricultural policies, their market orientation has prevailed.

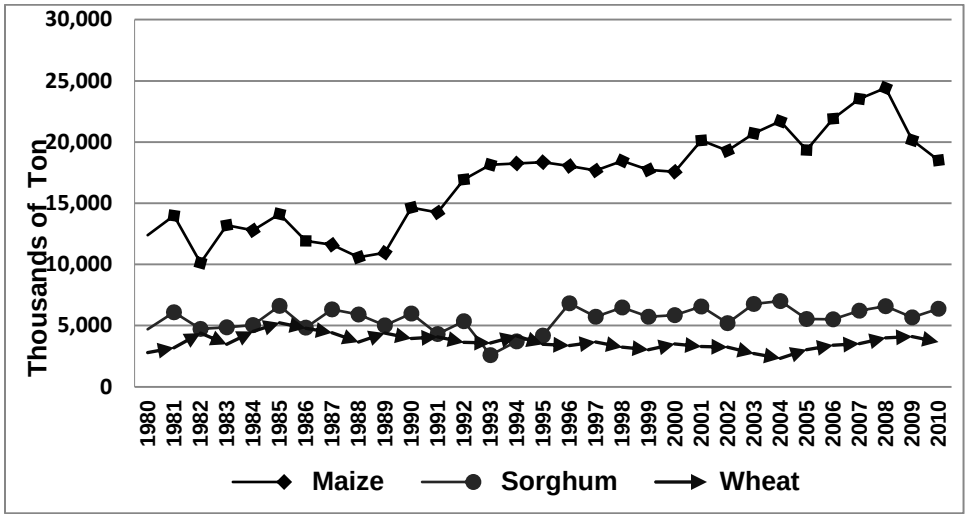
Since the beginning of the 1990s Mexico abolished import licensing for sensitive crops and processed foods. For the period of transition under NAFTA, Mexico introduced in January 1994 tariff rate quotas (TRQ) for maize, beans, barley and powder milk that were reduced yearly until January 2008, when agricultural trade between Canada, Mexico and the U.S. became fully liberalized. However, in years when Mexico imports of maize form the U.S. were higher that the

quota, no tariffs were charged. So, one can argue that maize form the U.S. has entered free to Mexico since 1994 (Yunez-Naude, A. 2011).

Production

Contrary to expectations that trade liberalization –NAFTA in particular—in agriculture would sharply reduce Mexico's production of non-competitive staple crops, domestic supply of some of them has increased since the beginning of NAFTA in 1994. For the case of the crops considered in this research, production of maize and sorghum has shown a tendency to increase, whereas that of wheat has remained with no major changes (Figure 1).

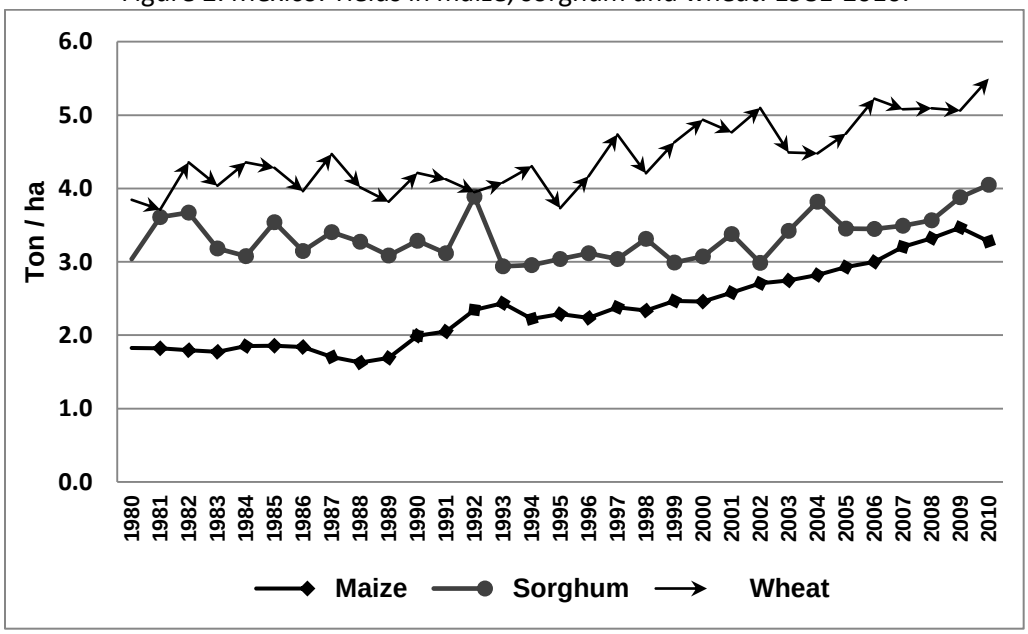
Figure 1. Mexico: Volume of production of main basic crops: 1981-2010.



Source: Author's elaboration with data from SIAP-SAGARPA website.

As Figure 2 shows, part of the explanation of these trends is the rise of yields. To this government income transfer to producers of basic–noncompetitive crops and marketing subsidies to commercial farmers provided by ASERCA must be added (see Yunez-Naude, 2011 and below).

Figure 2. Mexico. Yields in maize, sorghum and wheat: 1981-2010.



Source: Author's elaboration with data from SIAP-SAGARPA, 2010

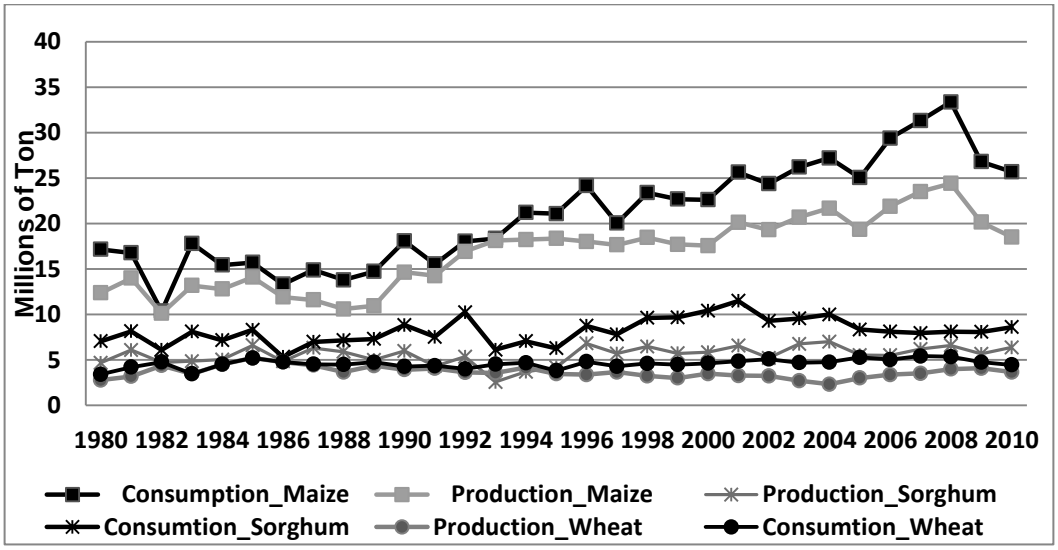
Apparent consumption

Domestic demand can be analyzed using the concept of apparent consumption, defined as the sum of net inventory, domestic production and imports, minus exports. This concept identifies the total availability of product for domestic consumption. In this interpretation, the existence of trade deficits indicates a higher growth rate of apparent consumption with respect to domestic production. For maize, the difference between domestic supply and apparent consumption has been increasing during the period of liberalization, rising from less than three million tons in the three-year period prior to 1995 to 7.9 million tons, on average, during 2001-2012. For sorghum and wheat, the difference between apparent consumption and domestic production increased during the first years of NAFTA, but for sorghum this difference experienced reductions during the last years (Figure 3).

The above is shown by the changes in "import dependency" (i.e. imports as a percentage of apparent consumption). For maize, the rate of import dependency has increased from 17% in the nineties to 27% in the period covering 2006 to 2010. The rate of dependency in sorghum had a significant decrease from 45% in the period 1990-1994 to 27% in the period 2006-2010. By contrast, for wheat, this rate increased from 13% in 1990-1994 to 47% in the period 2006-2010. If we consider FAO´s recommendation that, for food safety purposes, import dependency rate must not exceed 10%, the trends experienced by maize and wheat are worrisome. This is especially so if

we consider the rise and increasing volatility of international grain prices experienced during the last years, and if we add that these situations may remain in the future due to the promotion of biofuel production in food exporting countries such as the U.S., and the effects of climate change in agricultural production.

Figure 3. Mexico. Consumption and domestic production of maize, sorghum and wheat: 1981-2010.

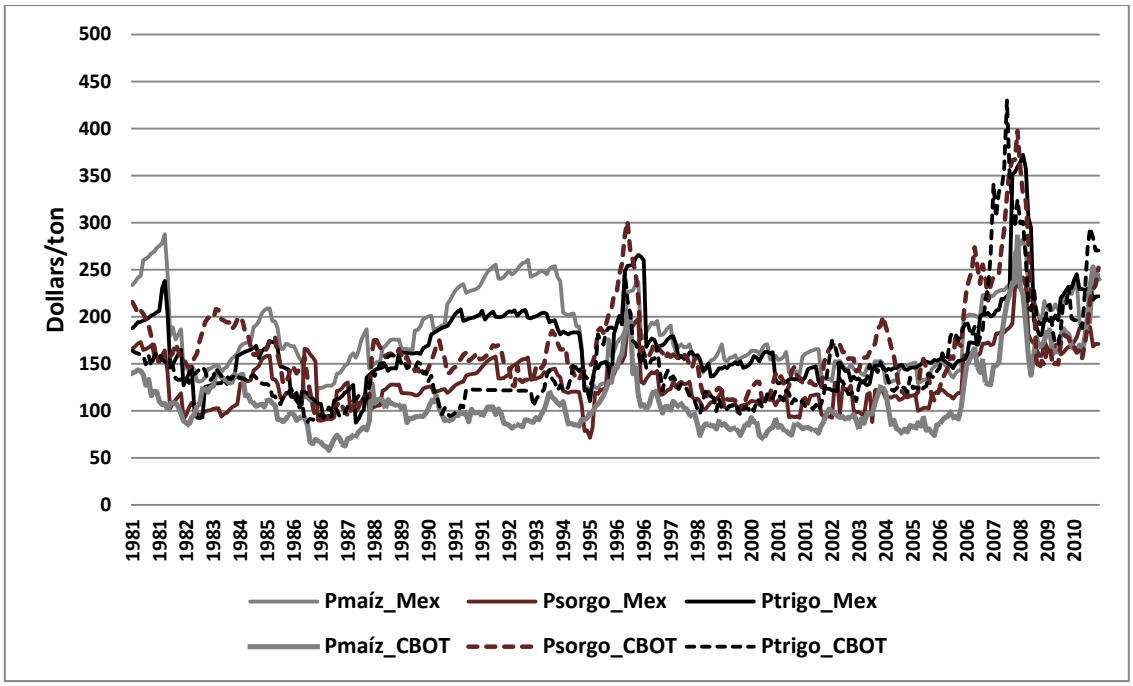


Source: Author's elaboration with data from SIAP-SAGARPA, 2010

Grain prices and marketing in Mexico

Price tendencies for the last 30 years show that, as expected, domestic prices of maize, sorghum and wheat have followed international prices more closely after NAFTA. This is especially so from 1996 onwards, once Mexico recovered from the macroeconomic crisis of 1994 (Figure 4). Figure 4 also shows that form this year to 2006, domestic and international prices dropped; a tendency that contrasts with the evolution of domestic production of maize, sorghum (and wheat to a lesser extent) during the same period. As well as yield increases experienced by production of these grains in Mexico, the reason is related to the relative market isolation of small farming maize producers and the subsidies granted by ASERCA to big commercial staple producers (Yunez-Naude, 2011).

Figure 4. Grain farm gate prices in Mexico and futures prices of the Chicago Board of Trade



Sources: Author's elaboration with data from SIAP-SAGARPA and CBOT 2011.

Staple crops marketing in Mexico faces difficulties particularly after the elimination of CONASUPO, due to problems associated with transaction costs arising, amongst others, from inadequate storage and marketing infrastructure sold or abandoned by CONASUPO, and because of a lack of marketing intelligence (ANEC, 2008). In addition, grain and oilseed imports of Mexico are controlled by large private companies since 1999, when CONASUPO was finally abolished. As well as being the major importers of maize, sorghum and wheat, these companies also purchase domestic production of these grains. This, together with the supports the U.S. government gives to its farmers, has meant that in order to promote domestic production and sales of these and other basic crops, the Mexican government has granted through ASERCA increasing subsidies to Mexican big commercial farmers and buyers.

IV. METHODOLOGY AND DATA

The speed and magnitude of a price response of a good in a region arising from a price movement of the same good in other region (i.e. price transmission) is associated with market efficiency, since fast and symmetrical responses commonly occur in efficient integrated markets. On the

contrary, asymmetric price transmission is associated with inefficient markets, with negative consequences to economic welfare.

There are different models reported in the literature for the analysis of market integration and price transmission. The best known are the switching regime model and the error correction model (VECM), and in this research we used the second approach.

The data used are monthly time series of prices for maize, sorghum and wheat, covering the period 1981-2010. The data for Mexico are producer prices, adjusted by the national producer price index, using official statistics from the Agricultural and Fisheries Information Service (SIAP) of Mexico's Ministry of Agriculture (SAGARPA) and from the Bank of Mexico (BM), respectively. For maize, U.S. futures prices of the Chicago Board of Trade (CBOT) were used for the months close to harvests in Mexico; i.e.: May for the autumn-winter harvest, and December for the spring-summer harvest. The source of future price series for sorghum and wheat is SIAP website and the Centre for the Study of Sustainable Rural Development of the Mexican Congress (CEDRSSA, Spanish acronym). U.S. future prices of grains are the most representative in the U.S. and worldwide of their dynamics. As a matter of fact, local and regional futures prices worldwide have the same direction than Chicago prices (Abbassian, 2006).

Using the price series data discussed above, the first set of estimations to conduct the study of spatial integration between Mexico and the U.S. in maize, sorghum and wheat markets is based on a unit root test using two approaches: the Augmented Dickey-Fuller (ADF) and the Phillips-Perron. Since with both tests the hypothesis of the presence of a unit root is not rejected, the conclusion is that the series are not stationary. [1]

Given this behavior, we applied the first difference of the logarithm of the variables and obtained the growth rate of the series, a stationary stochastic process, with which the direction of the trend was not altered and the order of data is maintained. Moreover, this transformation avoids distortions that might cause the units of measurement and multiplying by 100, the changes are measured in units of percentage changes (Hamilton, 1994).

When the parameters that determine a series are modified, we say that a structural change has occurred. In particular, if in a time series modeled by $Y_t = \alpha + \rho Y_{t-1} + e_t$ (where p <1), at least one of its parameters is modified (α, ρ, σ^2), there is a structural change that may affect model parameters: changes in α, would affect the mean and the trend of the series; changes in

[1] Results are available to the interested reader upon request to the authors.

ρ would reflect changes in the serial correlation of Y_t; and modifications in its variance involve changes in the volatility of the series.

Zivot and Andrews (1992) developed an endogenous test to identify structural change in the intercept, and/or trend of the series. The test is based on a sequential analysis of data and it uses the entire sample, using a *dummy* variable for each observation in the series that is evaluated as a possible break. This is identified when the t-statistic of an ADF is more negative, and so, if the ADF test shows evidence of stationarity of the series, the greater the probability of finding breaks. The values of the t-statistic of Zivot and Andrews have their own asymptotic theory and critical values, [2] and are more negative than those used in procedures that specify the date of structural change which conduct to more difficulty to reject the unit root hypothesis.

In addition of experiencing structural changes, the time series could present outliers leading to errors in the rejection of the null hypothesis of unit root. For this reason we also used a test to detect the presence of outliers in series with a unit root behavior. Vogelsang (1999) developed a test to capture sudden atypical values in the series. The null hypothesis of this test is the presence of unit root when the data have an additive outlier. An additive outlier is a temporary shock or a deviation in the dynamics of the data. Atypical values alter the component moving average (MA) in the series. [3] That is, the presence of outliers results in moving average errors with negative coefficients and these, in turn, result in oversized unit root tests. When the presence of outliers is not tackled, the tests use the Dickey-Fuller procedure, and when outliers are considered, a sequentially t-statistic is performed to determine the lag-length used in the Augmented Dickey Fuller.

V. RESULTS

The price series for maize, sorghum and wheat were analyzed with the econometric tests discussed in the previous section. We found that both Mexico and the U.S. prices of these crops show temporary shock and structural change in several periods (Table 1). Based on this dates of structural change, we divided the series in different periods to inquire if Purchasing Power Parity

[2] Zivot y Andrews (1992) offer both asymptotic critical values and small simple critical values.

[3] The process of a MA of first order is represented by $x_t=e_t+a_1e_{t-1}$, where x_t is a weighted average of e_t and e_{t-1} . If a process is MA (1), its values are defined by very recent external effects, i.e. by the current x_t and the previous x_{t-1}. The MA process has short memory and absorbs impacts very quietly.

(PPP) between the prices of Mexico and the United States of the three crops under study is observed.

Table 1. Unit root and structural change in price series, 1981-2010.

Serie	ADF	PHillips-Perron	temporary shock	Zandrews structural break
Maize México	I(1)	I(1)	2007; 2008	1995m5
Maize U.S.	I(1)	I(1)	2007; 2008	2006m5
Sorghum México	I(1)	I(1)	2008	1998m5
Sorghum U.S.	I(1)	I(1)	2007; 2008	1998m7
Wheat México	I(1)	I(1)	2008	1988m1
Wheat U.S.	I(1)	I(1)	2007; 2008	1997m5

Source: Authors elaboration

Purchasing Power Parity (PPP)

PPP theory states that goods should be sold at the same price paid in two spaces (countries for the present study). If p_t, p_t^* and s_t denote, respectively, the logarithm of the price of Mexico, the logarithm of the U.S. price and the logarithm of nominal exchange rate, the PPP requires that foreign prices in domestic currency, $z_t = p_t + s_t$ are cointegrated with domestic prices p_t. In other words, there is PPP in prices if $z_t = \beta_0 + \beta_1 p_\tau + \upsilon_\tau$, maintains a linear combination such that μ_t is stationary ($\upsilon_t = 0$) and $\beta_1 = 1$. The strict version of PPP would imply that $r_t = z_t - p_t$, should be zero in any period, which also means that the real exchange rate would not be affected over time. In this sense, r_t can be considered as a variable that reflects the real exchange rate. Nevertheless in practice, errors in measuring prices, transportation and transaction costs and differences in product quality, prevent that PPP is observed with accuracy in each period *t*. That is, under normal conditions r_t takes, usually, values different from zero. Consequently, a weak version of PPP hypothesis is that the variable r_t is stationary, notwithstanding the individual elements that define it (p_t, s_t and/or p_t^*) are all non-stationary.

The results of the PPP estimations are presented in Table 2, where the β_1 coefficients show that Mexico and the U.S. price series of the three crops under study are cointegrated.

Table 2. Cointegration results: Estimated results for β_1 coefficients

Periods	Maize	Sorghum	Wheat
1981:01 - 2010:12	0.3898 (10.92)		
1981:01 - 1994:05	0.3593 (3.85)		
1994:05 - 2006:05	0.2834 (5.13)		
2006:05 - 2010:12	0.4956 (9.23)		
1981:01 - 2010:12		0.5001 (14.42)	
1981:01 - 1998:05		0.3224 (5.73)	
1998:05 - 2006:10		0.1074 (1.94)	
2006:10 - 2010:12		0.2340 (5.40)	
1981:01 - 2010:12			0.4529 (7.25)
1981:01 - 1988:01			1.3999 (8.49)
1988:01 - 1997:05			-0.5163 (-3.20)
1997:05 - 2010:12			0.3211 (8.86)

Note: t-statistics in parenthesis
Source: own estimations.

Error correction model (ECM)

Given the existence of a long-run relationship between Mexico and the U.S. prices of maize, sorghum and wheat, we used an ECM to estimate the short and long-run relationship between them. The ECM is:

$$\Delta p_t = \alpha_1 + \alpha_2 \Delta z_t + \alpha_3 [p_{t-1} - \beta_0 - \beta_1 z_{t-1}] + \varepsilon_t \quad (1)$$

However, due to identification problems that arise with α_1, α_3 and β_0, the estimation was based on the following specification:

$$\Delta p_t = \alpha_1 + \alpha_2 \Delta f_t + \alpha_3 [p_{t-1} - \beta_1 z_{t-1}] + \varepsilon_t \qquad (2)$$

$f_t = S_t + P_t^*$ and $z_t = p_t + s_t$, where p_t, p_t^* and s_t denote, respectively, the logarithm of the price in Mexico, the logarithm of the U.S. price and the logarithm of the nominal exchange rate.

Under this methodological framework, the stationarity of the differential ($p_{t-1} - \beta_1 z_{t-1}$) implies the existence of an error correction mechanism, and therefore, α_2 must be significantly different from zero. In such models, α_2 can be interpreted as the transmission to the domestic price (p_t) derived from a change in the foreign price adjusted by the exchange rate (f_t) in the first period, an effect known as “short-run”. But the most important feature of the ECM model refers to the interpretation of the parameter α_3, as it accounts for how the difference between the domestic and the foreign prices, adjusted for exchange rate, is eliminated from one period to a later period, an effect known as "error correction" or "speed of adjustment."

In theory, short-term coefficient can take any value, but the value of the error correction must be between zero and two in absolute value. The closer is the last one to unity, the greater the speed of adjustment. A symmetric value with respect to the unit (e.g, 0.8 and 1.2) would indicate that the speed of adjustment is the same, but the path differs (monotonous for the first value of our example, and oscillatory for the second value). It is convenient to mention that long-term convergence requires, as necessary and sufficient condition, that α_3 is significantly different from zero (Baffes and Ajwad, 1997).

The usefulness of ECM model is that its parameters or a function of them have a direct interpretation in terms of the linkages between prices. In other words, the model helps to determine if the law of one price (LOP) of a particular good in markets located in different spaces holds, as well as to know how fast the price in one location adjusts to the price of the other location (for the present study, the Mexican producers´ price of maize, sorghum and wheat and the futures prices of the CBOT, respectively).

In our study of the LOP we included the following. If *n* is the period in which a percentage *k* of adjustment takes place, Baffes and Ajwad (1997) show that the cumulative adjustment in the period *n* is given by: $k = 1 - (1- \alpha_2)(1 - \alpha_3)^n$ This is captured by the following expression:

$$n = \frac{\log(1-k) - \log(1-\alpha_2)}{\log(1-\alpha_3)}$$

This expression can be interpreted as the number of periods required to reach a certain level of adjustment *k*.

The results of the application of this model are summarized in Table 3. The error term coefficient,α_3, is statistically different from zero in all cases. Hence, the results provide evidence of a long-term relationship between Mexico and the international prices of the grains under study.

Table 3. Short and long-run relationship between Mexico and U.S prices (CBOT)

Maize	**Num. of Obser-vations**	**α_2**	**α_3**	**Adjus-ted R^2**	**DW**	**% of adjustment in t=5**	**95% of adjust-ment**
1981:01-2010:12	360	0.076	-0.066	0.50	1,92	0.231	45.663
		(1.96)	(-3.86)				
1981:01-1994:05	161	0.012	-0.035	0.20	1,83	0.153	84.420
		(0.19)	(-1.97)				
1994:05-2006:05	144	0.008	-0.170	0.11	1.91	0.603	16.120
		(-0.12)	(-4.15)				
2006:05-2010:12	55	0.216	-0.302	0.30	1.98	0.799	8.876
		(2.50)	(-3.66)				
Sorghum							
1981:01-2010:12	360	0.152	-0.151	0.11	1.95	0.492	19.165
		(2.34)	(-5.81)				
1981:01-1998:05	209	0.191	-0.149	0.11	1.78	0.468	19.651
		(1.91)	(-4.14)				
1998:05-2006:10	101	0.054	-0.518	0.23	1.86	0.973	4.177
		(0.44)	(-5.41)				
2006:10-2010:12	50	0.111	-0.213	0.15	1.83	0.665	12.946
		(1.47)	(-2.43)				
Wheat							
1981:01-2010:12	360	0.033	-0.126	0.02	1.84	0.473	22.485
		(0.61)	(-2.38)				
1981:01-1988:01	205	-0.034	-0.092	0.07	1.85	0.404	30.682
		(-0.61)	(-2.47)				
1988:01-1997:05	173	0.017	0.05	0.05	1.70	0.298	61.746
		(-0.17)	(-2.32)				
1997:05-2010:12	163	0.042	-0.096	0.08	2.01	0.371	30.090
		(-0.77)	(-3.56)				

Note: t-values in parenthesis
Source: Own estimations.

For maize and for the whole period under study (1981 to 2010), the results indicate that if its price in Mexico was 1% higher than that of the U.S. in period one, then the price of the grain in Mexico will fall 0.066% in the next month. In addition, maize price in Mexico will take 45.7 periods to adjust to 95% of U.S. price. The cointegration between maize prices between the two countries is different before and after structural change. Before 1981-1994, the number of period needs for a 95% adjustment was 84.4, and after (i.e. 1994-2006 and 2006-2010), the price adjustment period showed a drastic reduction: to 16.1 and to 8.8 respectively (last column of Table 3). Similar results apply to sorghum and wheat. So, our results provide evidence of greater market integration between Mexico and the U.S. markets of three of Mexico´s major crops.

VI. CONCLUDING REMARKS

Agricultural trade liberalization undertaken by Mexico in the late 80s was deepened with the signing of NAFTA. In this paper we inquire if the later has conducted to enhance market integration between Mexico and the U.S. (by much, Mexico´s major trade partner) in maize, sorghum and wheat through price transmission. The study provides evidence that NAFTA has led to greater integration of agricultural markets of these major food staples in Mexico. This is shown empirically by the existence of a long-term relationship between Mexico and U.S. price series of these crops and by the result of an increase in the speed of adjustment of farm gate prices in Mexico in response to changes in international prices.

In addition, Mexico´s imports of maize, sorghum and wheat (as well as other grains and oilseeds) has increased since the beginning of NAFTA implementation. However, domestic production of maize and sorghum grew during the period of low international prices (from mid 1990s to 2006), and that of wheat did not decreased sharply. This can be explained in part by increases in yields and by the supports the Mexican government has granted to commercial farmers of these three crops. For the case of maize –the main staple for human consumption in Mexico--, small subsistence production relatively isolated from the market is another reason explaining the prevalence of its domestic cultivation (Dyer, *et. al.* (2005) and Dyer and Taylor (2011)).This later phenomenon indicates that trade and domestic liberalization are not a sufficient conditions for economic agents in emerging and less developed economies to follow market signals.

Consumption of maize, sorghum and wheat in Mexico increased from 1996 to 2007; i.e. after the macroeconomic crisis Mexico suffered during 1994/5 until the growth of international

grain prices. This, together with the observed increase of Mexico food import dependency, the rise of poverty since 2008 [4] and the nature of agricultural policies, asks for a revision of government interventions in agriculture. That is, a reorientation of agricultural policies in Mexico is required in order to transit from the current interventions, regressive and based mainly on the provision of private goods (e.g. income transfers to big commercial farmers and marketing and processing enterprises, see Scott, 2010), to the provision of public goods. We are referring, amongst others, to public investment in rural transport and communications, and in research, development and application of adequate technologies for the agro-ecological conditions of Mexico and for dealing with the effects of climate change.

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