Spatial Integration of Mexico-U.S. Grain Markets: The Case of Maize, Wheat and Sorghum

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▪ **Abstract:** The Mexican government embarked on agricultural trade liberalization in the 1990s, and agricultural trade flows in North America increased. Based on data on Mexico and United States of America (U.S.) prices of maize, sorghum and wheat from 1981 to 2010 we show that trade liberalization between Mexico and the U.S. under the North American Free Trade Agreement (NAFTA) resulted in a structural change in prices received by Mexican producers of these crops. We found that this change coincides with convergence with U.S. prices of maize, sorghum and wheat in Mexico food consumption. Hence, the study provides evidence that trade liberalization led to greater integration of Mexico-U.S. agricultural markets. We also shown that for the three studied crops, there is a long-term relationship between their price series and an increase in the speed of adjustment of domestic prices in response to changes in international/U.S. prices.

▪ **Keywords:** grain markets; price convergence; structural change.
▪ **JEL classification:** Q17.

▪ **Resumen.** El gobierno mexicano profundizó la liberalización del comercio agrícola en los 1990 y ello condujo al aumento en los flujos de comercio de granos en América del Norte. Utilizando datos de precios de México e internacionales para el maíz, sorgo y trigo, de 1981 a 2010, mostramos que el comercio entre México y los Estados Unidos de América (EUA) bajo el Tratado de Libre Comercio de América del Norte (TLCAN) ha implicado cambio estructural en los precios recibidos por los productores mexicanos de estos granos, y que esto ha estado acompañado por la convergencia con sus precios internacionales. Se muestra evidencia que la liberalización condujo a mayor integración de los mercados agrícolas y que hay una relación

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a largo plazo entre las series de precios, y un aumento en la velocidad de ajuste de los precios internos del maíz, sorgo y trigo en respuesta a cambios en los precios internacionales.

- **Palabras clave:** mercado de cereales, convergencia de precios, cambio estructural.
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Introduction

Mexico's trade liberalization began in 1986 with the country's accession to the General Agreement on Tariffs and Trade (GATT), but it continued protecting producers through its price support program for "basic crops" (maize, wheat, sorghum, among other field crops). This program was administered by a state enterprise, the National Company of Popular Subsistence (Spanish acronym: CONASUPO), as well as by way of the issuance of import licenses. Import controls and direct support to producers of basic crops, except for maize and beans, were eliminated between 1990 and 1991, and subsidies for inputs, credit and agricultural insurance were drastically reduced (see Yunez-Naude, 2003).

In 1991 the Agricultural Marketing Board (ASERCA) was created to replace direct government intervention through CONASUPO. In order to avoid unfair external competition caused, among other things, by agricultural subsidies in the United States and transportation cost differences between the two countries, ASERCA applied a system of ''indifference prices" for buyers of some of domestically produced basic crops, including maize, sorghum and wheat. ASERCA has shifted its support for domestic basic crop production from target income to risk management through "Price hedges" operated with futures market instruments, essentially through future options.

Government created PROCAMPO in 1993, a major program with broad coverage of income supports to producers of basic crops. In contrast to Target Income, the program is decoupled from production. It 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's implementation. PROCAMPO was designed to operate from 1993 to 2008, i.e., during a transition period towards full liberalization of agricultural markets under NAFTA. However, the administration of President Calderon decided to extend it indefinitely.

At the beginning of the 1990s Mexico abolished import licensing for sensitive crops and processed foods. In January 1994, during the period of transition under NAFTA, Mexico introduced tariff rate quotas (TRQ) for maize, beans, barley and powder milk. These were reduced yearly until January 2008, when agricultural trade between Canada, Mexico and the United States became fully liberalized. However, under the TRQ, in years when Mexican imports of maize form the United States were higher that the quota, no tariffs were charged. Thus, one can argue that U.S. maize has entered Mexico freely since 1994 (Yunez-Naude, 2011).

Contrary to expectations that agricultural trade liberalization and NAFTA in particular, would sharply reduce Mexico's production of non-competitive staple crops, domestic supply of some staples has increased since the beginning of NAFTA in 1994. Production of both maize and sorghum has trended upward; whereas wheat production has remained fairly stable (Table 1).

In Mexico, maize has remained the most important agricultural product. In 2010 it represented 51.3% of cultivated land and, among a total of about four million farmers, 80% of them produced between 20 and 24 million tons of the grain annually during 2006-2009. In addition to maize, other major staple crops produced in the country are sorghum and wheat. Maize and these two grains accounted for 68% of agricultural planted land and 46% of the value of total agricultural production in Mexico (Agricultural and Fisheries Information Services (SIAP) web site).

In 2010, maize, sorghum and wheat accounted for 31.6% of total imports. Maize shows the most marked increase; imports of maize jumped from 1.7 million tons on average in 1990-1995 to 7.9 million tons in the period 2006-2010 (Economic Research Service (ERS), 2012). Part of the explanation for these trends is a rise in crop yields, particularly on irrigated land. In the case of maize, yield rose from 1.8 to 3.2 ton/ha during the analyzed period, while sorghum and wheat grew from 3.4 and 4.1 to 3.7 and 5.2 ton/ha respectively. Government income transfers to producers of noncompetitive basic crops and ASERCA's marketing subsidies to commercial farmers also had an effect (see Yunez-Naude, 2011).

Table 1
Production, consumption and imports of Maize, Sorghum and Wheat in México

	Production (Thousand ton)			*Imports (thousand ton)*		
Period	*Maize*	*Sorghum*	*Wheat*	*Maize*	*Sorghum*	*Wheat*
1981-1985	12837.6	5461.5	4153.5	2380.2	2104.5	287.1
1986-1990	11939.4	5605.4	4231.1	3023.1	1521.3	337.1
1991-1995	17179.0	4022.6	3776.6	1703.0	3433.0	611.3
1996-2000	17879.6	6111.7	3356.2	4792.1	3148.2	1524.3
2001-2005	20231.6	6212.1	2912.8	5504.8	3527.5	2475.9
2006-2010	21693.4	6071.1	3726.4	7914.7	2104.2	2342.5

	Yield (ton/ha)			*Consumption (thousand ton)*		
Period	*Maize*	*Sorghum*	*Wheat*	*Maize*	*Sorghum*	*Wheat*
1981-1985	1.8224	3.4188	4.1506	15217.8	7566.0	4440.6
1986-1990	1.7726	3.241	4.0976	14962.4	7126.3	4567.7
1991-1995	2.2702	3.1896	4.0394	18845.0	7447.3	4283.9
1996-2000	2.3778	3.108	4.5362	22578.7	9259.3	4566.5
2001-2005	2.758	3.4136	4.7174	25688.7	9739.6	4937.6
2006-2010	3.2554	3.6892	5.1938	29312.4	8175.3	5002.9

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

Domestic and international Price trends show that, as expected, domestic prices of maize, sorghum, and wheat followed international prices more closely after NAFTA. This is especially true from 1996 onwards, once Mexico recovered from the macroeconomic crisis of 1994. It can be seen that domestic and international prices dropped from 1996 to 2006, a tendency that contrasts with the evolution of domestic production of maize, sorghum, and (to a lesser extent) wheat during the same period (SIAP-SAGARPA, 2012). This combination of falling prices and rising production is related to yield increases as well as the relative market isolation of small maize producers and the subsidies granted by ASERCA to big commercial staple producers (Yunez-Naude, 2011).

An argument for signing the North American Free Trade Agreement (NAFTA) was that greater market integration would bring economic benefits to both producers and consumers. Economic theory predicts that market integration generates welfare gains for trade partners, because in addition to promoting economic growth, it affects relative prices and alters the distribution and location of economic activities towards a more efficient outcome. However, in view of structural, functional and policy asymmetries between Mexican and U.S. agriculture, some authors have expressed concerns about the distribution of benefits from market integration under NAFTA (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 Obstfeld, 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 towards greater integration has formed a major agri-food market in the three countries and improved the transmission of market signals among countries, contributing to the efficiency of these markets.

The definition, delimitation and functioning of a market has implications for the efficient allocation of goods and services as well as for public policies. Therefore, the study of spatially separated agricultural markets has been a topic of great interest for decades, with an emphasis on understanding the implications for economic welfare (Baffes, 1991; Barrett and Li, 2002; McNew, 1996).

The theory used in studies of the integration of spatially separated markets of a homogeneous product is the equilibrium condition known as the Law of One Price (LOP), which guarantees the absence of arbitrage opportunities; it is required 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 consists purely of transaction costs between markets. This rarely occurs, due to the presence of market power, other types of transaction costs, strong government intervention, and other intervening variables.

In this context, the study of market integration of Mexican and International grain market is relevant as grain producers could benefit from spatial arbitrage and that income of these producers could be enhanced with expanded opportunities and incentives for them to intensify their production and trade of grains. The fact that the speed of adjustment improved over time means that producers and traders can take more efficient decisions McNew (1996) 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. A lack of integration means that there is no mechanism by which changes in excess demand can be transferred spatially, and therefore price changes are not transmitted across markets. Barrett (2001) argues that spatial integration can be studied using trade data, while efficiency is directly related to an equilibrium situation for which the analysis of price data is more 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 the regions are integrated as a single market (Barrett, 2001). Continuous trade flows constitute evidence of trade integration between two or more spatially separated regions (Doan et al., 2005). Mexico's imports of maize, wheat and sorghum from the U.S. grew at average annual rates of 17%, 12% and 11%, respectively, during the period 1995-2010 (Food and Agricultural Organization (FAO) website).

For the case of Mexico, Araujo (2009) estimated the cointegration between U.S. and Mexico maize prices using prices in supply centers. The methodology used allowed the authors to estimate asymmetric price transmission. They found that prices in Mexico share a common long-term relationship with prices in the United States.

In our empirical research, we put special attention in studying if price convergence between Mexico and U.S. prices of maize, sorghum and wheat coincides with domestic reforms in Mexico and NAFTA and if during the period domestic prices of these crops experienced structural change. The study of price convergence and structural change of producer prices of three of the major crops for Mexico is relevant because its results help to provide evidence of a fundamental expectation about the effects of domestic agricultural reforms and NAFTA; namely, that these policy changes would lead to the establishment of what we call the Law of One Price.

Price equalization between countries has several effects; standing out increasing international competition and with it, efficiency gains in production. For the case of foods as the studied crops, to efficiency gains, price convergence has impacts on food consumption. In this later respect, convergence between Mexican and U.S. prices of the studied crops would benefit Mexican consumers when international prices decrease and would suffer when these prices rise. [4]

The hypothesis of this research is that Trade Liberalization has led to greater trade integration between Mexico and the United States in maize, sorghum and wheat markets, as reflected in increased trade flows of these grains and improved transmission of market signals. So, the objective is to estimate the degree at which Trade Liberalization has led to greater trade integration between Mexico and the United States in maize, sorghum and wheat markets.

■ *Methodology and data*

The speed and magnitude of a good's price response in one region to a change in price of the same good in other region (i.e., price transmission) depends on market efficiency. Fast and symmetric responses occur in efficient and integrated markets. In contrast, inefficient markets are characterized by limited and asymmetric price transmission, with negative consequences to economic welfare. Different modeling approaches to analyzing market integration and price transmission appear in the literature. The best known is the Vector Error Correction Model (VECM).

The usefulness of the VECM model is that its parameters, or a function of them, have a direct interpretation in terms of the linkages between prices; that is: the model determines if the LOP holds for a particular good in markets located in different spaces, as well as to estimate how fast the price in one location adjusts to the price in other location (for the present study, the Mexican producers' price of maize, sorghum and wheat and the futures prices from the Chicago Board of Trade (CBOT), respectively).

[4] For example, price convergence and the international maize and wheat price surge during 2006-2007 could be phenomena explaining the increase in poverty index experienced in Mexico during 2008 (Yunez-Naude, 2013).

The data we use 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 from the 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 futures price series for sorghum and wheat is the SIAP website and the Centre for the Study of Sustainable Rural Development of the Mexican Congress (CEDRSSA, Spanish acronym). CBOT prices are the most representative of U.S. and worldwide commodity price dynamics. As a matter of fact, local and regional futures prices worldwide follow Chicago prices (Abbassian, 2006).

Using the price series data discussed above, we study spatial integration between Mexico and the United States in maize, sorghum and wheat markets first by conducting unit root tests following two approaches: the Augmented Dickey-Fuller (ADF) and Phillips-Perron. Under both tests the hypothesis of the presence of a unit root is not rejected, at 95% of confidence; thus, we conclude that the series are not stationary.[5]

Given this result, 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 maintained. This transformation avoids distortions that might cause the original units of measurement and multiplying by 100, the changes are measured in percentages (Hamilton and Susmel 1994).

When parameters that determine series shift we say that structural change has occurred. Specifically, there is a structural change if, in a time series modeled by $Y_t = \alpha + \rho Y_{t-1} + e_t$ (where p <1), at least one parameter (α, ρ, σ^2) changes. Changes in α affect the mean and trend of the series; changes in ρ imply changes in serial correlation of Y_t; and modifications in variance involve changes in the volatility of the series.

Andrews and Zivot (1992) developed an endogenous test to identify structural change in the intercept and/or trend of the series. This test, in this research, was based on a sequential analysis of data, and it used the entire sample, with a *dummy* variable for each observation in the series that is evaluated as a possible structural break. It is identified when the t-statistic of an ADF is more negative; thus, if the ADF test shows evidence of stationarity in the series, the probability of finding breaks is greater. The Zivot-Andrews t-statistics have their own asymptotic theory and critical values. They are more negative than those used in procedures that specify the date of structural change, which makes it more difficult to reject the unit root hypothesis.[6]

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[5] The whole set of STATA output is available to interested readers upon request.

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

Purchasing Power Parity (PPP)
PPP theory states that goods should be sold at the same price in two spaces (countries, in the present study). If p_t, p_t^* and s_t denote, respectively, the logarithm of the Mexican price, the logarithm of the U.S. price, and the logarithm of the nominal exchange rate, 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 $z_t = \beta_0 + \beta_1 p_t + \upsilon_t$, maintains a linear combination such that υ_t is stationary $\upsilon_t = 0$ y $\beta_1 = 0$. The strict version of PPP would imply that $r_t = z_t - p_t = 0$ in any period, which also means that the real exchange rate is not 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 measurement of prices, transportation costs, and transaction costs and differences in product quality prevent the PPP from being observed with accuracy in each period *t*. That is, under normal conditions r_t takes on values different from zero. Consequently, a weak version of the PPP hypothesis is that the variable r_t is stationary, notwithstanding that the individual elements that define it (p_t, s_t and/or p_t^*) are all non-stationary. Based on this theory, the long run relationship between price series in Mexico and those of the United States was estimated.

Error Correction Model (ECM)
We used an ECM to estimate the short and long-run relationship between Mexican and U.S. prices of maize, sorghum and wheat. The ECM is:

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

However, due to identification problems that arise with regard to α1, α3 and β0, the estimation was based on the following specification:

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

$f_t = s_t + p_t^*$ 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) of 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 α3, as it accounts for how the difference between the domestic and the foreign prices, adjusted for the exchange rate, is eliminated from one period to a later period, an effect known as "error correction" or "speed of adjustment."

In theory the short-term coefficient can take on any value, but the value of the error correction must be between zero and two in absolute value. The closer the error correction is 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 a necessary and sufficient condition, that α_3 is significantly different from zero (Baffes and Ajwad, 1998). In this study of the LOP, it was included the following: If n is the period in which a percentage k of adjustment takes place, Baffes and Ajwad (1998) show that the cumulative adjustment in period n is given by: $k=1-(1-\alpha_2)(1-\alpha_3)^n$. This is captured by the following expression:

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

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

■ *Results and discussion*

The price series for maize, sorghum and wheat were analyzed with the econometric tests described in the previous section. First, under ADF and PP, the hypothesis of the presence of a unit root is not rejected, at 95% of confidence for maize and wheat series, and at 1% for sorghum (Table 2). Thus, we conclude that the series are not stationary. Second, we found that both Mexican and U.S. prices of these crops show evidence of structural change in several periods (Table 2). Based on the dates at which structural change occurs, we divided the series into different periods to investigate whether PPP between the Mexican and U.S. prices of the three crops occurred. Under both tests the hypothesis of the presence of a unit root is not rejected, at 95% of confidence; thus, we conclude that the series are not stationary.

Table 2
Unit root and structural change in price series, 1981-2010

Serie	ADF test	Phillips-Perron test	Zandrews structural break
Maize in México	-2.682	-2.911	1994m5
Maize in U.S.	-2.313	-2.599	2006m5
Sorghum in México	-3.941	-3.960	1998m5

Serie	ADF test	Phillips-Perron test	Zandrews structural break
Sorghum in U.S.	-2.568	-3.388	1998m7
Wheat in México	-2.470	-2.755	1988m1
Wheat in U.S.	-2.516	-2.669	1997m5

Source: Author estimates.

The results of the estimation of equation 2 are summarized in Table 3. The error term coefficient, α3, is statistically different from zero in all cases. Hence, the results provide evidence of a long-term relationship between Mexican and international prices (CBOT) for the grains under study.

To be confident on the estimated results, the assumptions on the model were tested. The Portmanteau test (Proposed by Box and Pierce) indicates that we do not reject the null hypothesis of white noise (the probability of Chi2 = 0.329). On the presence of heterocedasticity, the results of the Breusch-Pagan test shows that we do not reject the hypothesis of constant variance (Prob≥0.0743) at 5% significance level. Dickey-Fuller and Phillips-Perron tests showed that the series are integrated of order 1. This fact indirectly shows the linearity of the series, since those, at the first difference, are stationary series (constant mean and variance).

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

	Number Observations	α_2	α_3	Adjusted R^2	DW*	% of adjustment in t=5	95% of adjustment
Maize							
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)				

	Number Observations	α_2	α_3	Adjusted R^2	DW*	% of adjustment in t=5	95% of adjustment
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. *DW account for Durbin-Watson statistic .
Source: Authors' estimates.

Over the whole period under study (1981 to 2010), the results indicate that if the Mexican maize price is 1% higher than the U.S. price in one period, it will fall by 0.066% in the next period. After a shock, the maize price in Mexico takes 45.7 periods to adjust 95% of the way to the U.S. price. The cointegration of maize prices between the two countries is different before and after structural change. Before 1981-1994, the time to 95% adjustment was 84.4, and after (i.e., 1994-2006 and 2006-2010), it fell to 16.1 and 8.8, respectively (Table 3).

In the case of sorghum, from 1981 to 1998 the price adjustment takes 19 periods, while from 1998 to 2006 the adjustment occurs in 4 periods. However, after 2006, prices adjust in 12 periods. In the case of wheat, our results show a decrease in the percentage adjustment in 1988-1997 compared to 1981-1988, as well as a rise in adjustment time. However, these trends are reversed in 1997-2010. Overall, then, our results provide evidence of greater market integration between Mexican and U.S. markets for maize, partial integration for sorghum, but no change for wheat.

The effect of agricultural trade liberalization on the Mexican agricultural sector is very difficult to isolate because of the macroeconomic effects that the U.S. economy has on Mexico. For example, according to Garcia and Williams (2004), Mexican maize production is sensitive to the exchange rate and trade policies of Mexico's northern neighbor. Sarker and Jaramillo (2007) reported that imports of maize and sorghum are negatively affected by the volatility of the bilateral Mexico-United States exchange rate, and that NAFTA significantly increased Mexico's maize imports.

The specific contribution of this research is to show empirically that trade liberalization led to greater integration of Mexico-U.S. agricultural markets. We also shown that for the three studied crops, there is a long-term relationship between their price series, greater flows of trade, and an increase in the speed of adjustment of domestic prices in response to changes in international/U.S. prices, implying increased integration of these markets. Our results point in the same direction as those reported by Yunez and Barceinas (2004) and Fiess and Lederman (2004), who found evidence of increased speed of adjustment. Their findings indicated that NAFTA did not significantly influence the behavior of domestic prices; instead, this behavior reflected a long-term trend prior to the trade agreement.

The implications of the results are that grain producers could benefit from spatial arbitrage and that income of these producers could be enhanced with expanded opportunities and incentives for them to intensify their production and trade of grains. The fact that the speed of adjustment improved over time means that producers and traders can take more efficient decisions. Finally, in the case of upward price movements, like those of 2007-2009, Mexican consumers in the grain supply chain are affected negatively (processor and final consumers) but primary producers could benefit. However, imperfect transmission in some rural areas of Mexico remains due to a number of factors, including inadequate market information and marketing infrastructure leading to high transaction costs. This has prevented recent increases in U.S./world grain prices from benefiting all rural producers. Using an agent-based, applied general-equilibrium model to explore the impacts of world maize-price increases in rural Mexico, Dyer and Taylor (2011) conclude that subsistence rural household's activities allowed part of the agriculture of Mexico to absorb the shock, limiting the benefits of higher prices to rural producers.

■ *Concluding remarks*

Mexico's imports of maize, sorghum and wheat increased since NAFTA's implementation. Nevertheless, contrary to most expectations, domestic production of maize and sorghum grew during a period of low international prices from the mid-1990s to 2006, and production of wheat did not decrease sharply. As we showed in table 1, this can be explained, in part, by increases in yields, especially for maize.

Agricultural trade liberalization undertaken by Mexico in the late 1980s deepened with the signing of NAFTA. In this paper we test whether these policies enhanced market integration between Mexico and the United States, Mexico´s major trade partner in maize, sorghum, and wheat, by increasing price transmission. Our cointegration analysis finds evidence that NAFTA led to a greater integration of agricultural markets for these major food staples. This is shown empirically by the existence of a long-term relationship between Mexican and U.S. price series for these crops and by an increase in the speed of adjustment of farm gate prices in Mexico to changes in international prices.

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