

## COMPETITION AND PRICE TRANSMISSION IN THE PRODUCTION OF NOPAL IN MILPA ALTA, MEXICO CITY, AND TLALNEPANTLA, MORELOS

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### ABSTRACT

The objective of the study is to determine whether there are anticompetitive practices in nopal production between the producing zones of Tlalnepantla, Morelos, and Milpa Alta, Mexico City. The hypothesis is that the amounts of production in the production zones of Milpa Alta and Tlalnepantla determine the process of price formation in both markets. The procedures were vector autoregressive models (VAR) and vector error correction models (VECM) applied to two sub-periods, 2000-2005 and 2006-2017. The results indicate that symmetry in price transmission was modified considerably between both periods, that is, that the price coefficients and amounts from Morelos in the first model (0.54317 and -0.00602) indicate that the price ratio between producing zones was not symmetrical and that production from Morelos affected marginally the price formation process between zones. However, the parameters obtained in the models of the second period indicated a practically symmetrical ratio, with a coefficient of 0.980452 for prices from Morelos. Likewise, the coefficient of the amounts of production from Morelos went from marginal to considerable (-0.635184), which implies effects by the market power of one over the other.

**Keywords:** Milpa Alta, Tlalnepantla, vector autoregressive (VAR), price transmission, effects of the amounts of production on the prices.

### INTRODUCTION

Nopal production in Milpa Alta has been present since the beginning of the 1940s and this crop is characterized by being a perennial plant of 15 to 20 years that sprouts nearly all year long, has low water needs and low-cost production, which gives it a high potential for commercialization as food (Bonilla, 2014). Its seasonality and (limited) demand are preponderant factors when explaining the effects of competition on its prices.

During the season of high productivity, the amounts of production from the municipality in Morelos put pressure on the prices to decrease in both producing zones. On the contrary, the season of low productivity begins when climate conditions (frosts and hail storms) in Milpa Alta cause scarcity in this area. Despite this, it operates as a stimulus to increase prices in the two production zones, with the exception of the climate effects in Milpa Alta which do not affect plots in the municipalities of Morelos, primarily Tlalnepantla.

In general terms, these conditions generate differences in the production prices in Tlalnepantla and Milpa Alta; that is, the amounts associated to the producing zone in Morelos are lower than those in Milpa Alta, because the productivity of the first production area is higher than the second, since the high temperatures induce more new cladodes (nopalitos) than fruits

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(prickly pear); low temperatures (<20/15°C day/night) can suppress the second sprouting (Food and Agriculture Organization, FAO, 2018). This could be associated with the presence of anticompetitive conditions, that is to say that it is assumed that the production area in Tlalnepantla exerts market power on the neighboring production area.

Milpa Alta is located at an altitude between 2500 and 3000 meters above sea level (masl), while the plots in the producing municipalities of Morelos (Tlalnepantla and Totolapan, for example) are located at a lower altitude, between 2000 and 2500 masl. In turn, the mean annual temperature in the producing zone of Milpa Alta ranges from 10 to 12 °C, while for the case of Tlalnepantla and Totolapan, the predominant temperature is between 14 and 16 °C.

The economic literature does not identify superiority in the results of the commercial policy on the competition policy or vice versa, which is why it is generally recommended to evaluate the results of their interrelation, considering that their application ought to correspond to specific characteristics of each case (Abbott, 1998). Some results of the commercial policy cause distortions or generate undesired incentives between agents, for example, the redistribution of income in favor of certain groups of agricultural producers which operates against the maximization of the consumer's welfare.

Argüello (2005) indicates that when it comes to neighboring production zones, support measures for agricultural production (particularly in developed countries), climate characteristics and producers' forms of organization generate undesirable effects in other production sites. In this sense, the author highlights that it is possible for anticompetitive<sup>3</sup> behaviors to originate in a different jurisdiction, although their effects are felt in the domestic market. Witker (2003) also indicated that this type of practices have the aim of restricting or eliminating the competition through market manipulation, of a product or service, of a specific production line or productive chain.

In this sense, competition and free concurrence are essential for any market, including agrifood markets, to perform correctly because they function as basic incentives for producers. In this regard, the Federal Economic Competition Commission (*Comisión Federal de Competencia Económica*, COFECE, 2015) indicated that the reasons why there is a lack of competition and free concurrence in this sector are structural characteristics themselves (physical, technological, geographic, administrative, institutional restrictions, among others) and the possible behaviors of participants.

For Meyer (2004), there are two types of asymmetries in price transmission: the one referring to the magnitude and the one associated to the speed, although a combination of both is plausible. The first refers to the proportion of variation of the producer price,  $p^{in}$ , which is transmitted to the consumer price,  $p^{out}$ ; and the second one expresses the speed at which this variation transmits (periods of time).

According to this when the response magnitude to an increase is higher than the response magnitude to a decrease, there is positive asymmetry. In contrast, when the response magnitude to an increase is lower than the response magnitude to a decrease, there is negative asymmetry (COFECE, 2015).

The interpretation of this interrelation must consider both the origin and the destination of the initial variations, since they can be relationships between producers-traders, traders-final consumers, producers-other producers, or producers-final consumers.

The econometric estimation corroborated anticompetitive conditions between nopal producers from Morelos and Milpa Alta, since a considerable modification was confirmed in the symmetry of price transmission between producing zones by virtue of the entry of the municipalities of Morelos into nopal production, between 2004-2005. Thus, the main effect of the modification of the coefficient associated to the prices in the Morelos zone implies higher interrelation between the producing areas.

A greater interrelation between production areas implied other results that were manifested in effects of the production behavior in Tlalnepantla on the price structure of the producing zone in Mexico City. This means that the coefficient associated to the amounts of production from Morelos between the period 2000-2005 and the period 2006-2017 increased considerably.

#### **STRUCTURE OF MARKET COMPETITION IN THE NOPAL PRODUCING ZONES OF MILPA ALTA AND MORELOS**

During the first years of this century, the production levels of the producing zone of Tlalnepantla, Morelos, grew considerably as a result of the increase in the surface planted and harvested in this zone. The surface went from 1,459 hectares sown in 2000 to 3,895 in 2015, which caused a considerable reduction in prices, situation that is described in the next paragraph. However, this behavior was accentuated between the years 2004 and 2005 because growth rates were found of the production measured in tons of 241.6% and 50.5%, respectively.

These growth rates meant moving from producing nearly 60,000 tons of nopal in 2000 to 280,000 tons at the end of 2005, while in 2015 the municipalities in Morelos of Tepoztlán, Tlalnepantla, Totolapan, Tlayacapan, Amacuzac and Yautepec in the rural development district Zacatepec-Galeana, produced 352,483 tons of this vegetable. The result of this was that the prices in this producing zone were traded at \$2,493.00 per ton in 2000 and \$1,100.00 in 2006 (year when a decrease of 42% was found). In 2015, the ton was sold at \$1,568 per ton, which implied a reduction of 63% compared to the year 2000. In contrast, the production levels of the Milpa Alta zone in Mexico City have remained stable because at the beginning of this century 284,962 tons were produced annually with maximum records of 336,883 in 2012 and minimum in 2015 with 254,611 tons per year. The production from Morelos went from representing nearly 21% of what Mexico City produced in 2000 to almost reaching the same production levels since 2005 (Rodríguez, Delgadillo and Sánchez, 2021).

A virtual equivalency between productions was seen in 2008, since Mexico City showed 272,823 tons, while the producing municipalities from Morelos produced 273,138. Later, from 2009 to 2011, both productions experienced a transition process in terms

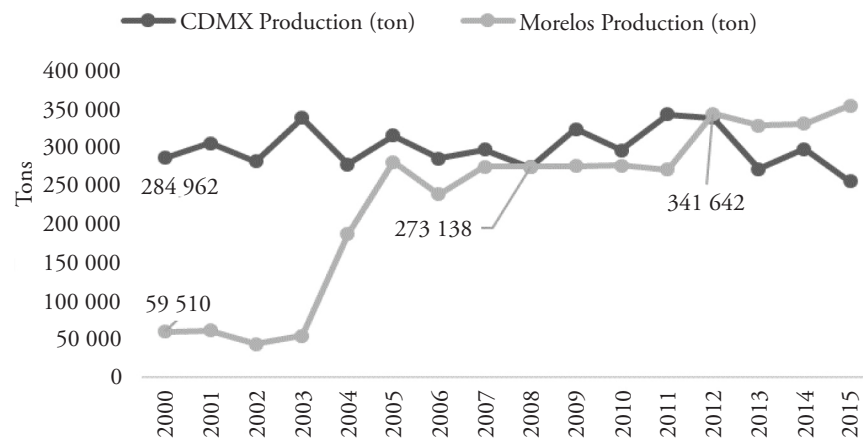
of the behavior of the production levels, since in 2012 the productions were equivalent again; however, this time it was to modify the production structure that prevailed at the beginning of the century (Figure 1).

In terms of market participation, production from the state of Morelos in 2000 only represented 20% of the joint production from both producing zone. For this analysis, both production levels were considered as the totality of production from the central region of the country, since the commercialization destinations of the harvests were and are the same. Then, this participation increased considerably, while that from Mexico City decreased. Later it was verified that the producing zone in Morelos overtook a large proportion of the market because in 2000 it barely had 17%.

Likewise, both participations were equivalent for the first time in 2008, although there was an increase from the zone of Milpa Alta and a decrease from the zone in Morelos. In 2012 the market participations became equal again, although the behavior of both participations was inverted since that year because the proportion of the Milpa Alta market went from 49.6% to 41.9% from 2012 to 2015, while that of Morelos increased from 50.3% to 58% in the same period, as is shown in Figure 2.

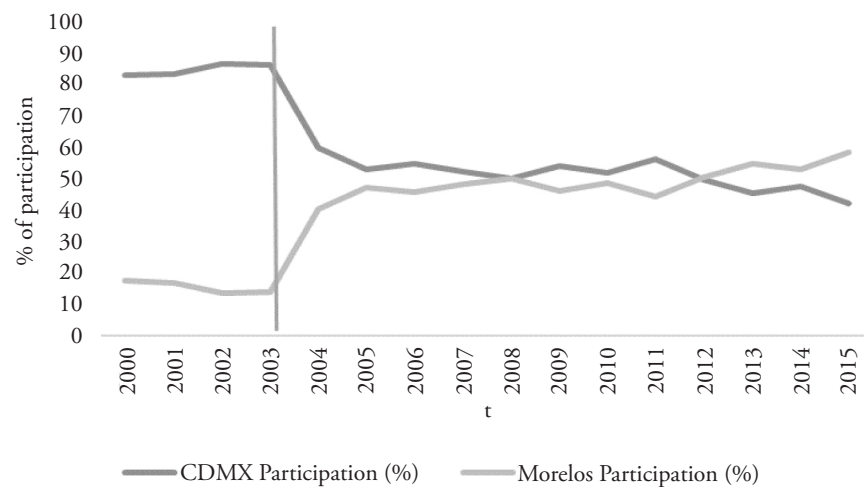
The critical point was experienced from 2003 to 2004 since the variation of participations was dramatic and because Mexico City went from having 86% of the market to almost 60%, while Morelos went from 14% in 2003 to 40% in the following year. Although there is statistical evidence (at the descriptive level) that dynamism in the production from Morelos affected the behavior of prices in both zones, its descriptive character only allowed making inferences regarding the interactions and causalities between the variables themselves. The results derived from the econometric exercise are presented next.

During the 16 years analyzed, the prices found in Milpa Alta presented the expected



Source: prepared by the authors based on the *Servicio de Información Agroalimentaria y Pesquera*, SIAP.

**Figure 1.** Behavior of the production from Morelos and Milpa Alta, 2000-2015.



Note: the production from Morelos includes the municipalities of Tepoztlán, Tlalnepantla, Totolapan, Tlayacapan, Amacuzac and Yautepec in the rural development district Zacatepec-Galeana.  
 Source: prepared by the authors based on SIAP.

**Figure 2.** Market participation of the production from Morelos and Milpa Alta, 2000-2015.

behavior which since with higher production from the producing zone in Morelos, the nopal price in Milpa Alta became lower. Thus, at the start of the period it is clear that while production from Morelos remained at levels of 40,000 to 60,000 tons per year, the prices per ton of the producing zone from Milpa Alta were around levels of \$2,730. However, when the production in Morelos increased, it affected negatively the prices of the producing zone of Mexico City for a decade (2003-2012), until, finally, during the years 2014 and 2015, the behavior that prevailed at the beginning of the century was completely inverted, since the production from the province continued increasing (to levels of 328,750 and 352,483 tons annually) and the price in Milpa Alta was reduced to \$1,784 per ton (2015).

Before the municipalities of Morelos produced nopal considerably, the speed of price transmission between both producing zones was low or moderate because commercialization in the province was done only locally and the low trade did not have any effect on the behavior of prices in Milpa Alta.

In fact, it is possible to state that the production from Morelos that was not consumed locally was traded in the Milpa Alta market without causing significant imbalances for local producers. Because of this, the estimation of the following models had the following objectives: to define the initial situation, where the only market for this crop was in Mexico City, and to quantify the modifications of the agricultural markets in both producing zones after the entry of the municipalities from Morelos to the production of nopal-vegetable. The results from this study are comparable with the error correction model that Feuerstein (2002) used to relate the production prices of green coffee and the retail prices in Germany.

Their results indicated that the changes in green coffee prices were completely transmitted to the prices in Germany in the long term, that is, that the adjustment was relatively slow and the transmission of variations in green coffee prices was asymmetrical. Likewise, Gómez and Castillo (2001) verified the hypothesis that the liberation of the global coffee trade in the 1990s generated market power for international wholesalers at the expense of the negotiation capacities of producing countries. Other authors such as Gómez and Koerner (2009) used an asymmetrical VECM to analyze the price transmission in the markets of the United States, France and Germany.

### METHODOLOGY

Detecting non-competitive behaviors in agricultural markets justifies the possibility of interventions (governmental) to regulate interrelationships between agents in a context of free trade. In the case of this study, we consider that productions from Tlalnepantla and from Milpa Alta are substitutes. This is so because in the consumption markets, and mainly in the Wholesale Market, it is not possible to differentiate between goods, which is why final consumers acquire both productions as if they were equal products, that is, of the Milpa Alta variety.

Authors such as Shepherd (2004), Tomek and Kaiser (2014), and Rapsomanikis, Hallam and Conforti (2004) recommend the use of temporal series and linear statistical estimations to model the behavior of the producer, since they are capable of capturing the systematic component of the prices through time. They are also adequate to contrast price levels, commercialization volumes (amounts of production), and transaction costs that evolve together, so the assumptions required *a priori* are minimal since they do not demand the use of specific functional forms.

According to this, for the estimation of the models that support this research, the starting point was the use of a vector autoregressive model (VAR). For Rudebush and Svensson (1999), VAR models are a tool used frequently to describe the dynamics of transmission mechanisms. This type of models is atheoretical because they are dynamic equation systems that examine the relationships between economic variables using a minimum of assumptions about the economy's structure (Bravo and García, 2002), and because of this, the coefficients do not have a clear interpretation.

The strategy used for the specification of the VAR model was defined as Shepherd (2004) did, analyzing the dynamics of price transmission during their formation in the nopal market of the producing zones of Milpa Alta and Tlalnepantla, Morelos. This allows reviewing the existence of asymmetry in the price transmission, since their impact in both zones is different when it comes from increases in prices from Milpa Alta, than when it results from decreases caused by high productivity, primarily from Morelos.

In addition to the review of price transmission, the econometric estimation evaluated the effect that the amounts exert on the prices. Hypothetical models were estimated that reflect the characteristics of the market before (2000-2005) and after the entry of the municipalities

from Morelos to the production of nopal (2006-2017). The objective was to determine, through the contrast of coefficients in both models, whether the activity of producers from Morelos exerts market power on that of Milpa Alta through amounts and prices.

In particular, the econometric estimation reviewed fundamental characteristics of price transmission, such as speed, direction, symmetry, and the effect that the amounts exert on the prices. The behaviors expected from the coefficients before the Morelos zone entered the nopal market are similar speed and completeness before and after. In terms of direction, during the first period of analysis it would be normal to consider that the prices and the amounts from Milpa Alta established the prices from both producing zones, given that this area was practically the only nopal producer in the region.

Regarding the symmetry between prices, before this occasion, a low or moderate behavior was predictable, while when Morelos entered as a producer that would equal production with Milpa Alta, the prediction corresponded to a more symmetrical transmission due to the higher interrelation between producing zones.

Finally, during the first period, the assumption is that it would be entirely normal for the amounts from Morelos not to affect, or only do so only marginally, the prices from both zones, although later it was expected that the amounts of production would affect considerably, and in function of the season, the process of price formation, both in Morelos and in Milpa Alta.

In this sense, the VAR model used four variables that were determined by their own contemporary interaction, by structural shocks and by the same delayed variables. This is because all the variables included in the VARs are considered as endogenous and this type of model only produces a representation of the data as shown in Equation 1. Therefore, it was necessary to resort to another modeling tool that allowed explaining the behavior of the variable of interest. The error correction model identifies the behavior of the variable of interest. The error correction model identifies certain long-term equilibrium relationships (cointegration vectors) that determine the behavior of some of the variables included in the VAR model.

$$\begin{aligned}
 PCDMX_t &= m_1 + a_{11}PCDMX_{t-1} + a_{12}QCDMX_{t-1} + a_{13}PMOR_{t-1} + a_{14}QMOR_{t-1} + \varepsilon_{1t} \\
 QCDMX_t &= m_2 + a_{21}PCDMX_{t-1} + a_{22}QCDMX_{t-1} + a_{23}PMOR_{t-1} + a_{24}QMOR_{t-1} + \varepsilon_{2t} \\
 PMOR_t &= m_3 + a_{31}PCDMX_{t-1} + a_{32}QCDMX_{t-1} + a_{33}PMOR_{t-1} + a_{34}QMOR_{t-1} + \varepsilon_{3t} \\
 QMOR_t &= m_4 + a_{41}PCDMX_{t-1} + a_{42}QCDMX_{t-1} + a_{43}PMOR_{t-1} + a_{44}QMOR_{t-1} + \varepsilon_{4t}
 \end{aligned} \tag{1}$$

where *PCDMX*: prices of the producing zone of Milpa Alta; *QCDMX*: production from the Milpa Alta zone; *PMOR*: prices of the producing zone of Morelos; *QMOR*: production from the Morelos zone

This equation system represents the model's solutions in the long term, although according to Hendry (1995), it is necessary to consider the continuous random shocks that an economic

system experiences, and which necessarily imply dynamic adjustments in the short term. This, in turn, can be specified with the Johansen procedure through the use of series in differences which are of the same order of integration and using the equivalency theorem between the cointegration vector and the mechanism of error correction to include the solutions in the long term and to avoid specification problems (Engle and Granger, 1987). In this case, the equation that is sought to be corroborated was the first, which is to say, that the price variable in the producing zone of Milpa Alta depends on the amounts of production from the entity itself, on the prices from the Morelos zone, and on its amounts of production; in addition, it should be influenced to a certain degree by its past values, that is, by the delayed dependent variable (prices from the Mexico City area). Next, the reduced form of the equation of interest is presented, whose specification required the incorporation of six delays of the variables in natural logarithm LPCDMX, LQDMX, LPMOR and LQMOR for the case of the period 2000-2005 and eight for the model of the period 2006-2017.

$$x_t = \beta_1 x_{t-1} + \beta_2 x_{t-2} + \dots + \beta_k x_{t-k} + Bz_t + u_t \quad (2)$$

where  $x_t$ : column vector that contains the four contemporary endogenous variables (LPCDMX: natural logarithm of the prices of the producing zone of Milpa Alta; LQCDMX: natural logarithm of the amounts from the producing zone of Milpa Alta; LPMOR: natural logarithm of the prices of the producing zone of Morelos ; and LQMOR: natural logarithm of the amounts from the producing zone of Morelos);  $x_{t-1}$ : column vector with the four prior delayed endogenous variables ( $i=1, 2, \dots, k$ );  $z_t$ : vector of exogenous deterministic variables: seasonal *dummy* (dseas09) and *dummies* (d0201, d0301, d0401, d0501);  $B_i, B$ : regression coefficient matrices to estimate for  $i=1, 2, \dots, k$ ;  $u_t$ : vector of innovations. Errors distributed normally with mean zero and constant variance.

### The data

The information used for the estimation of econometric models was the SIAP series that refer to the amounts of production, measured in tons, and the rural mean price, measured in pesos per ton annually; although this information was only reported until 2015. Therefore, the data of the amounts of production for the years 2016 and 2017 were estimated using the average growth rate of the last 10 years with the aim of capturing the recent behavior of the producing zones studied.

For the case of the prices, there were visits to the markets from the nopal producing zones of Morelos and Milpa Alta. As a result of the visits to the Milpa Alta Stockpile Center performed in the months of February and March 2018, the prices with daily periodicity were obtained from 2016 and 2017, which are product of the increase in prices at the place of commercialization carried out by the administration of the commercial facility. Regarding the data of the most significant market prices from Morelos, Tlalnepantla, it

was impossible to gather that information in the same way since price recording is not carried out in these stockpiling centers.

Because of this, another method was used to gain access to this information from primary sources. There were meetings with representatives and former representatives of nopal producers from the municipality of Tlalnepantla, whose work activity allows them to have the record of current prices per day. In this way, there could be access to the nopal prices from Tlalnepantla, Morelos, in the years 2016 and 2017.

The analysis period for this study was years 2000 to 2017, with monthly periodicity and divided into two sub-periods. The entry of the Morelos producing area to this agricultural market in the central area of the country was considered as a breaking point, which was in 2005 according to the statistical analysis conducted.

In order to obtain the information of monthly prices from 2000 to 2015, they were adjusted by the monthly percentage variation of the National Producer Prices Index (*Índice Nacional de Precios al Productor*, INPP)<sup>4</sup> for those years: this means that inflation was discounted (observed for agricultural producers) from the prices that were gathered directly at the local markets of Milpa Alta and Tlalnepantla to report the one from the immediate year prior and thus, successively. In this way, the specific attributes of the productive cycle of the nopal-vegetable good were captured.

## RESULTS

The initial model from 2000 to 2005 corresponds to the part of the study period when nopal production from the central zone of the country was practically exclusive to the area of Milpa Alta in Mexico City. Thus, the estimation of the first model seeks to characterize the behavior of the producing zone in question, considering that the neighboring municipalities of Morelos began producing nopal without being able to be considered competition for Milpa Alta, since both in surface sown and production they were not significant. The second model corresponds to the period when both the surface sown and the production of the producing zone in Morelos have been on the same level as that from Milpa Alta.

### Model 2000-2005

#### **Determination of the integration order of the series: Unit root tests**

To verify that the cointegration relationship of the series has the economic meaning that this study suggests, unit root tests were applied: Augmented Dickey-Fuller (ADF), Phillips-Perron (PP) and Kwiatkowski-Phillips-Schmidt-Shin (KPPS). Table 1 shows the results from the tests mentioned of the four series in levels for the model 2000-2005.

The series are stationary of order zero since, although they have passed the KPPS test in their two models and some models of the PP test, when the ADF was applied, what was indicated by the other two tests could not be corroborated in any case.

Therefore, the evaluation of the series in first differences was necessary, (Table 2). Based on this valuation, it is verified that the series LPCDMX, LQCDMX, LPMOR and LQMOR

**Table 1.** Unit root test in levels.

Variables	Augmented Dickey-Fuller			Phillips-Perron			KPSS	
	A	B	C	A	B	C	A	
PCDMX	-1.3002 [0.6241]	-0.9779 [ 0.9392]	-7.3000 [ 0.6787]	-2.9578 [ 0.0439]	-3.014 [ 0.1358]	-0.0382 [ 0.6667]	0.0708	0.0285
QCDMX	-0.9328 [ 0.7710]	-0.9257 [ 0.9460]	0.9596 [ 0.9087]	-18.0588 [ 0.0001]	-18.6484 [ 0.0001]	0.0307 [ 0.6893]	0.4759	0.3772
PMOR	-2.2800 [ 1.0000]	-2.2400 [ 1.0000]	-0.0054 [ 0.6770]	-3.6983 [ 0.0061]	-3.7071 [ 0.0282]	-0.2051 [ 0.6089]	0.0326	0.0217
QMOR	2.6176 [1.0000]	-0.7530 [0.9640]	3.6572 [0.9999]	-5.5400 [0.0000]	-6.1493 [0.0000]	0.1662 [0.7315]	0.9506	0.1691

\*Significance of the tests at 05 %; the model A includes intercept with value of tables of -2.8895; the model B includes tendency and intercept with value in tables of -3.4535; the model C does not include tendency or intercept and has value of -1.94. The values in bold letters denote the rejections of the null hypothesis.

\*\*The values in square brackets are the probabilities of the statistic  $t$ .

are stationary in first differences, which indicates that their order of integration is  $I(1)$ . In this sense, because the series are of the same order of integration, it is possible to establish a long-term relationship between the variables given that they have a stochastic tendency that move together through time (Bravo and García, 2002).

This indicates that there is evidence that justifies an inspection to verify the possibility of cointegration between the endogenous variables of the VAR; under this logic, the search for cointegration vectors should be essentially guided by economic theory. Once the unit

**Table 2.** Unit root test in first differences.

Variables	Augmented Dickey-Fuller			Phillips-Perron			KPSS	
	A	B	C	A	B	C	A	B
PCDMX	-6.5623 [0.0000]	-6.508 [ 0.0000]	-1348.3590 [ 0.0000]	-6.5722 [ 0.0000]	-6.5184 [ 0.0000]	-6.6025 [ 0.0000]	0.0337	0.0255
QCDMX	-9.7046 [0.0000]	-9.6414 [ 0.0000]	-1.8277 [ 0.0647]	-24.2174 [ 0.0001]	-24.5194 [ 0.0001]	-22.3941 [ 0.0000]	0.2047	0.1932
PMOR	-4.3228 [0.0009]	-4.2576 [ 0.0063]	-7.13 [ 0.0000]	-7.4692 [ 0.0000]	-7.4579 [ 0.0000]	-7.5204 [ 0.0000]	0.0625	0.0346
QMOR	-9.8212 [0.0000]	-9.7511 [0.0000]	-9.8753 [0.0000]	-23.8835 [0.0001]	-24.2954 [0.0001]	-20.8405 [0.0000]	0.1275	0.1275

\*Significance of the tests at 05 %; the model A includes intercept with value of tables of -2.8895; the model B includes tendency and intercept with value in tables of -3.4535; the model C does not include tendency or intercept and has value of -1.94. The values in bold letters denote the rejections of the null hypothesis.

\*\*The values in square brackets are the probabilities of the statistic  $t$ .

Source: prepared by the authors.

root test was conducted, the study carried out the development of the Vector Autoregressive methodology.

### Empirical specification of the VAR model

The estimation of the VAR model followed the methodology from the general to the particular (Krolzig and Hendry, 2002) to obtain a parsimonious estimation of the model, and the coefficients are shown in Table 3. In the specification of the VAR a seasonal *dummy* variable was used, since these are series that evidently present temporary behaviors. This variable was called “dseas09” and corresponds to the finalization of the high production period and the beginning of low production.

In addition, four *dummies* variables that described another seasonal behavior were included in the specification of the VAR, this time from the month of January, and whose explanation remits to the beginning of the marked decreases in prices derived from a considerable increase of the production. The correct specification of the VAR model is of an optimal structure of six months of delay in the endogenous variables.

As indicated, the specification of the VAR model for the first analysis period required the incorporation of six delays from the variables LPCDMX, LQCDMX, LPMOR and LQMOR, four *dummies* variables (d0201, d0301, d0401, d0501), and one seasonal *dummy* (dseas09). However, because the VAR technique is relatively flexible and is dominated by the endogeneity of the variables, it is not relevant to analyze the regression coefficients estimated or their statistical significance, nor the goodness of adjustment (adjusted R<sup>2</sup>) of the individual equation (Arias and Torres, 2004).

**Table 3.** Specification of the VAR model.

Variable	Coefficient	Std. Error	t-value	Variable	Coefficient	Std. Error	t-value
LPCDMX_1	1.11188	-0.18480	[ 6.01666]	LPMOR_3	-1.88338	-0.06864	[-27.43720]
LPCDMX_2	0.41993	-0.12822	[ 3.27494]	LPMOR_4	-0.74258	-0.27265	[-2.72354]
LPCDMX_3	0.80243	-0.10829	[ 7.41014]	LPMOR_5	0.59955	-0.20609	[ 2.90918]
LPCDMX_4	0.00940	-0.17456	[ 0.05386]	LPMOR_6	-0.60438	-0.09783	[-6.17800]
LPCDMX_5	1.86347	-0.06790	[ 27.44570]	LQMOR_1	0.00086	-0.00418	[ 0.20526]
LPCDMX_6	-0.05624	-0.32518	[-0.17295]	LQMOR_2	-0.00167	-0.00587	[-0.28449]
LQCDMX_1	0.01223	-0.01603	[ 0.76298]	LQMOR_3	-0.00775	-0.00586	[-1.32295]
LQCDMX_2	-0.01077	-0.02157	[-0.49943]	LQMOR_4	0.01456	-0.00579	[ 2.51659]
LQCDMX_3	-0.00993	-0.02147	[-0.46225]	LQMOR_5	-0.00402	-0.00608	[-0.66035]
LQCDMX_4	0.01186	-0.02121	[ 0.55932]	LQMOR_6	-0.00167	-0.00438	[-0.38063]
LQCDMX_5	0.00035	-0.02162	[ 0.01632]	D0201	-0.00081	-0.00628	[-0.12969]
LQCDMX_6	0.00737	-0.01650	[ 0.44666]	D0301	0.00023	-0.00626	[ 0.03594]
LPMOR_1	-0.75967	-0.14836	[-5.12030]	D0401	-0.00185	-0.00646	[-0.28595]
LPMOR_2	0.16266	-0.12680	[ 1.28280]	D0501	-0.00017	-0.00633	[-0.02615]
				DSEAS09	0.16594	-0.15007	[ 1.10575]

Source: prepared by the authors.

The model obtained fulfills the conditions of stability, since the characteristic roots are lower than the unit, as shown in Table 4. The unit root test and inverse roots of the characteristic polynomial indicate that all the roots are lower than the unit and, therefore, located within the unit circle.

Next, the serial correlation diagnosis tests are presented, normality and heteroscedasticity.

### Diagnosis tests of the VAR model

The model satisfies the assumptions of ordinary least squares and, therefore, the conditions of the Gauss-Markov theorem, which is why it is possible to consider the estimators are BLUE (Best Linear Unbiased Estimator) (Table 5).

According to what was reported in the previous table, it is observed that in the VAR model there is only evidence of autocorrelation of the first order and it does not present this problem between combinations of contemporary and delayed variables in six periods. Likewise, the residues from the VAR model estimated show the approximate behavior to a normal distribution described by the statistics of bias and those that refer to kurtosis and Jaque-Bera are at 10% of statistical significance. Finally, the estimation did not present non-constant variance problems. This validates the correct specification of the model.

### Cointegration analysis

Once the assumptions of the VAR model are validated, it is possible to carry out the cointegration tests under the methodology by Johansen (1988), which considers the hypothesis contrast through the Trace statistics and the Maximum Eigenvalue; in this sense, both the first and the second indicate that there are two cointegration vectors (Table 6).

The objective of the VEC modelling is the correction of the short term imbalances and the

**Table 4.** Unit root test and inverse roots of the characteristic polynomial.

Root	Modulus	Root	Modulus
0.999327	0.999327	-0.600752 + 0.636593i	0.875303
0.995800 + 0.004609i	0.995810	-0.558320 - 0.455398i	0.720492
0.995800 - 0.004609i	0.995810	-0.558320 + 0.455398i	0.720492
-0.086451 + 0.990857i	0.994621	0.319969 + 0.315660i	0.449468
-0.086451 - 0.990857i	0.994621	0.319969 - 0.315660i	0.449468
0.836745 - 0.507166i	0.978447	-0.332532 - 0.299865i	0.447769
0.836745 + 0.507166i	0.978447	-0.332532 + 0.299865i	0.447769
0.476903 + 0.850774i	0.975322	0.420612	0.420612
0.476903 - 0.850774i	0.975322	0.128640 + 0.394070i	0.414536
-0.867011 - 0.217353i	0.893840	0.128640 - 0.394070i	0.414536
-0.867011 + 0.217353i	0.893840	0.069092 + 0.148818i	0.164074
-0.600752 - 0.636593i	0.875303	0.069092 - 0.148818i	0.164074

No root lies outside the unit circle.  
 VAR satisfies the stability condition  
 Source: prepared by the authors.

**Table 5.** Diagnosis tests of the VAR model

VAR Residual Serial Correlation LM test		
Lags	LM-Stat	Prob
1	100.8599	0.0000
2	28.39354	0.0284*
3	12.91369	0.6791
4	12.39775	0.7162
5	18.43209	0.2992
6	8.431892	0.935

\*Significance at 10%.

VAR Residual Normality Test			VAR Residual Heteroskedasticity Tests: No Cross Terms		
	Statistic (Joint)	Prob	Joint Test		
			Chi-sq	df	Prob.
Skewness	7.4205	0.1153	485.6869	450.0000	0.1187
Kurtosis	55.0565	0.0101*			
Jarque-Bera	62.4770	0.0108*			

\*Denotes significance at 10%.

Orthogonalization: Residual Correlation (Doornik-Hansen)

Source: prepared by the authors.

efficiency or speed with which this correction is carried out. As indicated, the search for cointegration vectors ought to be guided essentially by economic theory.

### Cointegration vector

According to Engle and Granger (1987), the cointegration vectors express the reaction functions of the economic agents that maintain the variables considered within the trajectories of balance. These vectors could then be interpreted as mechanisms of error correction. The cointegration vector of interest that is established by the long term relationship of the normalized equation and which represents the behavior of the formation of prices in Milpa Alta during the period of 2000 to 2005 is:

$$LPCDMX = (\alpha * 3.94605) - (0.05653 * LQCDMX) + (0.54317 * LPMOR) - (0.00602 * LQMOR) + (0.00025 * @trend[00M01]) \quad (3)$$

This equation expresses elasticities because the model's estimation was carried out using the natural logarithm of each of these series, which is why the interpretation of the results can be read in terms of percentage variations. In this sense, this function of reaction prescribes that, facing a variation of 1% in the amounts of production of the Milpa Alta producing zone, the prices from the producing zone of Milpa Alta are adjusted by 0.05653%.

**Table 6.** Identification of the cointegration vector.

Unrestricted Cointegration Rank Test (Trace) – (Maximum Eigenvalue)				
Hypothesized	Eigenvalue	Trace	0.05	Prob.**
No. of CE(s)		Statistic	Critical Value	
None*	0.996442	855.6897	63.87610	0.0001
At most 1*	0.980067	472.2640	42.91525	0.0001
At most 2	0.951563	206.0173	25.87211	0.0938
At most 3	0.002182	0.148544	12.51798	1.0000

Trace test indicates 2 cointegrating eqn(s) at the 0.05 level.

\*denotes rejection of the hypothesis at the 0.05 level.

\*\*MacKinnon-Haug-Michelis (1999) p-values.

Hypothesized	Eigenvalue	Trace	0.05	Prob.**
No. of CE(s)		Statistic	Critical Value	
None*	0.996442	383.4257	32.11832	0.0000
At most 1*	0.980067	266.2467	25.82321	0.0001
At most 2	0.951563	205.8687	19.38704	0.0940
At most 3	0.002182	0.148544	12.51798	1.0000

Max-eigenvalue test indicates 2 cointegrating eqn(s) at the 0.05 level.

\*denotes rejection of the hypothesis at the 0.05 level.

\*\*MacKinnon-Haug-Michelis (1999) p-values.

Source: prepared by the authors.

Likewise, facing a variation of 1% of the prices of the Morelos producing zone, the prices from Milpa Alta adjust by -0.54317%. Finally, when a variation of one percentage point in the amounts of production from Morelos is seen, then the prices from Mexico City should adjust slightly (0.00602%).

It should be highlighted that the signs of each of the coefficients was the one expected given the interaction between variables. That is, when the amounts of production increase, the prices from Milpa Alta decrease, and vice versa. On the contrary, when the prices from Morelos decrease, then the Milpa Alta prices also do; and when the prices from Milpa Alta increase, those from Morelos also do.

This indicates that there is an inverse relationship between the Milpa Alta prices and the amounts (from both producing zones) and a direct relationship between the prices from Milpa Alta and the prices from Morelos in the long term.

### Specification of the VEC model

Once the cointegration vector is attained, it is possible to use it as an error correction mechanism for the equation in differences from the VEC model. Table 7 presents the specification of such model. In this specification, 13 *dummy* variables are used (d0101, d0201, d0301, d0401, d0501, d0102, d0103, d0202, d0203, d0204, d0304, d0409, d0504, dseas07).

The justification of the first five and the last dichotomous variable corresponds to a seasonal

**Table 7.** Estimation of the error corrector vector.

Variable	Coefficient	Std. Error	t-value	Variable	Coefficient	Std. Error	t-value
CointEq1	-0.7774	-0.1287	[ 6.03842]	D0301	-2.3861	-0.2635	[-9.05504]
D(LPCDMX_2)	-0.248	-0.1462	[-1.69571]	D0401	-2.3927	-0.2639	[-9.06439]
D(LPCDMX_3)	0.5838	-0.132	[ 4.42308]	D0501	-2.3878	-0.2636	[-9.05740]
D(LQCDMX_2)	-0.3409	-0.1812	[-1.88127]	D0102	-0.2091	-0.2159	[-0.96872]
D(LQCDMX_3)	-0.0019	-0.1851	[-0.01034]	D0103	0.342	-0.2415	[ 1.41615]
D(LPMOR_2)	-0.5614	-0.099	[-5.66926]	D0202	-0.2017	-0.2164	[-0.93216]
D(LPMOR_3)	-0.0377	-0.0958	[-0.39355]	D0203	0.3989	-0.2603	[ 1.53244]
D(LQMOR_2)	0.2699	-0.177	[ 1.52491]	D0204	-0.1397	-0.2897	[-0.48217]
D(LQMOR_3)	-0.094	-0.1833	[-0.51262]	D0304	-0.1031	-0.2612	[-0.39494]
C	0.205	-0.0337	[ 6.06994]	D0409	-0.1007	-0.2065	[-0.48785]
D0101	-2.3931	-0.264	[-9.06498]	D0504	-0.0762	-0.2445	[-0.31188]
D0201	-2.3936	-0.264	[-9.06559]	DSEAS07	0.0849	-0.1005	[ 0.84466]

Sample (adjusted):2000M05 2005M12.  
 Included observations:68 after adjustments.  
 Standard errors in ( ) and t-statistics in [ ].  
 Source: prepared by the authors.

component in the month of January, when the transition from the season of high prices or low production to the period of low prices and high production happens. Regarding the *dummy* variables February (d0102, d0202), March (d0103, d0203) and April (d0204, d0304, d0504), their inclusion responds to notable overproduction processes. Finally, that of September (d0409) is associated to a climate situation.

Modeling of the VAR and, then, the VECM presented particular characteristics. The main one of them is that each equation from the system has the same explicative variables, but with different number of delays and *dummy* variables. This is because it is a specification of an asymmetrical VAR (AVAR), as Keating (2000) specifies, VAR models frequently estimate a considerable number of non-significant coefficients, which is why the analyses of the impulse-response function and of the variance decomposition constructed from those coefficients are often imprecise.

The cointegration vector is negative and statistically significant. This determines the speed at which the equilibrium is re-established in the long term, which implies that this equation contributes to re-establishing the equilibrium relationship of the series in the long term, when a conjunction in the short term makes the behavior of endogenous variables become temporarily diverted.

This means that the cointegration vector corrects 77% of the imbalance in each month. Thus, during the period that ranges from the month of January 2000 to the month of December 2005, the deviations regarding the behavior of the variables in the long term are better described as transitory movements of the prices from Morelos, than as transitory movements of the deviations in the amounts from Milpa Alta and the amounts from Morelos.

### Diagnosis tests of the VEC model

Table 8 summarizes the serial autocorrelation, normality and heteroscedasticity tests, which validate the correct specification of the VECM. The specification of the model required the use of dichotomous variables and some of seasonal character. As can be appreciated, the error correction model does not present problems of serial correlation (with the exception of its first delay and the second which is statistically significant at 10%). Regarding the assumption of statistical normality, the model from the period 2000:01 to 2005:12 is normal in the bias and it is at 10% of statistical significance in kurtosis and in the Jarque-Bera statistic. Finally, when speaking of heteroscedasticity in the model, it is concluded that the variance is constant during the period in question.

### Model 2006-2017

#### Determination of the integration order of the series: Unit root tests

The series are not stationary in levels, and therefore, the evaluation of the series in first differences was necessary and it was verified that the series LPCDMX, LQCDMX, LPMOR and LQMOR are stationary in first differences, that is, that their order of integration is I(1) (Tables 9 and 10).

#### Empirical specification of VAR

Thirteen (13) *dummy* variables were used, although it is important to note that the first nine (d0701, d0801, d0901, d1001, d1101, d1201, d1301, d1401 and d1501)<sup>5</sup> correspond to a

**Table 8.** Diagnosis test of the VEC model.

VEC Residual Serial Correlation LM test		
Lags	LM-Stat	Prob
1	49.90495	0.0002
2	26.93140	0.0423*
3	22.42506	0.1300

\*Denotes significance at 10%.  
 Probs from chi-square with 16 df.

VEC Residual Normality Test			VEC Residual Heteroskedasticity Tests: No Cross Terms		
	Statistic (Joint)	Prob	Joint Test		
			Chi-sq	df	Prob.
Skewness	4.2487	0.0562	315.6129	320	0.5588
Kurtosis	17.7703	0.0060*			
Jarque-Bera	22.0191	0.0026*			

\*Denotes significance at 10%.  
 Orthogonalization: Residual Correlation (Doornik-Hansen)  
 Source: prepared by the authors.

**Table 9.** Unit root test in levels.

Variables	Augmented Dickey-Fuller			Phillips-Perron			KPSS	
	A	B	C	A	B	C	A	B
LPCDMX	-1.1114 [0.7101]	-1.6212 [0.7795]	0.9999 [0.9158]	-3.2495 [0.0192]	-3.268 [0.0759]	0.5481 [0.8334]	0.1613	0.1418
LQCDMX	-2.2967 [0.1746]	-2.7256 [0.2282]	-0.2015 [0.6119]	-15.2597 [0.0000]	-16.0044 [0.0000]	-0.1718 [0.6226]	0.1613	0.1418
LPMOR	-4.4534 [0.0004]	-4.0987 [0.0081]	0.9997 [0.9158]	-5.3318 [0.0000]	-5.3285 [0.0001]	-0.4529 [0.5172]	0.0230	0.0153
LQMOR	-0.4832 [0.8897]	-3.4067 [0.0549]	1.2691 [0.9477]	-11.5642 [0.0000]	-17.7703 [0.0000]	-0.084 [0.6530]	0.6596	0.1133

\*Significance of the tests at 05%; model A includes intercept with value of tables of -2.8895; model B includes tendency and intercept with value in tables of -3.4535; model C does not include tendency or intercept and has value of -1.94. The values in bold letters denote the rejections of the null hypothesis.

\*\*The values in square brackets are the probabilities of the statistic *t*.

seasonal behavior that is found in the month of January (as it happens in the estimation of the 2000-2005 model) and that it is due, essentially, to the beginning of marked decreases in the prices derived from a considerable increase in the production.

The correct specification of the VAR model is of an optimal structure of eight months of delay in the endogenous variables (Table 11). Likewise, four additional *dummy* variables were included in the VAR specification, which are associated to isolated events during the three consecutive months of the year 2006 (d0609, d0610 and d0611) and the month of February 2010 (d1002).

**Table 10.** Unit root test in first differences.

Variables	Augmented Dickey-Fuller			Phillips-Perron			KPSS	
	A	B	C	A	B	C	A	B
(LPCDMX)	-2.9116 [0.0467]	-9.1759 [0.0000]	-4635.4830 [0.0000]	-12.6113 [0.0000]	-12.5036 [0.0000]	-12.5163 [0.0000]	0.2296	0.1766
(LQCDMX)	-2.9116 [0.0467]	-2.9114 [0.1624]	-2.918 [0.0038]	-26.537 [0.0000]	-26.4018 [0.0000]	-26.6878 [0.0000]	0.109	0.0998
(LPMOR)	-5.971 [0.0000]	-5.9384 [0.0000]	-5050.4450 [0.0000]	-10.7752 [0.0000]	-10.7538 [0.0000]	-10.8104 [0.0000]	0.0233	0.0129
(LQMOR)	-2.7216 [0.0731]	-13.7813 [0.0000]	-2.4038 [0.0162]	-26.6227 [0.0000]	-31.7064 [0.0001]	-26.6442 [0.0000]	0.106	0.1000

\*Significance of the tests at 05%; model A includes intercept with value of tables of -2.8895; model B includes tendency and intercept with value in tables of -3.4535; model C does not include tendency or intercept and has value of -1.94. The values in bold letters denote the rejections of the null hypothesis.

\*\*The values in square brackets are the probabilities of the statistic *t*.

Source: prepared by the authors.

**Table 11.** Estimation of the vector autoregressive model.

Variable	Coefficient	Std. Error	t-value	Variable	Coefficient	Std. Error	t-value
LPCDMX_1	-0.1723	-0.1395	[-1.23554]	LPMOR_8	0.8768	-0.0912	[ 9.61388]
LPCDMX_2	0.0058	-0.13	[ 0.04492]	LQMOR_1	-0.004	-0.011	[-0.36639]
LPCDMX_3	-0.5265	-0.1488	[-3.53748]	LQMOR_2	0.0388	-0.0144	[ 2.68586]
LPCDMX_4	-0.1336	-0.1122	[-1.19007]	LQMOR_3	-0.0377	-0.0139	[-2.71493]
LPCDMX_5	0.7977	-0.1181	[ 6.75180]	LQMOR_4	-0.015	-0.0136	[-1.10184]
LPCDMX_6	0.6805	-0.2136	[ 3.18556]	LQMOR_5	0.0193	-0.0139	[ 1.38660]
LPCDMX_7	-0.0059	-0.1411	[-0.04219]	LQMOR_6	0.0127	-0.0138	[ 0.91806]
LPCDMX_8	-0.7874	-0.1763	[-4.46535]	LQMOR_7	-0.0143	-0.0139	[-1.03061]
LQCDMX_1	-0.0001	-0.0077	[-0.02144]	LQMOR_8	-0.0016	-0.0105	[-0.15214]
LQCDMX_2	-0.0052	-0.01	[-0.52280]	TREND	1.92E-05	-2.10E-05	[ 0.89717]
LQCDMX_3	0.0043	-0.0098	[ 0.44458]	D0701	0.0105	-0.0043	[ 2.43429]
LQCDMX_4	-0.0017	-0.0093	[-0.18285]	D0801	0.0078	0.00389	[ 2.02214]
LQCDMX_5	0.0009	-0.0093	[ 0.10156]	D0901	0.008	0.00389	[ 2.07239]
LQCDMX_6	0.0002	-0.0094	[ 0.02872]	D1001	0.0077	0.00387	[ 2.01010]
LQCDMX_7	0.0029	-0.0093	[ 0.31118]	D1101	0.0075	0.00383	[ 1.96816]
LQCDMX_8	-0.001	-0.0069	[-0.15537]	D1201	0.0004	0.00333	[ 0.12771]
LPMOR_1	1.0081	-0.1871	[ 5.38724]	D1301	0.0006	0.00338	[ 0.19969]
LPMOR_2	0.8472	-0.1326	[ 6.38773]	D1401	0.0003	0.00321	[ 0.11941]
LPMOR_3	-0.4659	-0.1318	[-3.53486]	D1501	1.39E-06	0.00322	[ 0.00043]
LPMOR_4	-1.2367	-0.1993	[-6.20420]	D1002	0.0002	0.00303	[ 0.07663]
LPMOR_5	-0.1036	-0.1695	[-0.61145]	D0609	0.0092	0.00302	[ 3.05695]
LPMOR_6	0.2318	-0.2099	[ 1.10431]	D0610	-0.0069	0.00297	[-2.34041]
LPMOR_7	0.0075	-0.1337	[ 0.05635]	D0611	-0.0125	0.00325	[-3.85241]

Sample (adjusted):2006M09 2005M12. Included observatons: 68 after adjustments. Standard errors in ( ) and t-statistics in [ ]. Source: prepared by the authors.

### Unit root test

The model obtained fulfills the conditions of stability since Table 12 indicates that all the roots are lower than the unit.

### Diagnosis tests of the VAR model

The estimators obtained in the VAR model are BLUE (Best Linear Unbiased Estimator) because the model satisfies the assumptions of ordinary least squares and, therefore, the conditions of the Gauss-Markov theorem (Table 13).

According to what was reported in the previous table, it is seen that the VAR model does not present problems of serial autocorrelation between combinations of contemporary and delayed variables in nine periods.<sup>6</sup> Likewise, the residues of the estimated VAR model show the approximate behavior to that of the normal distribution described by the bias and Jarque-Bera statistics, while the one that refers to kurtosis is at 10% of statistical significance. Finally, the estimation of the VAR did not present problems of inconstant variance since the model is homoscedastic at 10% of significance. This validates the correct specification of the model.

**Table 12.** Unit root test and inverse roots of the characteristic polynomial.

Root	Modulus	Root	Modulus
0.999962	0.999962	-0.669499 + 0.107034i	0.678001
-0.866028 + 0.499498i	0.999752	0.353064 - 0.576495i	0.676019
-0.866028 - 0.499498i	0.999752	0.353064 + 0.576495i	0.676019
-0.999467	0.999467	0.565098	0.565098
0.981957	0.981957	0.033321 + 0.558373i	0.559367
-0.770755	0.770755	0.033321 - 0.558373i	0.559367
-0.348041 - 0.641368i	0.729716	-0.380138 - 0.393498i	0.547125
-0.348041 + 0.641368i	0.729716	-0.380138 + 0.393498i	0.547125
0.653557 + 0.274149i	0.708727	0.543348	0.543348
0.653557 - 0.274149i	0.708727	0.421662 + 0.308722i	0.522598
-0.669499 - 0.107034i	0.678001	0.421662 - 0.308722i	0.522598
		-0.386845	0.386845

No root lies outside the unit circle. VAR satisfies the stability condition. Source: prepared by the authors.

**Table 13.** Diagnosis tests of the VAR model.

VAR Residual Serial Correlation LM test		
Lags	LM-Stat	Prob
1	103.0664	0.0017*
2	89.7040	0.0134*
3	72.7573	0.0672
4	63.3182	0.0502
5	35.8514	0.0001*
6	41.1858	0.0165*
7	26.9710	0.0393*
8	18.8894	0.0456*
9	13.8957	0.8629

\* Denotes significance at 10%. Probs from chi-square with 16 df.

VAR Residual Normality Test			VAR Residual Heteroskedasticity Tests: No Cross Terms		
	Statistic (Joint)	Prob	Joint Test		
			Chi-sq	df	Prob.
Skewness	7.4205	0.5981	739.2312	670	0.0323*
Kurtosis	55.0565	0.0158*			
Jarque-Bera	62.4770	0.0026*			

\* Denotes significance at 10%. Orthogonalization: Residual Correlation (Doornik-Hansen). Source: prepared by the authors.

### Cointegration analysis

Next, the cointegration tests were conducted under the methodology by Johansen (1988), which considers the hypothesis contrast through the Trace statistic and the Maximum Eigenvalue; in this sense, both the first and the second indicate that there are two cointegration vectors (Table 14).

### Cointegration vector

The cointegration vector of interest that establishes the relationship in the long term of the normalized equation and which represents the behavior of price formation between producing zones of Milpa Alta and Morelos during the period of 2006 to 2017 is:

$$LPCDMX = (\alpha * 6.416753) - (0.060032 * LQCDMX) + (0.980452 * LPMOR) - (0.635184 * LQMOR) \quad (4)$$

The interpretation of results is read in terms of percentage variations. In this sense, this reaction function prescribes that, in face of a variation of 1% of the amounts of production from the producing zone of Milpa Alta, the prices of the producing zone of Milpa Alta

**Table 14.** Identification of the cointegration vector.

Unrestricted Cointegration Rank Test (Trace) – (Maximum Eigenvalue)				
Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None*	0.817040	381.3664	54.07904	0.0001
At most 1*	0.584623	143.5785	35.19275	0.0000
At most 2	0.126709	20.57895	20.26184	0.0652
At most 3	0.011440	1.610821	9.164546	0.8531

Trace test indicates 2 cointegrating eqn(s) at the 0.05 level.

\*denotes rejection of the hypothesis at the 0.05 level.

\*\*MacKinnon-Haug-Michelis (1999) p-values.

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None*	0.817040	237.7879	28.58808	0.0001
At most 1*	0.584623	122.9995	22.29962	0.0000
At most 2	0.126709	18.96813	15.89210	0.0559
At most 3	0.011440	1.610821	9.164546	0.8531

Max-eigenvalue test indicates 2 cointegrating eqn(s) at the 0.05 level.

\*denotes rejection of the hypothesis at the 0.05 level.

\*\*MacKinnon-Haug-Michelis (1999) p-values.

Source: prepared by the authors.

are adjusted by 0.060032%. Likewise, facing a variation of 1% of the prices from the producing zone of Morelos, the Milpa Alta prices adjust by 0.980452%. Finally, when a variation of one percentage point of the amounts of production from Morelos are found, the Milpa Alta prices should adjust significantly (0.635184 %), situation that is contrary to what is described by the cointegration vector of the estimation of the model from the initial period, when the impact of the amounts from Morelos were marginal.

**Specification of the VEC model**

Once the cointegration vector was identified, it is possible to use it as an error correction mechanism for the VEC model’s equation in differences. Table 15 shows the specification of the VECM, where 13 *dummy* variables are used (d0701, d0801, d0901, d1001, d1101, d1202, d1303, d1401, d1501, d1002, d0609, d0610 and d0611), of which the first nine correspond to a seasonal component in the month of January when the transition from the season of the high prices or low production takes place, the others are related to a conjunction of three months in the year 2006, in addition to one isolated from February 2010. A tendency was also included.

According to the previous table, the cointegration vector is negative and statistically significant, which indicates that this vector corrects 7.35% of the imbalance in each month. It should be highlighted that for the modeling case of the period 2006-2017, both VAR and VECM are specified with the same number of delays in each equation of the system, in addition to the use of seasonal *dummy* variables.

This way, during the period from January 2006 to December 2017, the deviations regarding the long-term behavior of the variables are better described as transitory movements of the prices from Morelos. In economic terms, this implies that the prices from Tlalnepantla are the ones that determine the price structure in both markets.

**Table 15.** Estimation of the vector error correction.

Variable	Coefficient	Std. Error	t-value	Variable	Coefficient	Std. Error	t-value
CointEq1	-0.0735	-0.0279	[ 2.63259]	D1001	-1.4303	-0.3534	[-4.04698]
D(LPCDMX_2)	0.3957	-0.1037	[ 3.81335]	D1101	-1.4369	-0.3534	[-4.06522]
D(LPCDMX_3)	0.5129	-0.7298	[ 0.70287]	D1201	-1.4435	-0.3535	[-4.08303]
D(LQCDMX_2)	-0.2208	-0.099	[-2.22966]	D1301	-1.4565	-0.3546	[-4.10659]
D(LQCDMX_3)	-0.6258	-0.73	[-0.85719]	D1401	-1.4601	-0.3546	[-4.11673]
D(LPMOR_2)	0.0005	-0.0003	[ 1. 52756]	D1501	-1.4679	-0.3549	[-4.13521]
D(LPMOR_3)	-1.4035	-0.3531	[-3.97427]	D1002	-0.6365	-0.3442	[-1.84943]
D(LQMOR_2)	-1.4223	-0.3533	[-4.02594]	D0609	0.3138	-0.3402	[ 0.92240]
D(LQMOR_3)	-1.4238	-0.3533	[-4.02895]	D0610	0.3469	-0.3486	[ 0.99522]
				D0611	-0.0485	-0.3416	[-0.14213]

Sample (adjusted):2006M05 2017M12. Included observatons: 140 after adjustments. Standard errors in ( ) and t-statistics in [ ]. Source: prepared by the authors.

However, the increase in the value of the coefficient associated to the amounts of production from the province suggests that the transitory variations of the production from Morelos are also relevant because this last variable increased considerably its effects on price formation in the producing zone from Milpa Alta of 0.00602 to 0.635184.

### Diagnosis tests of the VECM model

Table 16 summarizes the serial autocorrelation, normality and constant variance tests, which validate the correct specification of the VECM. The specification of the model required the use of dichotomous variables and a tendency. The error correction model does not present serial correlation problems (with the exception of their first delay). Regarding the assumption of statistical normality, the model of the period 2006:01 to 2017:12 is normal in the bias, kurtosis and Jarque-Bera statistic at 10% of the statistical significance. Finally, regarding the heteroscedasticity in the model, it is concluded that the variance is constant during the period in question.

## DISCUSSION

Based on the empirical analysis, the way in which the price variables and amounts of nopal from both producing zones are interrelated was determined regarding the direction, speed, symmetry, and amounts of production between the zones of Morelos and Milpa Alta.

### Symmetry of the price transmission. Model 2000:01-2005:12

Before Morelos entered nopal production, the symmetry in price transmission between

**Table 16.** Diagnosis tests of the VEC model.

VEC Residual Serial Correlation LM test		
Lags	LM-Stat	Prob
1	110.9275	0.0001
2	30.54871	0.0102*
3	45.29849	0.0404*
4	23.19376	0.0413*

\*Denotes significance at 10%.  
 Probs from chi-square with 16 df.

VEC Residual Normality Test			VEC Residual Heteroskedasticity Tests: No Cross Terms		
	Statistic (Joint)	Prob	Joint Test		
Skewness	7.0564	0.0329*	Chi-sq	df	Prob.
Kurtosis	12.5222	0.0248*	1296.981	1220	0.0618
Jarque-Bera	19.5786	0.0121*			

\*Denotes significance at 10%. Orthogonalization: Residual Correlation (Doornik-Hansen). Source: prepared by the authors.

producing zones could be considered as moderate in the direction Milpa Alta-Morelos and vice versa, since the coefficient associated to the prices of the producing zone of Morelos is 0.54317. This way it was possible to identify that the prices found in the Morelos market did not have a considerable effect on the price formation in Milpa Alta.

Therefore, when both an increase and a decrease were found in the prices of the nopal producing zone of Milpa Alta ( $p^{in}$ ), the magnitude of response in the Morelos zone was fast and small ( $p^{out}$ ) because of a limited interrelationship between markets, and considering the proximity between the production areas.

Therefore, certain independence was verified between the nopal markets from Milpa Alta and Tlalnepantla during this period, since the estimation of VECM confirms that before the producing zone from Morelos participated in the nopal market of the central region of the country, the amounts of production from the province impacted marginally on the prices of the Milpa Alta producing zone (-0.0060).

#### **Symmetry of price transmission. Model 2006:01-2017:12**

After the crops from Morelos were incorporated to the nopal production, the price transmission was nearly symmetrical in the direction Milpa Alta-Morelos and vice versa, because the production from the province was practically equivalent and even exceeded that from Mexico City. This verified that the price structure from Morelos has impacted considerably the price formation in Milpa Alta, since the coefficient of the prices in the Morelos zone is 0.9805, which required for the price transmission between production zones to be practically symmetrical during the 2006-2017 period.

Regarding the coefficient associated to the amounts of production from Morelos, a considerable increase was observed when it went from a marginal incidence on the Milpa Alta prices (-0.0060) to have a determinant effect on price formation of the area of Mexico City with an associated coefficient of -0.6352 (Table 17).

An additional result that supports the estimations was that the coefficients of the amounts from Milpa Alta (QCDMX) are similar in both models. As variations in the coefficients of prices and amounts from Morelos (PMOR and QMOR) were found, the similarity between the coefficients associated to the amounts of production from Mexico City in both periods was the reflection that both the surface sown and the production have remained constant.

#### **Quantitative transmission on the prices.**

In addition to the result of the symmetry of price transmission between the producing zones from Morelos and Milpa Alta, this study verified an additional type of transmission to the analysis and methodology that Shepherd (2004) proposed. In this sense, the effect of the amounts of production from Morelos on the prices from Milpa Alta was null before the structural change, and from the Morelos market to the Milpa Alta market after such a rupture. This means that the magnitude of the coefficient of the amounts of production

**Table 17.** Identified cointegration vectors. 2000-2005 and 2006-2017.

Coefficients of Cointegration Vectors					
Analysis period	$\alpha$	QCDMX	PMOR	QMOR	Trend
2000:01-2005:12	3.9461	-0.0565	0.5432	-0.006	0.0003
2006:01-2017:12	6.4168	-0.06	0.9805	-0.6352	n/a

Source: prepared by the authors.

from Morelos of the model from the second period (-0.635184), denoted a significant increase in the symmetry regarding the same coefficient before the *shock* (-0.00602), which could be considered as marginal.

This is because in the first years of the analysis period, the amount of tons of nopal from Morelos that was traded was not significant. However, when the competition between producing zones began, the amounts produced in Morelos impacted the behavior of the prices in both areas, which generated an effect of a real variable on a nominal variable.

From this, the effects of the production amounts on the prices from both nopal producing zones operated in both directions and in function of the season. This means that if it is high production, the variations of the decreasing prices from the Tlalnepantla market transferred to the Milpa Alta market. On the contrary, if the season is of low production, the variations of the increasing prices from the Milpa Alta market are transmitted to the Tlalnepantla market, both of the order of  $\pm 63.51\%$ .

### Modification of the conditions of competition

The interpretation of these results is that when it is the high productivity season, the magnitude of transmission is reflected in the adoption of the price of the Tlalnepantla producing zone, since its greater productivity transfers the price reductions not only in this market but also in the neighboring market of Milpa Alta. This causes, in turn, for producers from both production areas to seek obtaining their yields via amounts, although in many cases, this practice is made unaffordable for the production units because the prices reach very low levels.

Bonilla (2014) indicates that the price can collapse to five pesos for one hundred and in the best case, it remains at between 25 and 60 pesos; or else when the prices increase, they can do it ten-fold, although only few producers take advantage of this because the frosts do not affect them or because they have greenhouses. However, according to some producers from Milpa Alta, the nopal prices during the season of high productivity can be null, that is, the demand is such that there is no one to offer any monetary amount for the product.

On the contrary, when the season is low productivity, the increments in prices reported in Milpa Alta immediately after a climate situation (frost or hail storm), are transferred with the same speed to the Morelos market. This means that the magnitude of price transmission

between producing zones is nearly symmetrical, with a coefficient that went from 0.54317 in the first period to 0.980452 during the second. This implied advantageous competition conditions for the producing zone of Morelos, because the scarcity of another competing producing zone causes the price increase in both.

Likewise, the greater interrelationship between production areas implied other results that are manifested in effects of the production level from Tlalnepantla on the price structure in the Mexico City zone. This means that the coefficient associated to the amounts of production from Morelos between the periods 2000-2005 and 2006-2017 increased considerably when going from marginal -0.00602 to representing a transfer effect in the order of 60% (-0.635184), always maintaining their inverse ratio.

The previous results implied anticompetitive effects that were exerted by the producing zone from Morelos on the Milpa Alta producing zone, because before the entry of Morelos to nopal production, the effects of the behavior both of prices and of amounts from Morelos on Milpa Alta were moderate and marginal, respectively. In fact, during the first period, the low interrelationship between producing zones benefited Morelos without considerably affecting Milpa Alta.

However, it is important to mention that the decreases in quality also affect the consumer's welfare because even when they can obtain the product at a lower price, the nopal from Morelos has a different taste, in addition to its intake including the chemical components of the frequent fumigations for their production, as well as more acidity, which decreases their quality.

For this reason, the anticompetitive effects that the operation of Morelos farmers exert are not manifested as price increments in this zone, as could be expected, but rather inversely due to the condition of high productivity of only one production zone. This means that the vast production causes reductions in their own prices, although this producing zone compensates the income expected through the amounts. These low prices serve as another entry barrier for new producers from Milpa Alta because, with this level of prices, it is not profitable to become inserted in this activity.

As part of the effects on the competition in this agricultural market, based on the new needs and conditions, producers from Milpa Alta ought to generate possible profits in efficiency, such as improvements in the quality and as differentiator between goods and the introduction of new products in the relevant market (agroindustry) to adjust the competitive conditions between the producing areas.

Then, the condition of vicinity and the consequences of the differential of climates between the production zones cause for the yields per hectare to be different and, at the same time, it happens that the product in the production zone of the province is offered at lower prices compared to those from Milpa Alta. And, as mentioned, although both productions present different qualities, since the products are substitutes, it is still not possible to differentiate them, which is why they are offered and sold in the markets as equals.

This has its implications. For example, under the conditions explained, it could be assured that the Morelos zone is the most efficient and, therefore, the most accurate policy would

be to stimulate and to improve their production conditions, establishing strategies to improve the quality of their harvests and to reduce and eliminate the use of chemicals, both to increase the production so as to eliminate the pests.

However, the implementation of this type of policies in an area with the climate characteristics of Tlalnepantla should consider the trade-off between high productivity and low quality of the products; that is, it is possible that the costs associated to these policies in Morelos could be even higher.

In addition, the absence of Milpa Alta as producing area of this agricultural market, in the context of producers facing difficulties to perform new investments and interrupting their production would affect the behavior of the prices (Rojas and Rodríguez, 2017), would have adverse repercussions for the crop and for the population not just of the demarcation in itself that is devoted to this activity, but also because the main affected ones would be the nopal producers from Morelos since the price increments derived from the scarcity of production in Milpa Alta would disappear; that is, the initial incentives which are why the production from Morelos was made attractive.

In the same way, the price structure of the Tlalnepantla producing zone would be modified in such a way that it would be impossible to replicate the present income from the season of low productivity, because there would not be indications of scarcity to pressure prices upwards in the production zone of the province. This would imply the existence of a single process of price formation, and the price transmission and the effects of the amounts from one producing zone on the prices of the other would be null.

In other words, without nopal crops in Milpa Alta, the considerable price increase would not be possible whenever a frost or hail storm affected totally or partially the production. This would imply a considerable reduction of the profits from producers from Morelos. In addition, it would force the population that is currently devoted to this activity in Milpa Alta to transit towards other activities and to intensify the advancement of the ill planned urbanization, since it would cover the current nopal crops, all of this with its implications of social and environmental costs.

In this context, this could even make it more attractive for producers from Morelos to return to the crop of other products such as, for example, avocado or tomato. It should be made clear that this phenomenon already exists today, since some producers from Tlalnepantla observe higher returns in other crops because of the high productivity. Based on this, it is necessary to establish palliative mechanisms that provide comparable conditions for competition, which initially recognize the role that the producing areas studied play.

Thus, we recommend an intervention that ties the conditions of competition between producing zones, not under the figure of government supports or subsidies to one in order to make equivalent the returns from the other, without allowing the market to assign *per se* a particular efficiency to each production area.

Finally, to mitigate the effects of the transmission of the amounts of production from Morelos on the prices from Milpa Alta, it is required for the differentiation of productions

to be carried out based on the qualities-prices of products from Morelos and Milpa Alta, which would allow placing the commercialization in function of the preferences of the final consumer. All of this framed, initially, in the context of a complementary although fundamental strategy of dissemination of the regional consumption of nopal. In this way, the coefficient associated to the prices and the amounts of production from Morelos on the Milpa Alta prices could be reduced again and, therefore, the anti-competitive effects between nopal producing zones could be mitigated.

### CONCLUSIONS

The results corroborated anticompetitive conditions between nopal producers from Morelos and Milpa Alta. Specifically, the anticompetitive conditions are manifested from the effects generated by the equivalence of surface sown and the production between Morelos and Milpa Alta, which implied decreases of the quality of the product (from Morelos) and limitations in the innovation from lack of competition. These effects are unilateral and consequence of the implicit coordination between producers.

However, it is necessary to mention that the decreases in quality also affect the wellbeing of the consumer because, although they can obtain the product at a lower price, the nopal from Morelos has a different flavor, in addition to its intake including the chemical components of fumigations for their production and higher acidity. That is, a lower quality. Another mechanism of non-competitive practices is that the potential competitors from Milpa Alta do not identify enough profitability to enter the market, insofar as it is very complicated to gain access to the low season prices, while the producers from Morelos traded their production that did not decrease (from frosts or hail storms) at these prices. Therefore, the anticompetitive effects that the operations of Morelos farmers exert do not manifest as increments in the prices of the producing zone from Morelos, as could be expected, but rather inversely due to the condition of overproduction. This means that the vast production causes reductions of their own prices, although this producing zone compensates their expected income through the amounts. These low prices would serve as another entry barrier for new producers from Milpa Alta because, with this level of prices, it is not profitable to be inserted into this activity.

Thus, it was confirmed through the considerable modification of the coefficient associated to the price transmission between producing zones before the entry of the municipalities from Morelos to nopal production, between 2004-2005, compared to the same coefficient for the 2006-2017 period. In this sense, during the second period, the disturbances caused by seasonal excesses of the nopal offer in both markets had effects on the price formation of both producing zones.

Currently, the transmission between areas is symmetrical, which generates the attainment of higher margins in production and the commercialization by producers from Morelos due, essentially, to the condition required by the season of low productivity. The presence of symmetry in the transmission of price variations evidences faults in this market. This

deficiency is manifested as anticompetitive practices of some producers (from Morelos) on the rest of the competitors (from Milpa Alta), which is an obstacle to the economic and social development, particularly in the municipalities or locations of the periphery, because it affects the social welfare of producers, traders, as well as the consumer (Alvarado, Rodríguez and Iturralde, 2016).

From this, the evidence provided by the estimation of the econometric models is that through the high productivity derived from the climate, producers from Morelos restrict the market entry plans of other competitors (from both producing zones), so this becomes an entry barrier that very few economic agents can overcome.

### NOTES

<sup>3</sup>As defined by Articles 52, 53, 54, 55 and 56 of the Federal Law of Economic Competition.

<sup>4</sup>National producer prices index, June base 2012=100 (Sistema de Clasificación Industrial de América del Norte, SCIAN 2007), excluding oil per sector and subsector of economic activity of origin. Total (Merchandise and final services). Agriculture, breeding and exploitation of animals, forest exploitation, fishing and hunting. Agriculture (Index June base 2012=100).

<sup>5</sup>During the estimation there was the need to resort to the substitution of the nine dichotomous variables from the month of January by a seasonal one, although the results did not validate their inclusion.

<sup>6</sup>There is only evidence of autocorrelation in the first and fifth delays.

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