Colegio de Postgraduados

State-level analysis of the relationship between agricultural production and prices in Mexico

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ABSTRACT

Objective: To determine the relationship between the quantity produced of the main agricultural product of each Mexican state and its price.

Design/Methodology/Approach: Sixty-two cointegration tests were conducted to examine the relationship between the production levels and the price of the main agricultural product of each state, with the exception of Baja California due to lack of data.

Results: Generally, the price does not influence the production of the main agricultural product in the 31 states analyzed over the long term. Only fifteen exceptions were found in the 62 tests conducted, which contradicts the existing literature. This lack of influence could be attributed to the specific characteristics of the crops studied, the available infrastructure, state-specific conditions, or the implementation of government programs. However, as mentioned, there are exceptions.

Study Limitations: The States were not characterized in detail.

Findings/Conclusions: Overall, there is no significant relationship between the price and the production levels of the main agricultural product of each Mexican state.

Keywords: agricultural production, agricultural sector, prices, production.

INTRODUCTION

There are various economic theories that attempt to explain the relationships between the economic agents in the agricultural sector, specifically between suppliers or producers and demanders or consumers. Among the main economic theories that seek to explain these relationships are the neoclassical, institutional, and critical theories (Hernández *et al.*, 2020, 2021; Cardona *et al.*, 2007).

The neoclassical theory suggests that the agents in the agricultural sector should be studied as if they were businesses. This implies that agricultural producers aim to maximize their profits, minimize costs, and adjust their production levels in response to price fluctuations (Hernández *et al.*, 2022 a, 2022 b; Cardona *et al.*, 2007).

Additionally, various studies indicate that agricultural production in several countries is influenced by product prices, supporting the supply and demand model of neoclassical theory. Therefore, it is suggested that an increase in the agricultural sector prices leads to a rise in production volume due to the incentives created (Tonconi, 2015; García, 2020; Benítez, 2022; OCDE-FAO, 2011; Brambila *et al.*, 2014; Hernández *et al.*, 2022 a, 2022 b; Hernández y González, 2022; Flores, 2014; Roitbarg, 2021). Similarly, Brambila *et al.*, (2014) points out that in Mexico, the relationship between price and production in the agricultural sector is positive, aligning with other studies that suggest producers are motivated to increase production when prices rise, primarily due to the potential of higher profits (Fernández, 2008; Márquez *et al.*, 2006, Cardona *et al.*, 2007).

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This aligns with the neoclassical microeconomics theory's supply and demand model, which posits that producers are rational and will seek to maximize profits and minimize costs. Consequently, when prices rise, producers are likely to respond by increasing their production levels (Tarza *et al.*, 2008; Jenneth, 2009; Cardona *et al.*, 2007; Roitbarg, 2021; Rivera, 2017; Pindyck and Rubinfeld, 2009). However, this price-production relationship is influenced by factors such as the type of producer. Producers with more economic and technological resources are less vulnerable to price decreases because they can offset income losses through increased competitiveness and productivity, a strategy not available to producers with limited resources (De Grammont, 2010; Guzmán *et al.*, 2012). Accordingly, the main agricultural products produced in 2021 by each of the 31 States, as shown in Figure 1, will be affected by price variations.

In Figure 1, it can be observed that in 41.9% of the Mexican states (that is, in 13 states), the main product produced in 2021 is sugarcane. According to neoclassical microeconomics theory, sugarcane should vary in response to price fluctuations. Furthermore, since it is the main product, the relationship between price and production should be evident (Tarza *et al.*, 2008; Jenneth, 2009; Cardona *et al.*, 2007; Roitbarg, 2021; Rivera, 2017; Pindyck and Rubinfeld, 2009).

Based on the points raised in this section, the objective of this research is to determine the relationship between the quantity produced of the main agricultural product in each state and its price in Mexico. It is also hypothesized that there is a relationship between the quantity produced of the main agricultural product in each state and its price in Mexico.

MATERIALS AND METHODS

The methodology used in this research aims to achieve the objective and test the hypothesis previously presented. A total of 62 cointegration tests were conducted (31 with a trend and 31 without a trend), which allowed us to determine the following: the existence of the relationship between the quantity produced of the main agricultural product produced in each state and its price; that this relationship is long term; and the relationship is not spurious (Gujarati and Porter, 2010; Wooldridge, 2010).

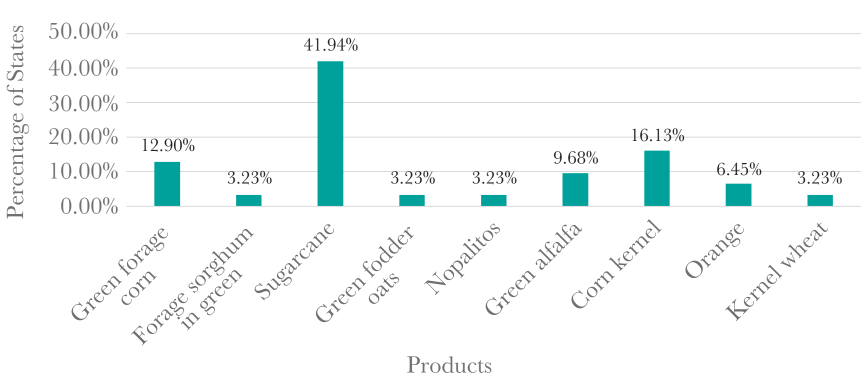

Figure 1. Main agricultural products produced in 2021 by each of the 31 states (the State of Baja California was excluded due to lack of data).
Source: Figure developed by the authors based SADER (2022) data.

The information used included the real price of crops per tons/hectares (deflated using the Índice Nacional de Precios al Consumidor published by the Instituto Nacional de Estadística y Geografía, 2022) and the quantity produced (production volume in tons related to the harvested area) of the main agricultural product of each Mexican state. The analysis period covered the years 1980 to 2021, and the data are annual (42 observations). This information was obtained from the databases on the website of the Secretaría de Agricultura y Desarrollo Rural (SADER, 2022).

Table 1 shows the main agricultural products produced in 2021 by each of the 31 states that were examined. It is worth mentioning that the state of Baja California was excluded from the study due to lack of information.

The States listed in Table 1 were analyzed through 62 cointegration tests, 31 with a trend and 31 without a trend, to provide a more comprehensive analysis. The goal was to determine if there is a long-term relationship between the quantity produced of each state's main agricultural product and its price, and to identify whether said relationship is spurious or not (Gujarati and Porter, 2010; Wooldridge, 2010). The models are based on the relationship between price and production as described and evidenced by several authors, including Tonconi (2015), García (2020), Benítez (2022), OECD-FAO (2011), Brambila *et al.*, (2014), Márquez *et al.*, (2006), Cardona *et al.*, (2007), and Roitbarg (2021), who suggest that producers seek to maximize their profits and, therefore, react to price variations.

In the cointegration tests conducted, price was treated as the exogenous variable, while the quantity produced was the endogenous variable, consistent with the supply and demand model of the neoclassical microeconomic theory. This approach also ensures that the model is free from endogeneity issues, as the price variable is not correlated with other unobserved variables (according to the cited literature).

Table 1. Products and States analyzed.

Federal entity	Main product produced	Represented by the abbreviations	Federal entity	Main product produced	Represented by the abbreviations
1. Aguascalientes	Green forage corn	A-MFV	16. Morelos	Sugarcane	Mor-CA
2. Baja California Sur	Forage sorghum in green	BCS-SFV	17. Nayarit	Sugarcane	N-CA
3. Campeche	Sugarcane	Ca-CA	18. Nuevo León	Orange	NL-N
4. Chiapas	Sugarcane	Chip-CA	19. Oaxaca	Sugar cane	O-CA
5. Chihuahua	Green fodder oats	Chih-AFV	20. Puebla	Sugar cane	P-CA
6. Ciudad de México	Nopalitos	CDMX-N	21. Querétaro	Green fodder corn	Que-MFV
7. Coahuila	Green alfalfa	Co-AV	22. Quintana roo	Sugarcane	QR-CA
8. Colima	Sugarcane	Col-CA	23. San Luís Potosí	Sugar cane	SLP-CA
9. Durango	Green fodder corn	D-MFV	24. Sinaloa	Corn kernel	Sin-MG
10. Estado de México	Corn kernel	EM-MG	25. Sonora	kernel wheat	Son-TG
11. Guanajuato	Green alfalfa	Gua-AV	26. Tabasco	Sugarcane	Tab-CA
12. Guerrero	Corn kernel	Gue-MG	27. Tamaulipas	Sugarcane	Tam-CA
13. Hidalgo	Green alfalfa	H-AV	28. Tlaxcala	Corn kernel	Tlax-MG
14. Jalisco	Sugarcane	J-CA	29. Veracruz	Sugarcane	V-CA
15. Michoacán	Corn kernel	Mich-MG	30. Yucatán	Orange	Y-N
			31. Zacatecas	Green fodder corn	Z-MFV

Source: Table developed by the authors based on SADER (2022) data.

According to Gujarati and Porter (2010) and Wooldridge (2010), before performing cointegration tests, it must first be established that the variables are non-stationary and of integration order one. To confirm that the variables are non-stationary, a unit root test of original order must be performed on each of the datasets analyzed. These authors suggest several unit root tests, one of which is the augmented Dickey-Fuller (ADF) test, known for its superior statistical properties compared to other tests like the Dickey-Fuller (DF), as it does not assume that the error term is uncorrelated.

It is important to note that the mention of 62 cointegration tests refers to the different conditions under which these tests were conducted. Each state's data (62 variables total) was tested both with and without a trend, leading to a total of 124 tests (62 with a trend and 62 without). These tests were further extended to analyze first differences, doubling the number to 248 tests, which ensures a comprehensive analysis of the variables under various scenarios.

To conduct the ADF test, Eviews software and the methodology described by Gujarati and Porter (2010) and Wooldridge (2010) were utilized. In total, 124 ADF tests were performed in their original order (62 with a trend and 62 without a trend). Specifically, four tests were conducted for each of the 31 States analyzed: two on the quantity produced of their main agricultural product (one with a trend and one without a trend) and two on the real price of the agricultural product (one with a trend and one without a trend). The ADF test in its original order is presented in Equation 1.

$$\Delta Y_t = \beta_1 + \beta_2 t + \delta Y_{t-1} + \sum_{i-1}^{m} \alpha_i \Delta Y_{t-1} + \varepsilon_t \quad (1)$$

Where: ε_t=is a pure white noise error term; ΔY_{t-1} =is the number of lagged difference terms that are included frequently.

In each of the ADF tests conducted in their original order, the Durbin-Watson statistic was first analyzed to ensure there were no autocorrelation issues. The Durbin-Watson statistic value needed to be above the point of significance (critical value) with an alpha of 5%, considering the respective values of k and n. Subsequently, the *p* values from the original order tests were analyzed. If the *p* value was greater than 0.05, the series had a unit root, meaning it was non-stationary; if it was less than 0.05, the series did not have a unit root, meaning it was stationary. Once it was determined that the variables analyzed were non-stationary in their original order, the order of integration was assessed.

To confirm that the analyzed variables were of integration order one, they needed to be stationary at the first difference. Thus, a second ADF test was conducted on all the variables, both with and without a trend, but this time using differences. Again, the Durbin-Watson statistic was analyzed to ensure there were no autocorrelation problems, followed by the analysis of the *p* values from these tests. This process involved performing 124 ADF tests, now with differences, to determine the order of integration. To verify that the variables analyzed were of integration order one, the series in the first difference had to be stationary, meaning that the *p* value of the ADF test needed to be less than 0.05.

If all the variables analyzed met the conditions of being non-stationary and of integration order one, the 62 cointegration tests were carried out. For this, the Eviews software was used. And following the methodology proposed by Gujarati and Porter (2010), and Wooldridge (2010), the augmented Engle-Grenger (AEG) method was applied. This involved conducting 62 cointegrations regressions using Eviews software, as presented in Equation 2.

$$Y_i = \beta_1 + \beta_2 X_{1i} + u_i \tag{2}$$

Where: Y_i=quantity produced from each state for a certain year i; β_1=intercept. β_2=cointegration parameter; X_{1i}=real price for each of the 31 products for a certain year i; u_i=estimated residuals from the cointegrating regression; u_i=year within the study period.

As mentioned by the authors, the residuals from the cointegrating regressions were obtained using Equation 2. Following this step, the AEG unit root test was applied to the 62 cointegration residuals to calculate the Engle-Granger tau statistic. This test is essential to determine whether the residuals are stationary and whether the variables are cointegrated. To do this, the p value of the Engle-Granger tau statistic is assessed. If the p value is less than 5%, it indicates that the cointegration residuals do not have a unit root and are therefore stationary, implying that the series are cointegrated in the long term. Conversely, if the p value of the Engle-Granger tau statistic is greater than 5%, it suggests that the cointegration residuals have unit roots and are non-stationary, indicating that the series are not cointegrated in the long term.

RESULTS AND DISCUSSION

The results of the 248 ADF unit root tests (conducted on the 62 variables analyzed from each of the 31 states, with and without trend in original order and with first differences) show no evidence of a positive serial correlation. In all cases, the value of the Durbin-Whatson statistic is above the critical point of significance (*i.e*, the critical Durbin-Whatson value with its respective k and n values).

In the 124 ADF unit root tests conducted on the 62 variables analyzed, both with and without trend in original order, all p values are greater than 0.05, indicating that the series have a unit root. This means that the variables —real price and quantity produced— are non-stationary in their original order with an alpha of 5%. Similarly, in the 124 ADF unit root tests conducted on the 62 variables analyzed, both with and without trend and with first differences, the p values of all the variables are less than 0.05, indicating that the series do not have a unit root and are stationary. Therefore, the variables are of integration order one. Based on the above, Table 2 presents the outcome of the 62 AEG unit root tests applied to the 62 residuals of the cointegration regressions (with and without trend), corresponding to the quantity produced with the real price for each state.

As shown on Table 2, in fifteen of the 62 tests, the p values of the Engle-Granger tau statistic from the AEG test, applied to the residuals of the cointegration regressions, are less than 0.05. This indicates that, according to Gujarati and Porter (2010), and Wooldridge

Table 2. Test results of the 62 cointegration tests from the 31 States.

State	Cointegration test	P-value of the Engle-Granger tau statistic	Constant	Trend	Series are cointegrated
A	MFV price with MFV production in A with trend	0.002	0	0	Yes
	MFV price with MFV output at A without trend	0.943	0.012	-	No
BCS	SFV price with SFV production in BCS with trend	0	0	0	Yes
	SFV price with SFV production in BCS without trend	0.972	0.211	-	No
Ca	CA price with CA production in Ca with trend	0.949	0.715	0.013	No
	CA price with CA production in Ca without trend	0.757	0.131	-	No
Chiap	Price of CA with the production of CA in Chiap with trend	0.988	0	0	No
	CA price with CA production in Chiap without trend	0.518	0.004	-	No
Chih	AFV price with AFV production in Chih with trend	0.565	0.848	0.018	No
	AFV price with AFV production in Chih without trend	0.244	0	-	No
CDMX	Price of N with N production in CDMX with trend	0.981	0.088	0.056	No
	Price of N with N production in CDMX without trend	0.21	0	-	No
Co	AV price with AV production in Co with trend	0.366	0.006	0	No
	AV price with AV production in Co without trend	0.821	0.383	-	No
Col	CA price with CA production in Col with trend	0.509	0.097	0	No
	CA price with CA production in Col without trend	0.689	0.309	-	No
D	MFV price with MFV production in D with trend	0.970	0.977	0	No
	MFV price with MFV production in D without trend	0.959	0	-	No
EM	MG price with MG production in EM with trend	0.011	0	0.954	Yes
	MG price with MG production in EM without trend	0.002	0	-	Yes
Gua	AV price with AV production in Gua with trend	0.158	0	0	No
	AV price with AV production in Gua without trend	0.536	0	-	No
Gue	MG price with MG production in Gue with trend	0	0	0	Yes
	MG price with MG production in Gue without trend	0	0	-	Yes
H	AV price with AV production in H with trend	0.552	0.003	0	No
	AV price with AV production in H without trend	0.771	0	-	No
J	CA price with CA production in J with trend	0.007	0	0	Yes
	CA price with CA production in J without trend	0.384	0.165	-	No
Mich	MG price with MG production in Mich with trend	0	0.011	0	Yes
	MG price with MG production in Mich without trend	0.517	0	-	No
Mor	CA price with CA production in Mor with trend	0.726	0.002	0.239	No
	CA price with CA production in Mor without trend	0.565	0.006	-	No
N	CA price with CA production in N with trend	0.176	0	0	No
	CA price with CA production in N without trend	0.246	0	-	No
NL	N price with N production in NL with trend	0.183	0.118	0.079	No
	N price with N production in NL without trend	0.191	0	-	No
O	CA price with CA production in O with trend	0.207	0.002	0.553	No
	CA price with CA production in O without trend	0.082	0	-	No

Table 2. Continues.

State	Cointegration test	P-value of the Engle-Granger tau statistic	Constant	Trend	Series are cointegrated
P	CA price with CA production in P with trend	0.005	0	0	Yes
	CA price with CA production in P without trend	0.089	0	-	No
Que	MFV price with MFV production in Que with trend	0.803	0.967	0	No
	MFV price with MFV production in Que without trend	0.93	0.03	-	No
QR	CA price with CA production in QR with trend	0.009	0.003	0	Yes
	CA price with CA production in QR without trend	0.272	0.202	-	No
SLP	Price of CA with CA production in SLP with trend	0.007	0	0	Yes
	Price of CA with CA production in SLP without trend	0.063	0.221	-	No
Sin	Price of MG with MG production in Sin with trend	0.154	0.797	0	No
	Price of MG with MG production in Sin without trend	0.710	0	-	No
Son	Price of TG with TG production in Son with trend	0.041	0.061	0.001	Yes
	Price of TG with TG production in Son without trend	0.119	0	-	No
Tab	Price of CA with CA production in Tab with trend	0.186	0	0	No
	Price of CA with CA production in Tab without trend	0.489	0.321	-	No
Tam	Price of CA with CA production in Tam with trend	0.085	0	0.003	No
	Price of CA with CA production in Tam without trend	0.075	0.056	-	No
Tlax	Price of MG with MG production in Tlax with trend	0	0.264	0.001	Yes
	Price of MG with MG production in Tlax without trend	0	0	-	Yes
V	Price of CA with CA production in V with trend	0.002	0	0	Yes
	Price of CA with CA production in V without trend	0.625	0	-	No
Y	Price of N with N production in Y with trend	0.378	0	0.189	No
	Price of N with N production in Y without trend trend	0.223	0	-	No
Z	MFV price with MFV production in Z with trend	0.525	0.143	0	No
	MFV price with MFV production in Z without trend	0.715	0	-	No

Source: developed by the authors based on SADER (2022) data.

(2010), with an alpha of 5%, the variables do not have unit roots, so they are stationary, meaning they are cointegrated, both with and without trend. This implies a long-term relationship between the variables. These exceptions include the real price and production in the states of Aguascalientes, Baja California Sur, Jalisco, Michoacán, Puebla, Quintana Roo, San Luis Potosí, Sonora, and Veracruz (with trend), as well as the State of Mexico, Guerrero, and Tlaxcala (with and without trend). Additionally, in 47 of the 62 tests conducted, the p values are greater than 0.05, which implies that, with an alpha of 5%, the variables have a unit root and are therefore non-stationary, meaning they are not cointegrated, whether with or without trend. This indicates that there is no long-term relationship between the real price and production of the main agricultural product in each State.

The results of the cointegration tests suggest that, in most cases, the real price does not have a relationship with the quantity produced of the main agricultural product in each

Mexican state during the period from 1980 to 2021. In other words, the results indicate that, in general, the main agricultural product in each state does not correlate with its price. These findings contradict studies presented by various authors —Tonconi (2015), García (2020), Benítez (2022), OECD-FAO (2011), Brambila *et al.* (2014), Márquez *et al.* (2006), Cardona *et al.* (2007), Roitbarg (2021)— who argue that when prices rise, producers have incentives to increase production, and conversely, when prices fall, producers have incentives to decrease production.

Additionally, it is important to note that other research —such as that by De Grammont (2010) and Guzmán *et al.* (2012)— indicates that the relationship between price and production can be influenced by the type of producer, as producers with more economic and technological resources are less exposed to the effects of price decreases. The neoclassical microeconomic theory's supply and demand model also suggests that the price-production relationship may not materialize due to factors such as government intervention through subsidized programs. In Mexico, government programs like PROCAMPO may explain the lack of a relationship between price and production. Another reason for the lack of reaction in production to price changes could be that producers lack the economic and technological resources needed to take advantage of price increases (Guzmán *et al.*, 2012; Roitbarg, 2021; De Grammont, 2010; Guzmán *et al.*, 2012; Hernández *et al.*, 2022 a, 2022 b). It is also important to mention that the results of this research do not determine whether the support programs for the agricultural sector provided by the Mexican government distort the relationship between prices and production (Brambila *et al.*, 2014; Márquez *et al.*, 2006; Flores, 2014).

The implications of these results for policymakers designing government programs are that they must consider the impact of these programs on the relationship between production and product prices, as they can distort it. Furthermore, they must recognize that there are products in Mexico's agricultural sector that do not respond to price fluctuations, possibly due to the sector's infrastructure. Therefore, policies should focus on creating conditions that enable producers to better capitalize on price variations. On the other hand, producers should acknowledge that if their production does not respond to price fluctuations, they need to take measures to better position themselves to take advantage of these variations.

CONCLUSIONS

The results of the 62 cointegration tests conducted to determine the relationship between the quantity produced of the main agricultural product of each state and its price in Mexico indicate that, in most cases, there is no significant relationship. However, there were 15 exceptions where evidence of a relationship was found. These exceptions include the states of Aguascalientes, Baja California Sur, Jalisco, Michoacán, Puebla, Quintana Roo, San Luis Potosí, Sonora, and Veracruz with a trend, and State of Mexico, Guerrero, and Tlaxcala with and without trend.

This research does not allow us to pinpoint the specific factors that cause the price to have no relationship with production in these states. However, according to the literature review, this relationship could be influenced by the conditions of the producers, which may prevent them from capitalizing on price variations, or by the government programs provided to the agricultural sector. These programs could potentially distort or even negate the relationship between price and production.

The research successfully achieved its objective, which was to determine the relationship between the quantity produced of the main agricultural product in each state and its price in Mexico. However, the hypothesis that there is a relationship between the quantity produced and its price is generally rejected, with the exception of the 15 cases noted earlier. Some limitations of the research include the fact that the conditions of the producers were not examined, and not all products by state were analyzed. As future lines of research, it is recommended to identify specific characteristics that cause the relationship between prices and production to be inconsistent.

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