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Economic cointegration of the North American agricultural sector

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ABSTRACT
Objective: To determine if the Mexican, Canadian, and American agricultural industries are cointegrated.
Methodology: Six cointegration tests were carried out between the Mexican, Canadian, and American agricultural, forestry, fishing, and hunting industries, as well as the Mexican animal husbandry and exploitation sector. The USA was the independent variable in all cases.
Results: The Mexican sector, with an α of 5% (with and without trend) is not cointegrated with the USA and Canada, while Canada and the USA, with an α of 5% (with and without trend) are cointegrated.
Study Limitations/Implications: The agricultural sector of the three countries were not analyzed separately and the Engle-Granger causality test was not used. Although some products from Mexico's agricultural sector have managed to make inroads in the USA and Canada, further advances are still possible. Therefore, there are areas of improvement for Mexican products. Likewise, NAFTA and the USMCA/CUSMA have failed to achieve their objective of cointegrating the agricultural sectors of the three nations.
Conclusions: The Mexican sector was not cointegrated with the American and Canadian sectors during the analysis period —*i.e.*, the Mexican sector is not influenced by and does not have the same long-term behavior (with delays) than the USA and Canadian sectors. However, the Canadian sector is cointegrated with the USA sector —*i.e.*, the Canadian sector is influenced and has the same long-term behavior than the USA sector.

Keywords: North America; agricultural sector; cointegration; NAFTA; USMCA; CUSMA.

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INTRODUCTION

Globalization included integration processes carried out through trade agreements. One of the most important agreements was the North American Free Trade Agreement (NAFTA) which came into force in January 1, 1994 and sought to integrate the economies of México, the United States, and Canada. It consisted of several measures, such as lifting tariffs. Nevertheless, Mexico has signed other important trade agreements with several countries, including Colombia, Nicaragua, and Israel. The most recent agreement is the Comprehensive and Progressive Agreement for Trans Pacific Partnership (CPTPP) (Puyana, 2020; Nava, 2021; Infante *et al.*, 2021). In addition, NAFTA was replaced in 2020 by a new treaty between Mexico, the United States, and Canada (USMCA/CUSMA). Both NAFTA and USMCA/CUSMA have impacted the economies of the three countries and they have led to an economic cointegration, as evidenced by the percentage of exports (85%) and imports (40%) of Mexico to and from the United States in 2019 (Santa, 2019; Morales *et al.*, 2016; Garza-Rodríguez, 2016; Valencia *et al.*, 2021; Leos and García, 2018).

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The aim of both treaties was to promote trade and to achieve the long-term integration (*i.e.*, the cointegration) of the Mexican, American, and Canadian economic sectors (such as agriculture). This cointegration would allow the economic sectors of the three countries to react to changes in demand in the other members of the group. For example, if consumer demand in the United States increases (independent variable), due an income increase, the Mexican agricultural sector would increase its production (dependent variable), although this reaction on the part of Mexico would be delayed. In this regard, some of the countries' agri-food products are co-integrated, as a result of several factors, including: long-term relationships between producers, traders, and consumers in the three countries; and the large percentage of products that some sectors of the Mexican agricultural sector export to the United States (*e.g.*, fruits and vegetables). The cointegration of Mexico with Canada and the USA is evidenced by the increase and diversity of Mexican exports. Likewise, some products from Mexico's agri-food sector, such as vegetables and fruits, have taken advantage of trade agreements to position themselves in the American market. Furthermore, Mexican producers have focused on the production of export goods, contributing to the cointegration of Mexico with Canada and the USA (Jaime *et al.*, 2015; Chávez *et al.*, 2019; González, 2017).

Meanwhile, not all sectors and markets in the three countries have achieved cointegration, particularly the labor market. Additionally, the commercial and financial integration within the region is heterogeneous. Finally, the evidence provided by theoretical and empirical models has not been conclusive with regard to the synchronization of economic cycles and the cointegration of the abovementioned sectors. Specifically, the cointegration of the agricultural sectors of the three countries will depend on the type of crop, the type of relationships formed between the countries, and the type of producer. Producers who have greater organization, education, and economic resources will be able to export their products and establish strategic alliances with groups from other countries (González, 2017; Pérez, 2019; Anguiano and Ruiz, 2022).

Mexican farmers are at a disadvantage compared with American producers, whose goods are subsidized, while in Mexico such support has decreased (Jaime *et al.*, 2015; Chávez *et al.*, 2019; Infante *et al.*, 2021). In this regard, if Mexico's agricultural sector is to take advantage of commercial openness and achieve co-integration, it must overcome the sector's structural lags, increase its productivity with technology, and design long-term strategies. In this sense, Pérez *et al.* (2019) indicate that the growth of the agricultural sector responds to: the production area that is irrigated; the economically active population of the agricultural sector; and the volume of fertilizers applied.

Meanwhile, the unbalanced rules and conditions established in the treaties that negatively affected Mexico have prevented the cointegration of the productive sectors; these factors were not taken into account during the negotiation of the trade agreements. For instance, the USA imposed its rules, such as the periods of tax relief on imports and the establishment of non-tariff barriers. The USA applied these rules to the entry of crops that could have a negative effect on its competitiveness. There is also an inequality between the economies of the three countries: for example, in 2017, the *per capita* income of Mexico, the USA, and Canada amounted to $8,688, $61,247, and $44,487 USD, respectively. Likewise, there are

differences in the competitiveness of the sectors in the three countries. For example, some agricultural products from the USA and Canada are more productive than their Mexican equivalents. Finally, the USA has had an enormous influence on Mexico's economy, even before the entry into force of the trade agreements (Puyana, 2020; Chávez *et al.*, 2019; Jaime *et al.*, 2015; Infante *et al.*, 2021). Therefore, the cointegration of the three countries must analyzed to determine the impact of trade agreements in Mexico's agricultural sector, detect potential areas of improvement, and develop policies to take advantage of those opportunities. In conclusion, the objective of the research was to determine whether the agricultural industries of Mexico, Canada, and the United States are cointegrated.

METHODOLOGY

The methodology of this research aims to determine if the agricultural industries in Mexico, Canada, and the United States are co-integrated. For this purpose, six cointegration tests of the three countries were carried out. In the case of Mexico, the *agricultura*, *cría y explotación de animales*, *aprovechamiento forestal*, *pesca y caza* (agriculture, animal husbandry and exploitation, forestry, fishing, and hunting) heading was extracted from the National Institute of Statistics and Geography website (INEGI, 2023); in the case of Canada, the agriculture, forestry, fishing, and hunting heading was obtained from the Statistics Canada website (StatCan, 2023); finally, the agriculture, forestry, fishing, and hunting sector was extracted from the Bureau of Economic Analysis of the U.S. Department of Commerce website (BEA, 2023). The analysis covered the quarterly databases from the January, 2012-December, 2022 period.

These sectors were chosen in view of their comparativeness, although not all countries have divided these sectors in the same way. In addition, the values of the Mexican and Canadian databases were changed to U.S. dollars. The value of the agriculture, animal husbandry and exploitation, forestry, fishing, and hunting sector in Mexico was changed from Mexican pesos to US dollars. A quarterly average of the FIX exchange rate extracted from the Banco de México website (BANXICO, 2023) was used; in the case of Canada, a quarterly average of the official exchange rate of the Bank of Canada (Statcan website, 2023) was used to calculate the exchange rate from Canadian dollars to US dollars. Averages were applied, because the reports for the three sectors are developed on a quarterly basis; likewise, the three sectors were already deflated. Cointegration tests were performed on the three sectors (Table 1).

Table 1. Cointegration tests between the North American countries.

Cointegration tests	Expected results
México-Estados Unidos without a trend	That they are cointegrated
México-Estados Unidos with a trend	
México-Canadá without a trend	
México-Canadá with a trend	
Canadá-Estados Unidos without a trend	
Canadá-Estados Unidos with a trend	

Source: Table developed by the authors.

The six cointegration tests (three with a trend and three without a trend) shown in Table 1 were carried out to determine the existence of a long-term relationship and to establish whether or not the relationship between the Mexican agriculture, animal husbandry and exploitation, forestry, fishing and hunting sector with the agriculture, forestry, fishing, and hunting sector in Canada and the United States —along with the relationship between the same sectors in Canada and USA. The expected result is that the three sectors are co-integrated. These tests are based on the authors mentioned in the theoretical framework, who state that NAFTA and the USMCA/CUSMA have co-integrated the economic sectors of Mexico, Canada, and the United States. For instance, some Mexican produces (such as vegetables) have managed to position themselves in the American market.

Hence, in two of the cointegration tests, the independent variable is the agriculture, forestry, fishing, and hunting sector of the USA and the dependent variable is the agriculture, animal husbandry and exploitation, forestry, fishing, and hunting sector of Mexico. In the other two, the independent variable is the agriculture, forestry, fishing, and hunting sector of Canada and the dependent variable is the agriculture, animal husbandry and exploitation, forestry, fishing, and hunting sector of Mexico. In the two last ones, the independent variable was the agriculture, forestry, fishing, and hunting sector of the United States and the dependent variable was the agriculture, forestry, fishing, and hunting sector of Canada. A bibliographic review supports the following conclusions: that the USA, as the largest of the North American countries, influences the Mexican and Canadian economic sectors; that NAFTA and USMCA/CUSMA have successfully co-integrated the economic sectors of the three countries; and that there is an asymmetry in the size of the economies of the NAFTA and USMCA/CUSMA countries. Therefore, the cointegration tests are free of endogeneity, since the variables are not correlated with the non-observed variables.

According to Gujarati and Porter (2010) and Wooldridge (2010), the initial step of cointegration tests is to determine if the variables meet the non-stationary condition and if they are all in the order of integration one. Therefore, to determine if the variables are non-stationary, a unit root test of original order must first be done for each one. According with the abovementioned authors, there are several unit root tests, including the augmented Dickey-Fuller test (DFA), which has greater statistical properties (*e.g.*, it does not assume that the error term is not correlated) than other tests, including the Dickey-Fuller test. The DFA tests, in original order, were executed using the Eviews software and the methodology described by Gujarati and Porter (2010) and Wooldridge (2010). In total, six DFA tests were performed in their original order, two for each of the three variables (three with a trend and three without a trend). The DFA test in its original order is shown 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} =the number of lagged difference terms that are frequently included.

The Durbin-Watson statistic will be examined in its original order, using the first six DFA tests to establish that they have no autocorrelation problems. Therefore, the Durbin-Watson statistic value must be above the critical value (α=5%), with its respective k and n values. The p values of the original order tests were then analyzed. If they were greater than 0.05, the series had a unitary root and it would not be stationary. Meanwhile, if they were lower than 0.05, the series had no unit root and it was therefore stationary. Determining that the three analyzed variables are non-stationary in their original order (with and without trend) meant that the variables were of order of integration one.

For the variables to be in order of integration one, they should be stationary in the first difference. According to the abovementioned authors, a second DFA test must be carried out, including diverse variables (three with a trend and three without a trend). In other words, six DFA tests were performed. The Durbin-Watson statistic is examined once more to establish that there are no autocorrelation problems. The p value of the DFA tests with differences is analyzed next to establish that the variables analyzed are of integration order one. In the first difference, the series must not have a unit root and will therefore be stationary, with a p value lower than 0.05.

If the variables are non-stationary and of integration order one (Table 1), the six integration tests (three with trend and three without trend) would then be performed. The Eviews software will be used for these tests and, following Gujarati and Porter (2010) and Wooldridge (2010), the Augmented Engle-Grenger (EGA) method will be applied. Therefore, six co-integral regressions were performed as shown in Equation 2.

$$Y_i = \beta_1 + \beta_2 X_{1i} + u_i \quad (2)$$

Where: Y_i = one of the sectors of the countries for a given quarter i. β_1 = intercept. β_2 = cointegrating parameter. X_{1i} = one of the sectors of the countries for a given quarter i. u_i = estimated residuals from the cointegrating regression. i = year within the study period.

Based on Gujarati and Porter (2010) and Wooldridge (2010), the cointegrated residuals are determined with the six cointegrated regressions. The EGA unit root test was applied to the six cointegranted residues, in order to obtain the Engle-Granger tau statistic and, subsequently, to establish if the residues are stationary and to determine if the variables are cointegrated. If the p value of the Engle-Granger tau statistic is less than 5%, the cointegrated residues have no unit root and, therefore, are stationary. This result would imply that the series are cointegrated in the long term, whereas, if the p value of the Engle-Granger tau statistic is greater than 5%, the cointegraded residues have roots and are not stationary, showing that the series are not cointegrated in the long term.

RESULTS AND DISCUSSION

As indicated in the methodology, the six DFA unit root tests (three without trend and three with trend, in original order) were estimated first for the analyzed variables. The DFA unit root test results are shown in their original order in Table 2.

Table 2. Results of the six DFA unit root tests (with and without trend) of the variables analyzed from the original order.

Variable	P value (DFA test at original order)	P value of the last lag	P value of the trend	Value of the Durbin-Watson statistic with an alpha of 5% and n=42.	Significance point of the Durbin-Watson statistic	Is there a positive serial correlation?
Agriculture, animal husbandry and exploitation, forestry, fishing and hunting sector of Mexico without trend	0.152	0	-	1.904	1.72	No, because 1.90 is greater than 1.72
Agriculture, forestry, fishing, and hunting sector of the USA without tred	0.117	0.094	-	1.933	1.666	No, because 1.933 is greater than 1.666
Agriculture, forestry, fishing, and hunting sector of Canada without tred	0.137	0.966	-	1.999	1.958	No, because 1.999 is greater than 1.958
Agriculture, animal husbandry and exploitation, forestry, fishing and hunting sector of Mexico with trend	0.377	0	0.496	1.924	1.776	No, because 1.924 is greater than 1.776
Agriculture, forestry, fishing, and hunting sector of the USA with tred	0.095	0.591	0.038	1.99	1.776	No, because 1.99 is greater than 1.776
Agriculture, forestry, fishing, and hunting sector of Canada with tred	0.204	0.602	0.183	2.024	2.022	No, because 1.024 is greater than 1.022

Source: Table developed by the authors.

Table 2 shows no evidence of a positive serial correlation, because the value of the Durbin-Watson statistic in all cases is above the significance point (with its respective k and n values). In the six DFA unit root tests (with and without trend, in original order), the p values were always >0.05, indicating that the series had a unit root, with and without trend. In conclusion, variables with and without trend are non-stationary in their original order ($\alpha=5\%$). Table 3 shows the DFA unit root tests, although their initial differences are included to determine the order of integration.

Table 3 shows the DFA unit root tests, with and without trend and with their initial differences, proving the lack of a positive serial correlation. In all cases, the value of the Durbin-Watson statistic is above the significance point (with its respective k and n values). Additionally, all the p values of the DFA unit root tests, with and without trend, with initial differences, are lower than 0.05, proving that the series have no unit root and are stationary. Therefore, all variables are in order of integration one. Table 4 shows the results of the six EGA unit root tests applied to the six residues of the cointegrated regressions (three without trend and three with trend).

In the case of the relationship of Mexico with the US and Canada, the p values of the Engle-Granger tau statistic from the EGA test, applied to the residues of cointegrant regressions, are greater than 0.05 (Table 4). According to Gujarati and Porter (2010) and Wooldridge (2010), variables with an α of 5% have unit roots and, therefore, are not stationary, since they are not cointegrated, with and without a trend. Consequently, they do not have a long-term relationship. Meanwhile, the p values of the Engle-Granger tau statistic from the EGA test for the relationship between Canada and the US, applied to the residues of cointegrant regressions, are lower than 0.05. According to Gujarati and Porter

Table 3. Results of the six DFA unit root tests (with and without trend) of the analyzed variables with first differences.

Variable	P value (DFA test with first differences)	P value of the last lag	P value of the trend	Value of the Durbin-Watson statistic with an alpha of 5% and n=42.	Significance point of the Durbin-Watson statistic	Is there a positive serial correlation?
Agriculture, animal husbandry and exploitation, forestry, fishing and hunting sector of Mexico without trend	0	0	-	2.122	1.666	No, because 2.12 is greater than 1.66
Agriculture, forestry, fishing, and hunting sector of the USA without tred	0	0	-	2.064	1.615	No, because 2.064 is greater than 1.615
Agriculture, forestry, fishing, and hunting sector of Canada without tred	0	0.77	-	2.06	1.835	No, because 1.06 is greater than 1.835
Agriculture, animal husbandry and exploitation, forestry, fishing and hunting sector of Mexico with trend	0	0	0.581	2.139	1.72	No, because 2.139 is greater than 1.72
Agriculture, forestry, fishing, and hunting sector of the USA with tred	0	0	0.815	2.067	1.666	No, because 2.067 is greater than 1.666
Agriculture, forestry, fishing, and hunting sector of Canada with tred	0	0.639	0.409	2.064	1.895	No, because 2.064 is greater than 1.895

Source: Table developed by the authors.

Table 4. Results of the six cointegration tests.

Cointegration test	Independent variable	Constant	Trend	P-value of the Engle-Granger tau statistic	Are they cointegrated?
México-Estados Unidos without trend	0.013	−0.002	-	0.431	No
México-Estados Unidos with trend	−0.102	−0.024	0.001	0.629	No
México-Canadá without trend	0.01	−0.001	-	0.384	No
México-Canadá with trend	0.01	−0.022	0	0.619	No
Canadá-Estados Unidos without trend	3.694	−0.03	-	0	Yes
Canadá-Estados Unidos with trend	3.169	0.068	0.004	0	Yes

Source: Table developed by the authors.

(2010) and Wooldridge (2010), variables with an alpha of 5% do not have unit roots and, therefore, are stationary —*i.e.*, they are cointegrated, with and without trend.

The agriculture, animal husbandry and exploitation, forestry, fishing, and hunting sectors of Mexico were not co-integrated with the agriculture, forestry, fishing, and hunting sectors of the United States and Canada during the analysis period (January, 2012-December, 2022); therefore, the Mexican sector is not influenced and does not have the same long-term behavior (with delays) than the American and Canadian sectors. However, Canadas' agriculture, forestry, fishing, and hunting sectors are co-integrated

with their American equivalents —in other words, the Canadian sector is influenced and has the same long-term behavior (with delays) than the US sector.

Consequently, NAFTA and USMCA/CUSMA had not successfully integrated the Mexican agriculture, animal husbandry and exploitation, forestry, fishing, and hunting sectors with the agriculture, forestry, fishing, and hunting sectors of the United States and Canada during the analysis period (January, 2012-December, 2022). Therefore, trade agreements have not achieved their objective for these sectors (Puyana, 2020; Puchet *et al.*, 2014; Anguiano and Ruiz, 2022; Nava, 2021; Infante and López, 2019).

The results match the conclusions of Pérez (2019), who points out that not all economic sectors are co-integrated, since co-integration can vary from sector to sector. Meanwhile, Anguiano and Ruiz (2022) established that the cointegration of economic sectors is not always achieved. For their part, González (2017), Jaime *et al.*, (2015) and Chávez *et al.*, (2019) agreed that some products from the Mexican agricultural sector (such as fruits and vegetables) are co-integrated with the USA, because Mexico exports a large percentage of its production to that country. However, these results have not been enough for the co-integration of this Mexican sector. The lack of cointegration of Mexico's agricultural sector can be attributed to its structural lags —*i.e.*, the lack of technology and the absence of long-term strategies that have hindered its productivity— as well its disadvantage with regard to other competitors, such as the USA —resulting from the subsidies that the American government has invested on its farmers, while in Mexico such supports have decreased (Infante and López, 2019; Chávez *et al.*, 2019; Infante *et al.*, 2021).

The objective of this research was to determine if the Mexican, Canadian, and American agricultural industries are co-integrated. For this purpose, six cointegration tests were applied to the agricultural sectors of the three countries. In the case of Mexico, the agriculture, animal husbandry and exploitation, forestry, fishing, and hunting heading was evaluated; in the case of Canada and the United States, the agriculture, forestry, fishing, and hunting heading was used. The analysis period ranged from January, 2012 to December, 2022. The results showed that the Mexican sector, with an α of 5% (with and without trend), is not co-integrated with the USA and Canada, whereas Canada and the USA, with an alpha of 5% (with and without trend), are co-integrated. Therefore, the agriculture, animal husbandry and exploitation, forestry, fishing, and hunting sector in Mexico was not co-integrated with the agriculture, forestry, fishing, and hunting sectors of the United States and Canada from January 2012 to december 2022.

CONCLUSIONS

The Mexican sector is not influenced and does not have the same long-term behavior (with delays) as the equivalent sectors in the US and Canada. The Canadian agricultural, forestry, fishing and hunting sector is cointegrated with its American counterpart; That is, the Canadian sector is influenced and has the same long-term behavior (with delays) as the US sector. Although some Mexican agricultural products have entered the United States and Canada, it has not been enough. This situation opens areas of improvement for the export of more products from Mexico to the United States and Canada. NAFTA and the USMCA/CUSMA have not cointegrated the Mexican, Canadian and US sectors.

Mechanisms, such as avoiding subsidies, should be explored and proposed to achieve the objectives of these treaties. Possible lines of research could include the disaggregation of the sectors and the application of the Engle and Granger causality test, as well as the short-term adjustment mechanism (in the case of Canada and the United States).

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