Agricultura, Sociedad y Desarrollo

SUB-SECTORS RELATED TO THE AGRICULTURAL SECTOR AND TO DEMAND FROM THE UNITED STATES OF AMERICA

Humberto **Banda-Ortiz**, Luis Miguel **Cruz-Lázaro***, Omar **Bautista-Hernández**

Universidad Autónoma de Querétaro. Facultad de Contaduría y Administración. Centro Universitario, Cerro de las Campanas s/n, Querétaro, Qro., México. 76010.
*Corresponding author: luis.miguel.cruz@uaq.mx

ABSTRACT

In this article, we aim to determine the relationship between various industrial subsectors linked to Mexico's agricultural sector, as well as to demand in the United States. Twenty co-integration tests and four data panels were implemented in five subsectors linked to Mexico's agricultural sector and to demand in the United States. The latter is represented by consumption expenditure and personal income in the United States. Results from co-integration tests indicate that the subsectors linked to Mexico's agricultural sector are not co-integrated with consumption expenditure and personal income in the United States; and the data panels corroborate the results from the co-integration tests. We conclude that the subsectors linked to Mexico's agricultural sector are not co-integrated with demand from the United States of America despite trade agreements, and that although Mexico's agricultural sector is co-integrated with demand from the United States of America; this does not benefit its subsectors. Therefore, areas of opportunity still exist, where policies could be created to support producers, so they can co-integrate with demand from the United States of America, and where those sectors that are already co-integrated can create production chains and benefit other sectors and subsectors.

Keywords: co-integration, demand, government support, mexican agricultural sector, mexican industrial sectors, North America.

Citation: Banda-Ortiz H, Cruz-Lázaro LM, Bautista-Hernández O. 2025. Sub-sectors related to the agricultural sector and to demand from the United States of America. Agricultura, Sociedad y Desarrollo https://doi.org/10.22231/asyd.v22i4.1719

ASyD(22): 476-494

Editor in Chief:
Dr. Benito Ramírez Valverde

Received: July 22, 2024.
Approved: January 15, 2025.

Estimated publication date:
September 12, 2025.

INTRODUCTION

Mexico has promoted its trade with other countries so that its producers can export their products, improve income, and generate productive chains, benefiting various sectors. Among the strategies implemented to achieve this objective are trade agreements with different countries such as the United States of America (USA), Colombia, Nicaragua, and Israel. Of these, the most important agreement is the North American Free Trade Agreement (NAFTA), later the United States-Mexico-Canada Agreement (USMCA), which aims to economically co-integrate countries in the North American region (Anguiano and Ruiz, 2022; Ramírez, 2021; Chávez *et al.*, 2019; Puchet *et al.*, 2011).

These agreements have deepened Mexico's trade with the US and have led several Mexican industrial sectors and subsectors to co-integrate with the US; that is to develop long-term economic relationships between industrial sectors and subsectors and the US economy. Thus, when a US economic variable changes Mexico's related economic variable reacts. For example, when demand for a US agricultural product increases, the agricultural sector and its related subsectors in Mexico respond by increasing their production, in order to maximize profits. Likewise, demand for sectors related to the agricultural sector increases, benefiting these sectors (Nava, 2021; Puyana, 2020; Santa, 2019; Chávez *et al*., 2019).

Notably, prior to the trade agreements, the US was already Mexico's principal trading partner. This is attributed to the proximity of both countries and the fact that the US is the world's largest economy. This has resulted in several Mexican industrial sectors and subsectors, such as the agricultural industry, specializing in production for export to the US; the creation of value chains or relationships between Mexico's industrial sectors and subsectors; and the dependence of producers in the agricultural sector and related subsectors on US demand (Hernández *et al*., 2020, 2021, 2022a, 2022b; Infante *et al*., 2021; Chávez *et al*., 2019; Infante and López, 2019).

However, some authors (Infante *et al*., 2021; González, 2017; Jaime *et al*., 2015) indicate that, although sectors are co-integrated, this can vary, if subsectors and the relationships between sectors and subsectors are analyzed. Analyzing these relationships allows us to identify areas of opportunity for the development of government policies that support subsectors related to Mexico's agricultural industry and to discover the relationships between the various subsectors. Therefore, our research objective is to determine the relationship between various subsectors linked to Mexico's agricultural sector, and to demand from the United States of America.

THEORETICAL FRAMEWORK

Mexico's main trading partner is the United States of America (USA), and its industrial sectors and subsectors are said to be co-integrated by: the trade agreement known as the North American Free Trade Agreement (NAFTA), later replaced by the United States-Mexico-Canada Agreement (USMCA); globalization. This has caused trade between these countries to increase due to the creation of trade chains between the countries; the fact that the United States is the largest economy in the world; Mexico's proximity to the United States and the trade relationships that have been formed between the two countries. Likewise, in search of greater profits and taking advantage of trade agreements, several Mexican producers have oriented their production to meet demand for agricultural products from the United States. This also affects the Mexican subsectors linked to those sectors that are co-integrated (export) with the USA, as by increasing their production, they demand greater production inputs (Ramírez, 2021; Infante and López, 2019; González, 2017).

This co-integration of Mexico with the US means that Mexico's industrial sectors and subsectors have long-term trade relationships with the US economy (they export their products to the US) and that these relationships are not spurious. This implies that when the independent economic variable increases; for example US demand (driven by an increase in consumer spending or personal income in the US), the dependent economic variable lags behind (takes time to react). For example, when demand for US agricultural products increases, Mexico's agricultural sector increases its production in order to export its products. This last factor affects the sectors that are linked to this, as the agricultural sector will demand greater production inputs. It should be added that not all economic sectors and subsectors in Mexico have managed to co-integrate with the US; those that have been successful are the automotive and agricultural sectors (Nava, 2021; Santa, 2019; Chávez *et al*., 2019; Polaski, 2006).

Regarding the economic co-integration of Mexico's agricultural sector with the US, some products from these sectors are more co-integrated with the US economy than others. Examples of this are some fruit and vegetable products, such as grapes, tomatoes, and asparagus, which have become successfully positioned in the US market (Infante *et al*., 2021; González, 2017; Jaime *et al*., 2015).

This co-integration of Mexico's agricultural sector with the United States also affects related sectors and subsectors, as variations in agricultural production impact demand for products linked to this sector. Thus, when agricultural production increases, demand for production inputs will increase (Infante *et al*., 2021; González, 2017; Jaime *et al*., 2015).

In this sense, discussion of co-integration in the agricultural sector has focused on determining the benefits it has provided to Mexico. For example, the impact on demand for production inputs provided by industries linked to the agricultural sector (Puyana, 2020; Pérez *et al*., 2019; Pérez, 2019; Puchet *et al*., 2011).

Moreover, factors that have limited the positioning of Mexican agricultural products in the US include: the fact that since the signing of trade agreements, the US has sought to protect its sectors, such as agriculture by imposing rules, including tariff reduction periods for its imports and the establishment of non-tariff barriers; and in the US, there are state laws that preclude trade agreements, whereas in Mexico this is not the case (Puyana, 2020; Pérez *et al*., 2019; Pérez, 2019; Puchet *et al*., 2011).

Along these lines, Puyana (2020) and Pérez *et al*. (2019) describe the characteristics of producers in the Mexican agricultural sector who export their products to the USA, that is, who are co-integrated with the USA, these are:

the productivity of the producer, type of product, relationships that producers form, level of organization of the producers, the level of education of the producer, the technology available to the producer, and access to economic resources.

The above is relevant because those producers in Mexico's agricultural sector who manage to export their products are co-integrated with the United States. They are also exposed to economic variables that affect US consumer demand, such as US consumer spending and personal income. They are also the producers who will affect the industrial subsectors linked to this sector, as they will demand more or less of their products, depending on the behavior of US demand for their products (Anguiano and Ruiz, 2022).

Additionally, according to economic theories, producers in Mexico's agricultural industry sectors, who export their products to the United States, will respond to changes in demand for their products in search of higher profits. In this sense, when the income of US consumers increases, consumption of agricultural products will increase, causing producers in Mexico's agricultural industry to choose to increase their production (affecting the subsectors linked to them), as they will seek to satisfy the increased demand for their products, as this will increase their profits (Hernández *et al*., 2020, 2021, 2022a, 2022b; Hernández and González, 2022; Roitbarg, 2021; Hernández and Martínez, 2009; Cardona *et al*., 2007).

In this regard, in the case of the Mexican agricultural industry, evidently producers react to variations in demand and product prices. This is consistent with the neoclassical theory of demand and corroborates the idea that Mexican producers would react to variations in demand for their products from US consumers (Benítez, 2022; García, 2020; Tonconi, 2015; Brambila *et al*., 2014; OECD-FAO, 2011; Fernández, 2008).

Similarly, we should also mention that there are models of international trade that attempt to explain trade relations between countries, such as: absolute advantage, comparative advantage, Heckscher-Ohlin, Brander and Krugman, and Paul Krugman's monopolistic competition model. Generally, these theories indicate that international trade contributes to participating countries having greater growth and development compared to the absence of it. For example, the Heckscher-Ohlin model indicates that a country will choose to export products that require large quantities of inputs or production factors that the country has in abundance (Suriaga *et al*., 2021; WTO, 2017). In this sense, Mexico's agricultural sector has demonstrated certain advantages in producing some products that are of better quality than those from the United States, helping the co-integration of this sector; among these products are asparagus (Infante *et al*., 2021; González, 2017; Jaime *et al*., 2015).

METHODOLOGY

This research aims to determine the relationship between various industrial subsectors linked to Mexico's agricultural sector and to demand in the United States of America. To this end, databases for five industrial subsectors linked to Mexico's agricultural sector were downloaded from the Monthly Indicator of Industrial Activity Base Year 2018 (IMAE), obtained from the National Institute of Statistics and Geography (INEGI 2024) (Table 1). From the databases of industrial subsectors linked to Mexico's agricultural sector from IMAE (INEGI 2024), we decided to use physical volume indices, with a base year of 2018. This was done to maintain consistency across all variables and strengthen the analysis. Personal consumption expenditures and personal income were used to represent US consumer demand; and the databases were obtained from the Bureau of Economic Analysis (BEA, 2024). The figures are constant for the 2018 base year, that is they are deflated (the 2023 figures are preliminary) and represent percentage variations. All databases have a time period from January 2000 to October 2023 and are monthly.

Each of the subsectors linked to Mexico's agricultural sector presented in Table 1 were analyzed, using co-integration tests to determine whether they have long-term and non-spurious relationships with US demand (consumption spending and personal income). Furthermore, to support and expand the results, this relationship was examined using panel data.

This research is based on the authors cited in the theoretical discussion, such as Nava (2021), Santa (2019), Chávez *et al*. (2019), and Polaski (2006), who indicate that there is economic co-integration between Mexico's sectors and subsectors and US demand; Infante *et al*. (2021), González (2017), and Jaime *et al*. (2015) indicate that Mexico's agricultural sector is co-integrated with the US; and Infante *et al*. (2021), González (2017), and Jaime *et al*. (2015) point out that the co-integration of the agricultural sector affects the sectors linked to it, because it impacts demand for production inputs.

Table 1. Name of the industrial subsectors linked to the agricultural sector of the Mexican IMAE.

Name of product
3111 - Animal feed production
3112 - Milling of grains and seeds to obtain oils and fats
3114 - Preservation of fruits, vegetables, casseroles and other prepared foods
3253 - Manufacture of fertilizers, pesticides and other agrochemicals
3331 - Manufacture of machinery and equipment for agriculture, construction, and the extractive industry

Source: self-elaborated based on INEGI (2024).

Co-integration tests

Co-integration tests, revealed whether or not there is a long-term relationship between US demand (consumption expenditure and personal income) and the industrial subsectors linked to the agricultural sector in Mexico, presented in Table 1. This is because co-integration tests make it possible to determine whether the variables examined have a long-term relationship, establishing that this is not a spurious relationship and indicating that US demand influences the production of the industry subsectors linked to the agricultural sector in Mexico, as the independent variables consist of personal consumption expenditure and personal income in the US; whereas the dependent variables will be the food industry subsectors in Mexico (Gujarati and Porter, 2010; Wooldridge, 2010). Thus, these tests were used to determine whether or not co-integration exists. If confirmed, this would imply that when US demand varies, the production of the industrial subsectors linked to Mexico's agricultural sector reacts. For example, when US demand increases, the production of the industrial subsectors linked to Mexico's agricultural sector increases. This is because, in order to increase their income, they attempt to satisfy the increase in US demand and the increase in demand for production inputs from Mexico's agricultural sector (Hernández *et al*., 2020, 2021, 2022a, 2022b; Cardona *et al*., 2007; Roitbarg, 2021). The co-integration tests performed are presented in Table 2.

The twenty co-integration tests presented in Table 2 were performed according to the methodology presented by Gujarati and Porter (2010) and Wooldridge (2010), using Eviews software. According to the authors, variables must fulfill two conditions for co-integration tests to be performed: they must be non-stationary in their original order and they must have an integration order of one. To determine these characteristics, unit root tests must be undertaken. Therefore, in this research, the augmented Dicky-Fuller (ADF) unit root tests were used because according to the authors, these tests are more robust than other tests such as the Dicky-Fuller. Accordingly, original order ADF tests, with and without tendency (two for each variable) were performed, as in Equation 1.

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

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

The first thing evaluated from the original-order ADF test results with and without tendency were the Durbin-Watson statistical values. The aim was

Table 2. Description of tests for co-integration between demand from the USA and industrial sub-sectors, linked to the agricultural sector in Mexico.

Co-integration tests Abbreviated name	Independent variable	Dependent variable	Tendency
G-EAA-N	Personal consumption expenditure in USA	3111 - Animal feed production	No
G-MGSAG-N	Personal consumption expenditure in USA	3112 - Milling of grains and seeds for obtaining oils and fats	No
G-CFVGO-N	Personal consumption expenditure in USA	3114 - Preservation of fruits, vegetables, casseroles and other prepared foods	No
G-FFPOA-N	Personal consumption expenditure in USA	3253 - Manufacture of fertilizers, pesticides and other agrochemicals	No
G-FMEACIE-N	Personal consumption expenditure in USA	3331 - Manufacture of machinery and equipment for agriculture, construction and the extractive industry	No
G-EAA-S	Personal consumption expenditure in USA	3111 - Animal feed production	Yes
G-MGSAG-S	Personal consumption expenditure in USA	3112 - Milling of grains and seeds for obtaining oils and fats	Yes
G-CFVGO-S	Personal consumption expenditure in USA	3114 - Preservation of fruits, vegetables, casseroles and other prepared foods	Yes
G-FFPOA-S	Personal consumption expenditure in USA	3253 - Manufacture of fertilizers, pesticides and other agrochemicals	Yes
G-FMEACIE-S	Personal consumption expenditure in USA	3331 - Manufacture of machinery and equipment for agriculture, construction and the extractive industry	Yes
I-EAA-N	Personal income in USA	3111 - Animal feed production	No
I-MGSAG-N	Personal income in USA	3112 - Milling of grains and seeds for obtaining oils and fats	No
I-CFVGO-N	Personal income in USA	3114 - Preservation of fruits, vegetables, casseroles and other prepared foods	No
I-FFPOA-N	Personal income in USA	3253 - Manufacture of fertilizers, pesticides and other agrochemicals	No
I-FMEACIE-N	Personal income in USA	3331 - Manufacture of machinery and equipment for agriculture, construction and the extractive industry	No
I-EAA-S	Personal income in USA	3111 - Animal feed production	Yes
I-MGSAG-S	Personal income in USA	3112 - Milling of grains and seeds for obtaining oils and fats	Yes
I-CFVGO-S	Personal income in USA	3114 - Preservation of fruits, vegetables, casseroles and other prepared foods	Yes
I-FFPOA-S	Personal income in USA	3253 - Manufacture of fertilizers, pesticides and other agrochemicals	Yes
I-FMEACIE-S	Personal income in USA	3331 - Manufacture of machinery and equipment for agriculture, construction and the extractive industry	Yes

Source: self-elaborated.

to ensure that the tests were free of perfect first-order multicollinearity. For this purpose, the Durbin-Watson statistic value must be above the significance point with an alpha of 5% (with its respective k value and its *n*).

The p value of the ADF tests was then evaluated. If the p value of the test exceeds 5%, the series has a unit root, meaning it is non-stationary; if it is less than 5%, the series does not have a unit root and is stationary. According to Gujarati and Porter (2010) and Wooldridge (2010), if the variables meet the condition of being non-stationary in original order, the integration order is determined.

To determine whether the variables were of order one of integration, ADF tests were again used, but with differences. Gujarati and Porter (2010) and Wooldridge (2010) indicate that variables must be stationary in first differences to determine whether they are of order one. Thus, applying the methodology described in the original order (but with first differences), ADF tests were performed and the results were examined.

Once again, the Durbin-Watson statistics were examined to determine that the tests did not present problems of perfect first-order multicollinearity. Next, the p values of the first-order ADF tests were analyzed. These values must be less than 0.05, thereby establishing that they do not have unit roots; that is, they must be stationary. If this is the case; integration is determined to be of first order.

If the variables are not stationary in the original order and are of first order integration, according to Gujarati and Porter (2010) and Wooldridge (2010), the co-integration tests presented by the authors should be continued. Thus, based on the methodology presented by the authors, the twenty co-integrating regressions shown in Table 2 were performed, taking the form of Equation (2).

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

where Y_i: physical volume index with base year 2018 of the subsector linked to the agricultural sector in Mexico for month i; β_1: intercept; β_2: cointegrating parameter; X_{1i}: US consumptio expenditures and personal income for month i; u_i: estimated residuals from the cointegrative regression; i: month within the study period.

The co-integrating residuals were obtained using the estimated co-integrating regressions in the form of Equation 2 (Table 2). Thus, according to the authors, the augmented Engle-Granger unit root tests were applied to the co-integrating residuals to obtain the Engle-Granger tau statistic and thus establish whether the residuals are stationary or not. Based on this, we determined whether the variables examined are co-integrated. The p values from these tests will establish whether the variables are co-integrated.

Thus, if the p-values are less than 5%, the co-integrating residuals do not have unit roots, indicating that they are stationary and that the variables are co-integrated in the long term; contrarily, when the *p* values of the Engle-Granger tau statistic from the Engle and Granger unit root tests exceed 5%, the co-integrating residuals have unit roots, that is, they are not stationary, which means that the variables are not co-integrated.

Thus, if co-integration tests indicate that products from the industrial subsectors linked to Mexico's agricultural sector are co-integrated with U.S. demand (U.S. consumption expenditure and personal income), this means that manufacturers of products in the industrial subsectors linked to Mexico's agricultural sector react in response to changes in U.S. demand; and that the co-integration of the agricultural sector with U.S. demand affects the sectors linked to it.

Panel data

Panel data regression models with fixed and random effects, shown in Table 3, were estimated to corroborate the results from the co-integration tests. To do this, we used the methodology shown by Gujarati and Porter (2010) and Wooldridge (2010) and the Eviews software. Before estimating the panel data models with fixed and random effects, it was established that the variables did not have unit roots. To do this, we used the Levin-Lin-Chu test, in which the *p* value was examined with an alpha of 0.05. Thus, if the *p* value is less than 0.05, the variables do not have unit roots, and if the *p* value exceeds 0.05, the variables have unit roots. If according to the authors, the variables do not have unit roots, we proceed to estimate the panel data models shown in Table 3.

The panel data regression models presented in Table 3 (with random and fixed effects) cover a time period from January 2000 to October 2023. Notably, although the same variables appear in the panel data regression models with fixed effects as in those with random effects, the difference between them is the treatment received by the random value v_{it}, so that in the panel data regression

Table 3. Data panels with fixed and random effects.

Model	Independent variable	Dependent variable	Effects
G-PA-F	Personal consumption expenditure in USA	Manufacture of products by the Mexican food industry sub sectors from Table 2	Fixed
I-PA-F	Personal income in USA	Manufacture of products by the Mexican food industry sub sectors	Fixed
G-PA-V	Personal consumption expenditure in USA	Manufacture of products by the Mexican food industry sub sectors	Variables
I-PA-V	Personal income in USA	Manufacture of products by the Mexican food industry sub sectors	Variables

Source: self-elaborated.

models with fixed effects, the effect is fixed and in the panel data regression models with random effects, it is random.

In this way, the results from the panel regression models with fixed and random effects were evaluated. First, the R^2 was assessed to validate the model; if it exceeds 0.75, it is considered valid. Next, the p value was evaluated; if it is less than 0.05, we assumed that the dependent variable (consumption expenditure and personal income) impacts the products of the subsectors examined.

Subsequently, Hausman tests were performed, following the procedure described by Gujarati and Porter (2010), in order to determine which model is best for examining these relationships. In the tests, the p values of the test statistics were examined; these have an asymptotic x^2 distribution with an alpha of 0.05. Thus, when the p value is less than 0.05, the estimators of the panel data model with fixed effects are not equal to those of random effects, therefore, the most appropriate model for analyzing the relationships is considered to be the fixed effects model; contrarily, when the p value exceeds 0.05, the estimators of the panel data model with fixed and random effects are equal, therefore, the most appropriate model is the random effects model. Finally, when the p value of the test statistic was greater than 0.05, a fixed effects redundancy test was performed using Eviews software.

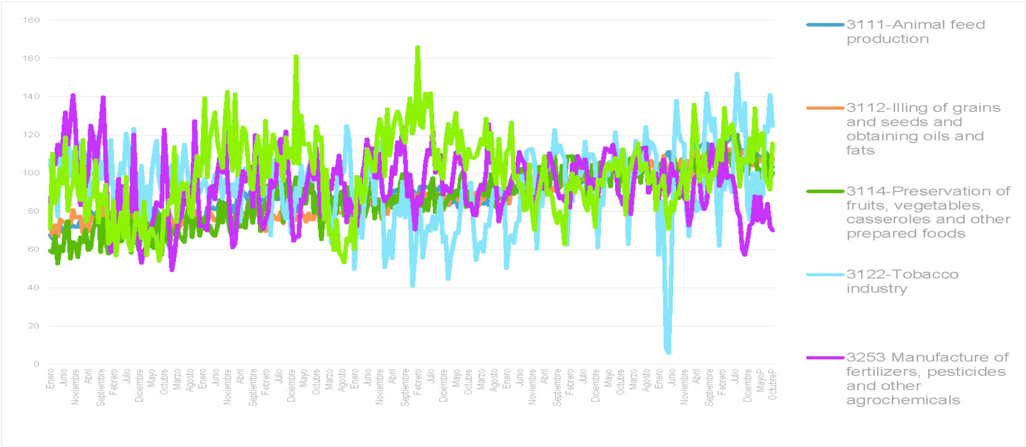
RESULTS

Prior to presenting the results from the co-integration tests and the data panels, the graphs of the databases of the variables used in the tests are presented in Figure 1. Graphs of variables present the monthly behavior of the variables from January 2000 to October 2023. Now, as indicated in the methodology, first the ADF unit root tests were estimated, with and without tendency in their original order, for the production of the industrial subsectors linked to the agricultural sector in Mexico and for personal income and consumption in the United States (Table 4).

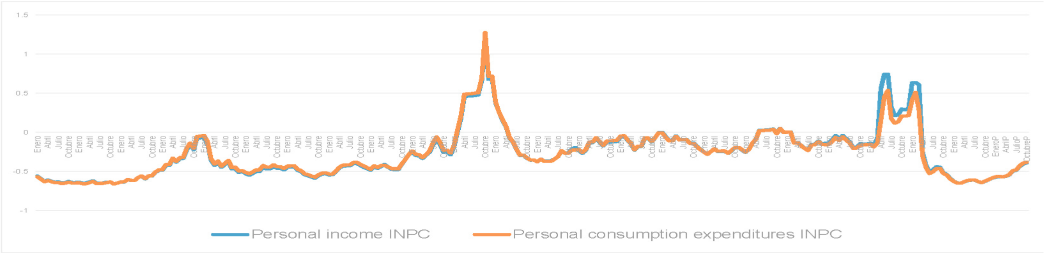
Table 4 shows that there is no positive serial correlation because the Durbin-Watson statistic is greater than the significance level in all cases. The second column of Table 4 shows the p values for the ADF unit root tests in their original order, with and without tendency in the variables. Apparently, in all cases the p values are greater than 0.05, in both the tests with and without tendency, implying that the series have unit roots and are non-stationary in their original order, with an alpha of 5%. Based on this methodology, ADF tests were performed with and without tendency, with first differences for the products of the industrial subsectors linked to the agricultural sector in Mexico and for income and personal consumption expenditure in the United States (Table 5).

Table 5 shows that in all cases, the ADF unit root tests with first differences, with and without tendency, there is no evidence of positive serial correlation,

A) Physical volume indices with a base year of 2018 for the subsectors of the industry linked to the agricultural sector in Mexico from the IMAE.



B) Percentage changes in US personal consumption expenditure and personal income.



Source: Self-elaborated based on INEGI (2024) and BEA (2024).
Figure 1. Graphs of the databases of the industry subsectors linked to the agricultural sector of the Mexican IMAE (A) and USA personal consumption expenditure and personal (B).

given that the Durbin-Watson statistic is greater than the significance level. Likewise, the second column of Table 5 shows the *p* values from the ADF unit root tests with first differences, with and without tendency, for the variables examined. This shows that in all cases, the *p* values are less than 0.05, with and without tendency, implying that the variables do not have unit roots and are stationary at first differences with an alpha of 5%, and therefore have a first integration order.

As the products from the industrial subsectors linked to the agricultural sector in Mexico and personal consumption income and expenditure in the United States fulfilled the required conditions, the co-integration tests continued. Table 6 presents the results of the Engle and Augmented Granger (EGA) unit root tests, applied to the residuals of the co-integrating regressions, with and without tendency.

Table 4. Results from the ADF unit root test with and without tendency for the variables examined in their original order.

Variable	P value (ADF test in order 0)	P tendency value	Significance point of the Durbin-Watson statistic with an alpha of 5% and n=286.	Durbin-Watson statistic	Is there positive serial correlation at order 0?
Animal feed production	0.715	Na	1.908	2.054	NO
Milling of grains and seeds for obtaining oils and fats	0.861	Na	1.943	1.983	NO
Preservation of fruits, vegetables, casseroles and other prepared foods	0.556	Na	1.919	2.012	NO
Manufacture of fertilizers, pesticides and other agrochemicals	0.120	Na	1.908	2.121	NO
Manufacture of machinery and equipment for agriculture, construction and the extractive industry	0.083	Na	1.863	1.991	NO
Personal income INPC (consumer price index)	0.063	Na	1.991	2.015	NO
Personal consumption expenditure INPC	0.073	Na	1.943	2.000	NO
Animal feed production	0.270	0.017	1.919	2.080	NO
Milling of grains and seeds for obtaining oils and fats	0.298	0.013	1.955	1.985	NO
Preservation of fruits, vegetables, casseroles and other prepared foods	0.224	0.015	1.931	2.033	NO
Manufacture of fertilizers, pesticides and other agrochemicals	0.163	0.646	1.931	2.0288	NO
Manufacture of machinery and equipment for agriculture, construction and the extractive industry	0.071	0.348	1.919	2.045	NO
Personal income INPC	0.162	0.491	1.820	2.002	NO
Personal consumption expenditure INPC	0.087	0.489	1.799	2.031	NO

Source: self-elaborated.

In Table 6, it is evident that in all the tests, the *p* values of the Engle-Granger tau statistic of the EGA test, applied to the residuals of the co-integrating regressions, exceed 0.05, which implies that, according to Gujarati and Porter (2010) and Wooldridge (2010), with an alpha of 5%, the variables have unit roots, that is they are non-stationary, which means that the products are not co-integrated with or without tendency, that is they have no long-term relationship. This means that consumption expenditure and personal income in the USA do not influence the production of the products analyzed, so that when consumption or income in the USA increases, the manufacture of products from the subsectors of the industry linked to the agricultural sector in Mexico does not increase.

Data panel

In accordance with the methodology, data were analyzed using panel data to strengthen the results from the co-integration tests. Therefore, the Levin, Lin, and Chu unit root tests for the variables analyzed are presented in Table 7.

Table 5. Results from the DFA unit root test with and without tendency of the variables with first differences that were examined.

Variable	P value (ADF test in order 1)	P value for trend	Significance point of the Durbin-Watson statistic with an alpha of 5% and n=286.	Durbin-Watson statistic	Is there positive serial correlation in order 0?
Animal feed production	0	Na	1.896	2.049	NO
Milling of grains and seeds for obtaining oils and fats	0.039	Na	1.931	1.982	NO
Preservation of fruits, vegetables, casseroles and other prepared foods	0	Na	1.908	2.012	NO
3253 - Manufacture of fertilizers, pesticides and other agrochemicals	0	Na	1.908	2.013	NO
3331 - Manufacture of machinery and equipment for agriculture, construction, and the extractive industry	0	Na	1.896	2.003	NO
Personal income INPC	0	Na	1.799	2.018	NO
Personal consumption expenditure INPC	0	Na	1.778	2.013	NO
3111 - Animal feed production	0	0.769	1.908	2.049	NO
3112 - Milling of grains and seeds for obtaining oils and fats	0	0.837	1.831	1.997	NO
3114 - Preservation of fruits, vegetables, casseroles and other prepared foods	0	0.434	1.919	2.010	NO
3253 - Manufacture of fertilizers, pesticides and other agrochemicals	0	0.939	1.919	2.013	NO
3331 - Manufacture of machinery and equipment for agriculture, construction, and the extractive industry	0.001	0.912	1.908	2.003	NO
Personal income INPC	0	0.622	1.810	2.019	NO
Personal consumption expenditure INPC	0	0.668	1.789	2.012	NO

Source: self-elaborated.

Table 7 shows that the *p* values for the Levin, Lin, and Chu unit root tests are less than 0.05. This means that the variables analyzed do not have unit roots. Based on this, the data panels were estimated, which are shown in Table 8.

Table 8 shows that the four data panels have a coefficient of determination close to zero, indicating that the panel data models are invalid; and the *p* values for the variables are greater than 0.05, indicating that they are not individually significant. This corroborates the suggestion that US consumer spending and personal income do not impact production from the examined industrial subsectors of Mexico's agricultural sector.

Notably, in the panel data with fixed effects, random effects were applied in the time section, and fixed effects were only applied in the cross-section of the panel data. This is due to the conditions of the databases (the independent variable was the same for each industrial subsector, linked to the agricultural sector). Because of this, Hausman tests could not be performed, but the cross-section fixed effect could be analyzed through fixed effects redundancy tests, which are presented in Table 9.

Table 6 Results from tests for co-integration.

Test	Independent variable	Constant	Tendency	P value for Engle-Granger tau statistic	Are co-integraded
G-EAA-N	7.563	92.267	NA	0.798	NO
G-MGSAG-N	10.99	90.481	NA	0.975	NO
G-CFVGO-N	14.994	91.23	NA	0.660	NO
G-FFPOA-N	4.105	94.532	NA	0.098	NO
G-FMEACIE-N	0.581	100.481	NA	0.080	NO
G-EAA-S	-7.815	67.615	0.142	0.508	NO
G-MGSAG-S	-4.41	65.788	0.142	0.623	NO
G-CFVGO-S	-1.616	64.637	0.153	0.493	NO
G-FFPOA-S	5.115	96.193	-0.009	0.243	NO
G-FMEACIE-S	-5.066	91.404	0.051	0.173	NO
I-EAA-N	9.294	92.706	NA	0.740	NO
I-MGSAG-N	12.61	90.878	NA	0.961	NO
I-CFVGO-N	15.673	91.358	NA	0.599	NO
I-FFPOA-N	4.142	94.526	NA	0.098	NO
I-FMEACIE-N	0.065	100.322	NA	0.081	NO
I-EAA-S	-7.01	67.817	0.142	0.544	NO
I-MGSAG-S	-3.663	66.037	0.142	0.664	NO
I-CFVGO-S	-2	64.421	0.154	0.514	NO
I-FFPOA-S	5.33	96.394	-0.010	0.242	NO
I-FMEACIE-S	-6.247	90.66	0.054	0.173	NO

Source: self-elaborated.

It is evident in Table 9 that the fixed effect in the cross-section is not redundant, so it must be taken into account.

DISCUSSION

Results indicate that production from the analyzed industrial subsectors linked to Mexico's agricultural sector is not co-integrated with U.S. income and personal consumption expenditure. This means that there are no long-term trade relationships between these industrial subsectors and U.S. demand (income and personal consumption expenditure). For example, when U.S. demand increases (due to an increase in income and personal consumption expenditure), there is no

Table 7 Tests for the Levin, Lin, and Chu unit root tests.

Analyzed variables	P value
Products from the sub sectors of industry linked to the Mexican agricultural sector	0.000
Personal income of the USA	0.000
Personal consumption expenditure in the USA	0.000

Source: self-elaborated.

Table 8. Fixed and random effects of data panels.

	Personal income from agricultural products		Personal consumption expenditure on agricultural products	
	Fixed panel data model only in the random-cross-section	Random-panel data model	Fixed panel data model only in the random-cross-section	Fixed panel data model only in the random-cross-section
Beta value sectors	-0.085	-0.085	0.229	0.229
Constant beta value	0.002	0.002	0.001	0.001
Standard error sector	0.093	0.093	0.239	0.239
Constant standard error	0	0.001	0.001	0.001
Statistical t sector	-0.912	-0.912	0.957	0.957
Constant t statistic	3.173	1.856	1.242	0.885
P sector value	0.361	0.361	0.338	0.338
Constant P value	0.001	0.064	0.214	0.376
R-squared	0.024	0.001	0.024	0.001
Durbin-Watson	0.718	0.712	0.736	0.730

Source: self-elaborated.

response in terms of production in the industrial subsectors linked to Mexico's agricultural sector.

Thus, although Mexico's agricultural sector is co-integrated with US demand, as pointed out by some authors such as Nava (2021), Santa (2019), Chávez *et al*. (2019), and Polaski (2006), it does not affect the subsectors of industry linked to Mexico's agricultural sector. This implies that although variations in the production of the agricultural sector impact the demand for its products, sectors linked to the agricultural sector are not affected by these variations in demand.

However, these results do not concur with authors such as Infante *et al.* (2021), González (2017) and Jaime *et al*. (2015), who indicate that the co-integration of Mexico's agricultural sector with the United States also affects the sectors and subsectors linked to it.

In spite of this, results from this research coincide and corroborate the statements of authors such as Infante *et al.* (2021), González (2017) and Jaime *et al*. (2015), who indicate that despite the trade agreements between Mexico

Table 9. Fixed effects redundancy test.

Data panel section	Personal income from agricultural products		Personal consumption expenditure on agricultural products	
	Statistical	Value	Statistical	Value
Cross section f	2.617	0.023	2.617	0.023

Source: self-elaborated.

and the United States, not all subsectors of the Mexican food industry are co-integrated with the United States.

Besides this, results from the study serve to demonstrate that there are still areas of opportunity to generate policies that support the co-integration of all sectors and subsectors of Mexico with the United States. Furthermore, the Mexican government should take these results into account to develop programs that allow those subsectors that have not yet achieved co-integration, to do so; and those that are co-integrated to generate production chains and benefit related sectors.

Along the same lines, it is necessary to create programs that enable producers to generate the necessary characteristics to achieve co-integration with the United States, which according to Puyana (2020) and Pérez *et al*. (2019), are: producer productivity, the relationships that producers form, the level of organization of producers, the level of education of producers, the technology available to producers, and access to economic resources. Besides this, create policies that promote the construction of value chains.

CONCLUSIONS

The objective of this research was to determine the relationship between various industrial subsectors linked to Mexico's agricultural sector and demand from the United States of America. Twenty co-integration tests and a data panel were conducted between the sectors linked to Mexico's agricultural sector and demand from the United States of America (US). The results indicated that the output of the industrial subsectors analyzed in Mexico's agricultural sector is not co-integrated with US demand (represented by consumer expenditure and personal income), and the data panels corroborate results from the co-integration tests.

These results imply that, despite the efforts made to encourage producers in Mexico's industrial subsectors to export their products to the US, for example the NAFTA and USMCA trade agreements, these efforts have not been sufficient, and there are still areas for opportunity. Therefore, it is necessary to develop government programs focused on these subsectors so that producers develop the characteristics they need to co-integrate with US demand.

It is also evident that although Mexico's agricultural sector has managed to co-integrate with the United States, this has not benefited all subsectors linked to it. This indicates that production chains that could generate greater wealth for all those involved in Mexico's agricultural sector have not been created. This also demonstrates that there are areas of opportunity for the development of government policies that foster the creation of production chains between sectors and subsectors, enabling greater economic benefits.

Based on the above, we conclude that our research objective was fulfilled. Limitations to this research are that we employed the IMAE instead of Mexico's GDP or IGAE, and that other Mexican subsectors remain to be analyzed. We suggest investigating other subsectors, as future lines of research using GDP and IGAE and other methodologies, such as structural equation modeling or instrumental variables.

REFERENCES

Anguiano J, Ruiz A. 2022. Determinantes de la sincronización de los ciclos económicos en América del Norte. Estudios de Economía. 49(1). 63-89. http://dx.doi.org/10.4067/S0718-52862022000100063.

BEA - Bureau for Economics Analysis del U.S. Department Of Commerce. 2024. Data Archive: Gross Domestic Product by Industry and Input-Output Statistics. https://apps.bea.gov/hist-data/histChildLevels.cfm?HMI=8&_gl=1*150p4xg*_ga*MzAzMjYwNjguMTcwM-DUxNT-MwNw..*_ga_J4698JNNFT*MTcwMDUxNTMwNy4xLjEuMTcwMDUxNTczOS4wLjAuMA (Recuperado: enero 2024).

Benítez OB. 2022. Influencia de los factores climáticos en la producción de maíz en México. El Semestre de las Especializaciones. 3(2). 83-112. https://www.depfe.unam.mx/especializaciones/revista/3-2-2022/03_EAE_Benitez-Lopez_2022.pdf.

Brambila JJ, Martínez MÁ, Rojas MM, Pérez V. 2014. El valor de la producción agrícola y pecuaria en México: fuentes del crecimiento, 1980-2010. Revista Mexicana de Ciencias Agrícolas. 5(4). 619-631. https://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S2007-09342014000400007.

Cardona M, Barrero YM, Gaviria CF, Álvarez EH, Muñoz JC. 2007. Aportes teóricos al debate de la agricultura desde la economía. Borradores Departamento de Economía. (27). 1-17. https://bibliotecadigital.udea.edu.co/entities/publication/82645cf9-6aae-46ef-9755-45a53937a804.

Chávez A, Ramírez N, Rodríguez DE. 2019. Del Tratado de Libre Comercio de América del Norte (TLCAN) al Tratado entre México, Estados Unidos y Canadá (T-MEC) y sus diferencias. Revista Contribuciones a la Economía. 17(4). 1-13. https://dialnet.unirioja.es/servlet/articulo?codigo=8957852.

Fernández DA. 2008. El fuelle del estado: sobre la incidencia de las políticas públicas en la concentración de la producción agrícola pampeana (1989-2001). Documentos del CIEA. (3). 33-67. https://www.ciea.com.ar/web/wp-content/uploads/2016/11/Doc3_2.pdf

García A. 2020. El sector agropecuario y el desarrollo económico: el caso cubano. Economía y Desarrollo. 164(2). e5. https://www.redalyc.org/journal/4255/425565064005/html/.

González H. 2017. La exportación de frutas y hortalizas de México a América del Norte: 1980-2015, 1ª ed.; Universidad de Guadalajara (UDG): México; pp: 1-149.

Gujarati DN, Porter DC. 2010. Econometría, 5ª ed.; McGraw Hill: México.

Hernández D, Alejos AA, Casique A. 2021. Impacts on Profitability for the Mexican 8 Strawberry Producers Due to an Increase in Exports to USA. International Journal of Agricultural Economics. 6(1). 1-11. https:/doi.org/10.11648/j.ijae.20210601.11.

Hernández D, Casique A, González JP. 2022a. Determination of the Economic Viability of Increasing Exports of Mexican Mango to the Canadian Market. International Journal of Agricultural Economics. 7(4). 163-174. https://www.sciencepublishinggroup.com/article/10.11648/10071096.

Hernández D, Cornejo MC, Galvan P. 2022b. Profitability of Mexican Avocado Production in the Face of an Increase in Exports to the Canadian Market. International Journal of Applied Agricultural Sciences. 8(2). 92-103. https://doi.org/10.11648/j.ijaas.20220802.15.

Hernández D, González JP. 2022. Competitiveness Analysis of Exporting Mexican Avocado to United States of America. The Journal of Globalization, Competitiveness, and Governability. 16(1): 66-80. https://gcgjournal.georgetown.edu/index.php/gcg/article/view/4260.

Hernández D, López FJ, Casique A. 2020. A partial equilibrium analysis of Mexican mango exports to the United States. Agricultura, Sociedad y Desarrollo. 17(1). 171-199. https://doi.org/10.22231/asyd.v17i1.1327.

Hernández D, Martínez MÁ. 2009. Procedure for a partial equilibrium analysis of the Mexican mango (Mangifera indica) exports to U.S.A. Revista Fitotecnia Mexicana. 32(3). 251–256. https://www.scielo.org.mx/scielo.php?pid=S0187-73802009000300013&script=sci_abstract&tlng=en.

INEGI (Instituto Nacional de Estadística y Geografía). 2024. Sistema de Cuentas Nacionales de México. Indicador Mensual de la Actividad Industrial. Año Base 2018. Serie de enero de 1993 a octubre de 2023. Series Originales/ Índice de volumen físico base 2018=100. INEGI IMAE. México. https://www.inegi.org.mx/temas/imai/#tabulados (Recuperado: enero 2024).

Infante ZT, López AJ. 2019. El trinomio de ventajas comparativas reveladas en la canasta básica de la Sader en América del Norte. The Anáhuac Journal. 19(2). 39-69. https://doi.org/10.36105/theanahuacjour.2019v19n2.02.

Infante ZT, Ortega P, López AJ. 2021. Competitividad de los productos agrícolas estratégicos de México en América del Norte. Repositorio de la Red Internacional de Investigadores en Competitividad. 14. 1-20. https://riico.net/index.php/riico/article/view/1932.

Jaime R, Hurtado BA, Romero NG. 2015. La competitividad en la exportación de espárragos sonorense hacia estados unidos en el marco del TLCAN. Revista Mexicana de Agronegocios. 36. 1265-1274. https://www.redalyc.org/pdf/141/14132408012.pdf.

Nava KM. 2021. La colaboración del sector privado en la renegociación del Tratado de Libre Comercio de América del Norte. Análisis de la industria automotriz Mexicana. CienciaUAT, 15(2). 102-121. https://doi.org/10.29059/cienciauat.v15i2.1427.

OCDE-FAO (Organización para la Cooperación y el Desarrollo Económicos-Organización de las Naciones Unidas para la Agricultura y la Alimentación). 2011. Perspectivas de la agricultura 2011-2020. OECD Publishing y FAO. http://herzog.economia.unam.mx/lecturas/inae2/u3l1.pdf .

OMC (Organización Mundial del Comercio). 2017. Informe sobre el comercio mundial 2017, comercio, tecnología y empleo. OMC: Suiza, Ginebra. https://www.wto.org/spanish/res_s/booksp_s/world_trade_report17_s.pdf.

Pérez A, Caamal I, Pat VG, Martínez D, Reza J. 2019. Influencia de adopción de tecnología y la mano de obra en la eficiencia productiva en el sector agrícola de México, 1979-2014. Acta Universitaria. 29. 1-15. https://doi.org/10.15174/au.2019.1631.

Pérez M. 2019. Vínculos productivos en América del Norte. Naciones Unidas, Comisión Económica para América Latina y el Caribe (CEPAL): México, https://www.cepal.org/es/publicaciones/44609-vinculos-productivos-america-norte. pp: 1-48.

Polaski S. 2006. Perspectivas sobre el futuro del TLCAN: la mano de obra mexicana en la integración de América del Norte. Universidad Nacional Autónoma de México, Coordinación de Humanidades, Centro de Investigaciones sobre América del Norte: México, https://ru.micisan.unam.mx/handle/123456789/20946. pp: 35-56.

Puchet M, Moreno JC, Ruiz P. 2011. La integración regional de México: condicionantes y oportunidades por su doble pertenencia a América del Norte y a Latinoamérica. Economía UNAM. 8(23). 3-36. https://www.scielo.org.mx/scielo.php?pid=S1665-952X2011000200001&script=sci_abstract&tlng=es.

Puyana A. 2020. Del Tratado de Libre Comercio de América del Norte al Acuerdo México-Estados Unidos-Canadá. ¿Nuevo capítulo de la integración México-Estados Unidos? El Trimestre Económico. 87(347). 635-668. https://doi.org/10.20430/ete.v87i347.1086.

Ramírez JJ. 2021. El proyecto transregional de la administración Trump y la competencia por la integración económica en el Pacífico. México y la Cuenca del Pacífico. 10(30). 33-56. https://doi.org/10.32870/mycp.v10i30.748.

Roitbarg HA. 2021. Factores detrás del aumento de precios en el sector agrícola a inicios del siglo XXI: rentas, salarios, petróleo y productividad. Desarrollo y Sociedad, (88). 169-199. https://doi.org/10.13043/DYS.88.5.

Rosenzweig A. 2005. El debate sobre el sector agropecuario mexicano en el Tratado de Libre Comercio de América del Norte. Unidad Agrícola de la sede subregional de la CEPAL, Naciones Unidas en México: México, https://www.cepal.org/es/publicaciones/4951-debate-sector-agropecuario-mexicano-tratado-libre-comercio-america-norte. pp: 1-88.

Santa A. 2019. La política de Enrique Peña Nieto hacia América del Norte: normalización e institucionalización. Foro Internacional. 59(3-4). 703-731. https://doi.org/10.24201/fi.v59i3-4.2638

Suriaga MA, Hidalgo WA. 2021. Pinceladas del comercio Internacional. E-IDEA Journal of Business Sciences. 3(13). 27-43. https://doi.org/10.53734/eidea.vol3.id142.

Tonconi J. 2015. Producción agrícola alimentaria y cambio climático: un análisis económico en el departamento de Puno, Perú. Idesia (Arica). 33(2). 119-136. https://www.scielo.cl/scielo.php?script=sci_arttext&pid=S0718-34292015000200014.

Wooldridge J. 2010. Introducción a la econometría: un enfoque moderno (7a.ed.); Cengage Learning Editores: México, DF, https://herioscarlanda.wordpress.com/wp-content/uploads/2018/10/wooldridge-2009-introduccic3b3n-a-la-econometrc3ada-un-enfoque-moderno.pdf. 865 p.