Colegio de Postgraduados

Impact of the USMCA on corn (*Zea mays* L.) trade dynamics and food security in Mexico

Luquez-Gaitan, Carlos E.[1]; Leos-Rodríguez, Juan A.[1]; Gómez-Gómez, Alma A.[1*]; Zavala-Pineda, María J.[2]

[1] Universidad Autónoma Chapingo, Texcoco, Estado de México, México, C. P. 56230.
[2] Universidad Politécnica de Texcoco, San Miguel Coatlinchán, Estado de México, México. C. P. 56250
* Correspondence: agomezg@chapingo.mx

ABSTRACT

Objective: To determine the impact of corn imports on food security in Mexico by describing the trade dynamics generated by the United States-Mexico-Canada Agreement (USMCA) to highlight the positive effects of foreign trade and free trade policies.

Design/Methodology/Approach: The research is based on a quantitative analysis of statistical data on corn involving 27 periods, coinciding with the entry into force of the North American Free Trade Agreement (NAFTA). We used a gravity model with two simultaneously estimated equations —very effective in describing the economies' trade dynamics.

Results: The estimate of the simultaneous equation model identified the United States as the country of greatest significance regarding corn trade with Mexico —an important consideration being that corn trade has a major influence on food security.

Study limitations/implications: The most relevant limitation was the lack of a unique source for data documentation.

Findings/Conclusions: Mexico's government policy aims to guarantee food supply. Yet, in 2020, imports supplied 36% of the national corn consumption. Corn imported from the United States is of the yellow variety; the tariff liberalization of this product as per USMCA and the geographical proximity to Mexico contribute to the imported volumes of yellow corn. As per the measurements provided by the Food and Agriculture Organization of the United Nations (FAO), the physical availability of food —in this case, corn— and the economic and physical access to food are met in Mexico. Nevertheless, food security has not been achieved, since 70% of the supply for consumption should come from national production.

Keywords: Gravity models, Agricultural econometrics, Trade dependency, International trade.

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INTRODUCTION

The Food and Agriculture Organization of the United Nations (FAO) posits four main dimensions for food security: the physical availability of food, economic and physical access to food, food utilization, and the stability of these three dimensions over time (IICA, 2019). Food security can be linked to foreign trade in Mexico in that the supply strategy regarding some strategic products such as corn, wheat, and beans has shown an increase in imports, particularly yellow corn (Luquez *et al.*, 2022a; Franco *et al.*, 2018, and Moreno *et al.*, 2016). This phenomenon has increased since the entry into force of the North American Free Trade Agreement (NAFTA) (Wise, 2023).

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The 1994 NAFTA allowed Mexico preferential treatment in terms of international trade with the United States (US) (Luquez *et al.*, 2022b); the United States-Mexico-Canada Agreement (USMCA) is the new trade agreement between Mexico, the US, and Canada, which replaced NAFTA as of July 1, 2020 (Gobierno de México, 2020).

According to the Food Security Agency (SEGALMEX) (2019), whose goal is to promote agri-food productivity and food distribution for the benefit of the most disadvantaged population in Mexico (SADER, 2019), the country's priority should be food self-sufficiency as regards corn, beans, rice, wheat, and milk.

Soria and Palacio (2014) maintain that sovereignty and food security in Mexico are affected by multiple factors, mainly the world market. This idea runs contrary to the traditional international trade theory, which states that the effects of foreign trade are positive. In the face of the quandary regarding the relationship between these variables, the relevance of corn consumption and production in Mexico, and the country's food self-sufficiency political strategy, it is relevant to analyze the effects of international trade on the physical availability of the grain. Even more so when more restrictive measures have been decreed on transgenic and white corn imports to Mexico, the types of corn purchased abroad (DOF, 2023).

This research aims to determine the impact of corn imports on food security by describing the trade dynamics generated by the USMCA to highlight the positive effects of foreign trade and free trade policies.

The tested hypothesis is that international trade has contributed to improving the physical availability of yellow corn. Hence, the USMCA has generated a stable supply, favoring food security in Mexico since this type of corn is an essential input for animal protein production.

MATERIALS AND METHODS

The research used annual statistical data on corn in Mexico from 1994 to 2020: production and trade volume, in addition to sociodemographic variables from Mexico, the United States, and Canada, such as population and income. These variables were collected from various sources: Trade statistics for international business development TRADEMAP (2023) and FAOSTAT (2023), US Department of Agriculture (USDA) (2023), Servicio de Información Agroalimentaria y Pesquera [Agri-food and fishing information service] (SIAP) (2023), Instituto Nacional de Estadística y Geografía [National Institute of Statistics and Geography] (INEGI) (2023), and World Bank (2023).

A rigorous identification of trade records was made based on the custom tariff classification: 10.05.90 for corn and 10.05.90.03 for yellow corn. The trade tax between Mexico and the US and Canada was also identified —corn imports and exports to/from Mexico are tariff-exempt due to the trade preferences acquired since NAFTA (TIGIE, 2022).

Gravity models

The first researchers to posit gravity models were Isard and Peck (1954), who proved that distance and flows of raw materials are related. For his part, Tinbergen (1963)

proposed that the size of bilateral trade flows between countries can be estimated using the gravity equation derived from Newton's theory of gravitation (Pöyhönen, 1963). These types of models are used to predict trade volume because estimates are obtained through regression models (Appleyard and Field, 2013). Such models have been used to analyze trade around the world (Ávila Aguirre, 2017; Albornoz-Flores and Tonon-Ordóñez, 2020; Alarcón Flores *et al.*, 2021; and Luquez *et al.*, 2022b).

An econometric gravity model is appropriate for explaining and predicting the exchange patterns of goods considering economic and geographical factors, such as those implicit in the USMCA trade agreement (WTO, 2017).

The basic form of the gravity equation, as expressed by the WTO (2017), is "based on the metaphor of Newton's universal law of gravitation, the gravity model of trade predicts that international trade (gravitational force) between two countries (objects) is directly proportional to the product of their sizes (masses) and inversely proportional to the trade frictions (the square of the distance) between them," such that the size of the masses is homologous to the size of the economy, which is expressed as follows:

$$X_{ij} = G\frac{Y_i E_j}{T_{ij}^{\theta}}$$

Where: X_{ij}: exports of countries i and j; G: inverse of world production $G=1/Y$; Y_i: national production of country i; E_j: aggregate expenditure of country j; T_{ij}: total trade costs between countries i and j.

Econometric estimation results usually present a series of inconsistencies, particularly in gravity models. One of the main drawbacks generating inconsistencies is the multicollinearity generated by variables such as the physical distance between economies. Yotov (2012) offers a solution to this problem and postulates that "the effect of distance on international trade between a given pair of countries is estimated relative to the effect of distance on international trade for another pair of countries," that is, it is assumed to be constant and, for that reason, including distance in the estimation is not necessary; furthermore, distance has ceased to be significant in estimations due to globalization processes (Cairncrooss, 1997).

Model formulation

Observing the trade balance behavior led to determining the effect of the USMCA on corn supply. The estimation of the proposed model was conducted using the simultaneous equations method (Gujarati, 2010), which can be expressed as follows:

$$Y_{1i} = \beta_{10} + \beta_{12}Y_{2i} + \gamma_{11}X_{1i} + \upsilon_{1i}$$

$$Y_{2i} = \beta_{20} + \beta_{21}Y_{1i} + \gamma_{21}X_{1i} + \upsilon_{2i}$$

Where Y_1 and Y_2 are dependent and stochastic variables, X_1 is an exogenous variable, and v_1 and v_2 are the stochastic disturbance terms. One must prove that the stochastic explanatory variables are distributed independently of v, so that the ordinary least squares (OLS) method can generate optimal results (Gujarati, 2010).

Two equations were constructed. The first one encompasses the effects of Mexico's trade dynamics with the US and Canada. In this equation, the dependent variable refers to Mexico's net imports, including imports from the US and Canada and Mexican exports to said countries. The second equation expresses the simultaneous relationship between trade and country income, meaning the trade balance directly influences the Gross National Income (GNI). The simultaneous equation model proposed to analyze the trade dynamics, and which can be replicated for any product, is:

$$\begin{aligned} LNvcomerialmx = {} & \alpha_0 + \alpha_1 INBpc_{USA} + \alpha_2 INBpc_{MX} + \alpha_3 INBpc_{CAN} + \alpha_4 PRODpc_{USA} \\ & + \alpha_5 CONSpc_{USA} + \alpha_6 PRODpc_{MX} + \alpha_7 CONSpc_{MX} + \alpha_8 PRODpc_{CAN} \\ & + \alpha_9 CONSpc_{CAN} + v_{ij} \end{aligned}$$

$$\begin{aligned} LNINBpc_{MX} = {} & \alpha_0 + \alpha_1 INBpc_{USA} + \alpha_2 vcomercial_{MX} + \alpha_3 INBpc_{CAN} + \alpha_4 PRODpc_{USA} \\ & + \alpha_5 CONSpc_{USA} + \alpha_6 PRODpc_{MX} + \alpha_7 CONSpc_{MX} + \alpha_8 PRODpc_{CAN} \\ & + \alpha_9 CONSpc_{CAN} + v_{ij} \end{aligned}$$

The dependent variables are defined as follows:

LNvcomerial is the natural logarithm of the volume of the international trade share in Mexico's apparent national consumption; and $LNINBpc_{MX}$ is the natural logarithm of the real GNI *per capita* in Mexican prices. The dependent variables are logarithmic so that the estimation analysis can be expressed in percentage terms; these variables are causal to each other, the positive trade balance contributes to the country's income and, in turn, the GNI is a measure of the country's income.

The independent variables are defined as follows:

$INBpc_{USA}$, GNI at real prices *per capita* in the US; $INBpc_{CAN}$, GNI at real prices *per capita* in Canada; $INBpc_{MX}$, GNI at real prices *per capita* in Mexico; $PRODpc_{USA}$, *per capita* production in the US; $PRODpc_{CAN}$, *per capita* production in Canada; $PRODpc_{MX}$, *per capita* production in Mexico; $CONSpc_{USA}$, *per capita* apparent national consumption in the US; $CONSpc_{CAN}$, *per capita* apparent national consumption in Canada; $CONSpc_{MX}$, *per capita* apparent national consumption in Mexico; and v_{ij}, estimation error for each equation.

Simultaneous equation models combine multiple regression and factor analysis, which allows the assessment of dependency interrelations (Cupani, 2012). In this research, the regression model estimation used the three-stage least squares method, which is the most common estimation method in the context of system estimation methods (SEM) (Wooldridge, 2009). Corn production is cyclical because its vegetative period lasts less than

12 months; however, the data examined are annual, so that there are no cycles within the analyzed series, and data seasonality was not a problem within the econometric model.

RESULTS AND DISCUSSION

The simultaneous model of corn

Gravity models are widely used to identify whether the implementation of a trade agreement has had a significant impact on trade evolution in specific trade blocs. Moreover, the implementation of this model shows the influence of trade agreements on the growth and rapprochement of economies. Table 1 presents the results of the simultaneous gravity model estimation for the three economies participating in the USMCA and its influence on the corn grain trade with Mexico.

Results show a very high adjustment due to the coefficient of determination for both equations in the model. In the model formulation, codependency was assumed, that is, the dependent variables in both equations are interrelated and mutually affect their values.

Table 1. Results of the gravity model with simultaneous equations.

Variable dependiente=Ln volumen comercial México	**Coeficiente**	**Error estándar**	**Z**	**p-value**
México INB *per capita*	0.00021	0.00023	9.26000	0.000
EE. UU. INB *per capita*	−0.00001	0.00007	−2.53000	0.012
Canadá INB *per capita*	−0.00001	0.00005	−3.47000	0.001
Producción *per capita* EE. UU.	0.10	0.75	0.13	0.89
CNA *per capita* EE. UU.	−0.05	0.70	−0.08	0.94
Producción *per capita* Canadá	1.52	0.85	1.77	0.08
CNA *per capita* Canadá	−0.83	0.62	−1.34	0.18
Producción *per capita* México	−22.14	2.26	−9.77	0.00
CNA *per capita* México	19.29	1.86	10.35	0.00
Constante	14.51	0.27	53.70	0.00
R-cuadrado 0.97	Chi^2=1024.96		Prob>p=0.000	
Variable dependiente=Ln México INB *per capita*	**Coeficiente**	**Error estándar**	**Z**	**p-value**
Volumen comercial México	−0.000001	0.000000003	−6.31	0.000
EE. UU. INB *per capita*	0.000030	0.000005800	5.13	0.000
Canadá INB *per capita*	0.000008	0.000003400	2.21	0.027
Producción *per capita* EE. UU.	0.0041	0.54	0.01	0.994
CNA *per capita* EE. UU.	0.16	0.50	0.32	0.747
Producción *per capita* Canadá	−0.77	0.60	−1.21	0.201
CNA *per capita* Canadá	1.06	0.42	2.49	0.013
Producción *per capita* México	−20.14	3.72	−5.40	0.000
CNA *per capita* México	20.29	3.75	5.41	0.000
Constante	7.11	0.21	33.73	0.000
R-cuadrado 0.94	Chi^2=535.08		Prob>p=0.000	

Source: Own elaboration.

In the first equation, the dependent variable was the logarithm of trade volume. Of the nine explanatory variables proposed, five were significant with 95% confidence. The sign of Mexico's GNI variable coefficient is consistent with the classical theory of international trade and the principle of absolute advantage, described by Adam Smith, which indicates the positive relationship between openness to foreign trade and the global wealth of countries. In this case, GNI is expressed as an approximation of this variable. On the other hand, the negative sign of the US' and Canada's GNIs reveals the effect of export demand in Mexico by its trading partners.

Consumption in the US and Canada was not significant, which shows that Mexico is not a net corn supplier for these countries. Regarding the production variables, Mexico's is the only significant one in the model estimation, which is consistent with the inverse effects of this variable on the net imports of the analyzed product. Moreover, the model's constant shows a positive behavior in the trade volume. Such growth —not explained by the independent variables— can be attributed to factors such as trade preferences within the USMCA and the distance variable between the countries, as Hernández-Pérez (2021) points out when discussing the characteristics of the neoliberal agro-export model balance in Mexican agriculture.

Six out of nine explanatory variables in the second equation were statistically significant. This equation estimates the effects of international trade on the country's GNI. The dependent variable is the natural logarithm of Mexico's GNI, determined by exports. Results show that trade volume influences the dependent variable negatively. In this regard, FAO (1996) mentions that international trade directly affects the population's access to food due to its effects on income and employment. The US' and Canada's income positively influences Mexico's GNI since, by increasing their purchasing power, they can boost their demand for imports and, in turn, increase Mexico's income. Canada's and Mexico's consumption was significant in explaining the behavior of the dependent variable. Both coefficients have the expected sign since they contribute positively to income. That is, an increase in Canadian consumption in the context of the USMCA can lead to an increase in bilateral trade, with lower tariff barriers and regulations that favor the flow of goods and services, benefiting Mexican exports and, therefore, its national income.

According to the model results, Mexico's trade volume is expected to continue growing. Therefore, corn food dependence will also increase. Our research determined that national production is the most efficient way to decrease this dependence, with a negative impact of just over 22% on net imports for each change unit (ton) in corn production. This result leads to a consideration of the particularities of the national productive sector. López-González *et al.* (2018) point out that family production is under threat due to the plurality of farmers' activities. This results in a decrease in yield per unit of corn, which, in addition to generating food insecurity, leads to economic problems and job instability.

Yellow corn in Mexican food security

The volume of corn imports in Mexico explains how trade contributes to food security. Trade records analysis must be complementary and differentiate the type

of imported corn to determine its final use in Mexico. Mexican consumers have a deep-rooted gastronomic culture and particular tastes. It is a fact that the Mexican population consumes the corn varieties produced in the country. Hence, imports are predominantly destined for animal diets or industrial processing (IDMAIZ, 2023). Consumption preferences for human use in the country will not change in the short term. Imports confirm the UN's assumption on food security, which postulates that food must be physically available. Compliance with this premise means that trade has contributed effectively to food security.

Figure 1 shows the evolution of corn imports insofar as they contribute to Mexico's consumption. Since the gravity model proved the US to be the most significant country in Mexico's trade flows (more than one-third of the corn consumed in Mexico is imported from that country), the figure shows the commercial records of Mexican imports from the US. The trend line takes an exponential form —a better fit when compared to other functional forms, such as the polynomial form. This line has an R^2 of 0.76, which implies a growth in the share of trade in the country's consumption. Hence, the dependence on imports to satisfy domestic consumption in Mexico is expected to continue growing. This evidence is consistent with the results of the econometric model estimation.

Deviations from the mean in the proportion of trade share growth in national consumption show that growth has occurred rapidly. This trend appears in 10 of the 27 studied periods and can also be identified as the predominant behavior in the last five years. Due to the relevance of imports from the US, the following graph shows the proportion of trade in the total imports of Mexico, as well as the proportion of yellow corn, the variety with the highest import volumes according to Zahniser *et al.* (2019).

Figure 2 shows the importance of the US market for the national food supply. The share of US exports in total imports for the represented period was, on average, 97%, which implies an almost total coverage in the national market. Yellow corn imports account for 87%, a percentage that is growing and reveals Mexico's vulnerability in terms of food

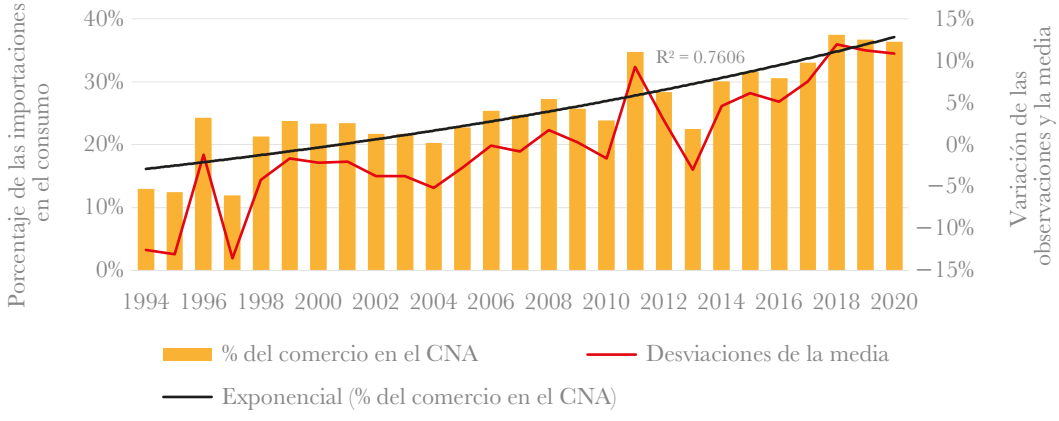

Figure 1. Proportion and variation rate of the share of corn trade between the US and Mexico in apparent national consumption.
Source: Own elaboration with data from USDA, SIAP, INEGI, FAOSTAT, and the World Bank.

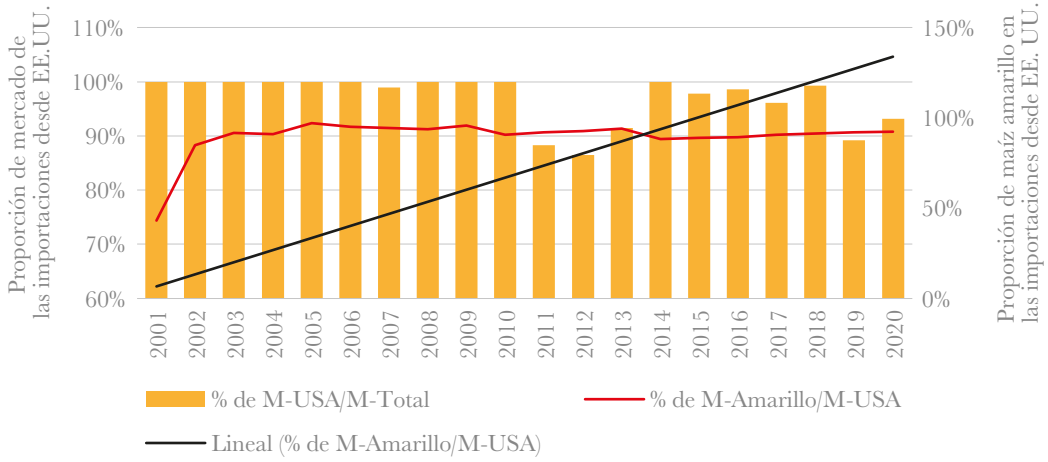

Figure 2. Share of imports from the US in total imports/Share of yellow corn imports in total imports from the US.
Source: Own elaboration using TRADEMAP data.

security for yellow corn. In this regard, FAO states that for food security to exist, national production must satisfy at least 70% of consumption (FAO, 2010).

The trend line has a very steep slope, indicating that the US holds a monopoly on sales to Mexico due to its market share. The remaining corn imports are corn varieties used for extracting high fructose corn syrup —used in the industry— and dry grains. Yellow corn imports are used for animal feed, which is especially important because it has the largest share in the cost structure of livestock production units (Nuñez-Torres, 2017).

CONCLUSIONS

Guaranteeing food supply by creating programs to ensure food availability is part of the national and international agenda as per the 2030 Sustainable Development Goals. In 2020, one-third (36%) of the Mexican national corn consumption was supplied through imports. Corn imported from the US is of the yellow variety. The USMCA tariff exemption for this product and the geographical proximity between Mexico and the US have contributed to the growth of imported volumes. Therefore, one can conclude that there is food dependency in the case of corn.

International trade, specifically the USMCA, contributes to fulfilling two of the four dimensions of food security highlighted by FAO: physical availability of food and economic and physical access to it —both met through strategies implemented by SEGALMEX. However, to achieve FAO indicators regarding the source of supply for national consumption, strengthening national production is still pending. According to FAO, at least 70% of consumption must be satisfied by national production.

The gravity model determined that the variables impacting the dynamics of international corn trade the most were production, commercial volumes and income, the influence on traded volumes, and the country's purchasing power. According to the estimate's results, national production is the most significant variable and should therefore be encouraged to reduce commercial dependence. Most of the imported corn is not consumed directly

but rather used in animal diets to produce protein for human consumption. International corn trade has been proven to influence food security and, as a result, to benefit national consumers.

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