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ECONOMIC FEASIBILITY OF AN INCREASE IN MEXICAN CUCUMBER EXPORTS TO THE UNITED STATES: ANALYSIS OF ELASTICITY

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ABSTRACT

Mexico is the principal exporter of cucumber (*Cucumis sativus*), while the United States is the main importer; to supplement its domestic consumption, it mainly imports from Mexico. Furthermore, between 1989 and 2023, imports of Mexican products into the United States increased at an average annual growth rate of 4.54%. This study analyzes the economic viability of increasing the quantity of Mexican cucumber exported to the United States, with emphasis on the export capacities of Sinaloa, Sonora, and Michoacán. Using an econometric model that incorporates price elasticity related to changes in demand, we project a 10% increase in exports, and evaluate impact on prices and traded volumes. Results suggest that price elasticity related to changes in demand plays a key role in determining whether increased export quantities generate net benefits for Mexican producers. The states of Sinaloa, Sonora, and Michoacán are the main producers, contributing 63.66% of national exports.

Keywords: competitiveness, international trade, regional economy.

INTRODUCTION

According to the Food and Agriculture Organization of the United Nations (FAO, 2024), in 2023, world cucumber production reached 97.81 million tons (t). Of this total, at 81.96%, China ranked first with 80.17 million t, while Mexico was the fourth producer with 1.04 million t (1.06%) and the United States, eighth with 646.64 thousand t (0.66%).

According to information from FAO (2024) in 2023, of the total world cucumber production (97.81 million t), 96.81% was consumed by the domestic market of exporting countries (96.81 million t) and 3.19% was destined for the international market. Mexico was the main exporter with 880.34 thousand t, which represented 28.19% of the world total; Spain ranked second with 670.03 thousand t (21.45%), the Netherlands was third with 452.24 thousand t (14.48%), Canada fourth with 249.85 thousand t (8.00%), Afghanistan fifth with 97.66 thousand t (3.13%), Turkey sixth with 93.90 thousand t (3.01%) and Greece seventh with 65.79 thousand t (2.11%).

Regarding imports, FAO data (2024) shows that in 2023, the United States imported 1.15 million tons of cucumber, which represented 34.91% of the total;

ranking first in the world, while Germany was second with 578.42 thousand tons (17.55%), Great Britain was third with 181.33 thousand tons (5.50%), Iraq was fourth with 180.00 thousand tons (5.46%), the Netherlands was fifth with 128.80 thousand tons (3.91%) and Pakistan was sixth with 97.21 thousand tons (2.95%).

Information from the United States Department of Agriculture (USDA, 2024) shows that, in 1989, the United States imported 205.75 thousand tons, whereas in 2023, 1.15 million tons were imported, that is, between 1989 and 2023, the annual growth rate of cucumber imports averaged 5.19%. During this same period (1989-2023), the average annual growth rate of cucumber imports originating in Mexico amounted to 4.54%, while the average annual growth rate of cucumber imports from Canada was 12.74%. This difference in the growth rates of imports into the United States market caused the market share of Mexican cucumber to decrease from 94.53% in 1989 to 76.37% in 2023 into the United States; whereas the market share of cucumbers originating in Canada has increased from 2.00% in 1989 to 21.02% in 2023, into the US market. That is, between 1989 and 2023, the market share of cucumbers originating in Mexico decreased by 18.16%, while the market share of Canadian cucumbers increased by 19.02% into the United States market (Table 1). The decrease in the competitiveness of Mexican cucumbers in the US market is contrary to the objectives of the North American Free Trade Agreement (NAFTA) and the Agreement between Mexico, the United States and Canada (USMCA).

For this reason, our aim was to determine the economic viability of increasing the imported quantity at an annual growth rate of 10%, even allowing for the resulting price decrease. Our hypothesis is that an increase in the average annual growth rate of cucumber imports from Mexico to the United States market of 10% per year is economically feasible.

To achieve this, we developed a partial equilibrium analysis to determine the feasibility of increasing cucumber exports to the United States market. This

Table 1. Market share of Mexican cucumber.

	1989		2023	
	Tons	%	Tons	%
Mexico	194,509	94.53	878,905	76.37
Canada	4,106	2.00	241,882	21.02
Others	7,140	3.47	29,991	2.61
Total	205,755	100.00	1’150,778	100.00

Source: USDA, 2024.

analysis can also be interpreted as a preview of international market quantities and prices to reveal how they operate (Abdalla, Stellmacher and Becker, 2023). From this perspective, it is possible to simulate a scenario under certain conditions to identify the repercussions, opportunities, and consequences of implementing an agricultural policy to increase the quantity of a good exported to a specific market.

THEORETICAL FRAMEWORK

According to Chacholiades (2017), each country is endowed with certain resources, together with its own levels of productive development, which are directly related to the abundance and utilization of its production factors. Likewise, these conditions; resource endowment and production factors, are determining factors in the goods that each country is able to produce efficiently and, on this basis, create a competitive advantage over other national economies. In this context, Ahmad-Hamidi *et al*. (2022) affirm that it is possible to use technical efficiency as a measure to describe the different levels of productivity at which countries can produce a commodity. Besides this, it is possible to identify the different levels of production with different levels of costs and benefits with which each national economy is capable of producing this commodity.

On this basis, Krugman *et al*. (2016) claim that these physical and technical differences are the reason for the existence of international trade in goods between countries, because if national economy A can produce a good X at a lower cost than national economy B, while national economy B can produce good Y at a lower cost than national economy A, it is more efficient for both economies to channel the use of the factors that each one has to produce the good for which it has better technical efficiency than the other national economy.

This aptitude in production that each economy has for each commodity directs its resources and efforts towards producing greater quantities of that commodity than those required for domestic consumption. When domestic demand is covered, the excess merchandise produced by each national economy can be exported to the other economy. In this sense, the exchange of surpluses between both national economies drives specialization in the production of that merchandise for which it has a comparative advantage, so that for both economies, international trade is beneficial (Carbaugh, 2017). Likewise, when national economy A has a comparative disadvantage in the production of commodity Y, compared to national economy B, it is more efficient to purchase it from national economy B, that is, it costs less to import it than to produce it domestically.

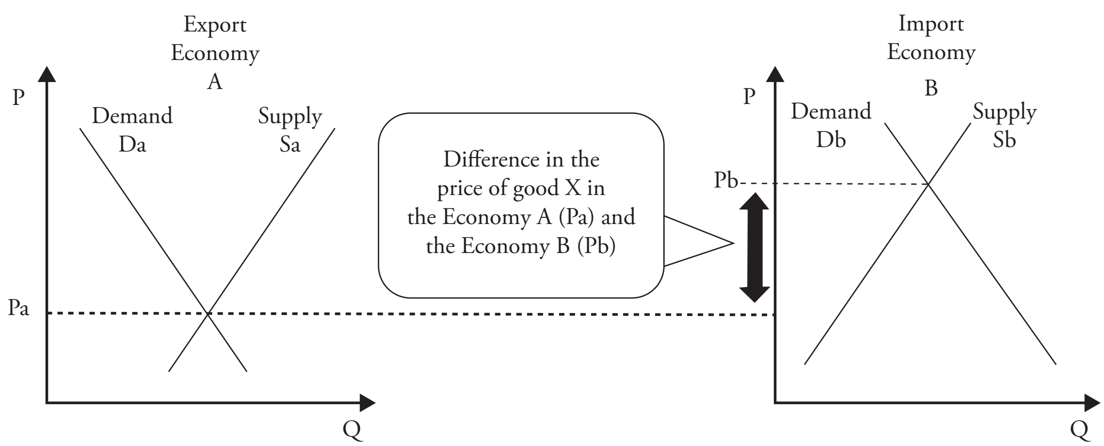
For national economy B, which has a comparative disadvantage in the production of merchandise X compared to national economy A, it is also of greater benefit to import it into national economy A, as it represents a lower cost to buy it on the international market than to produce it domestically. In this way, each national economy specializes in the production of merchandise for which it is most technically efficient, compared to other countries. In this sense, international trade results in overall advantages for the participating national economies.

Carbaugh (2017) states that international trade of good X between two national economies can be achieved, when economy A produces good X more efficiently than economy B, that is at a lower cost. Similarly, for national economy B, it is more efficient to import it than to produce it domestically. Likewise, the price at which national economy A can offer good X is lower than the price at which national economy B can offer it in the market (Figure 1).

For Williams and Capps-Jr. (2019), international trade of a commodity X between national economy A and national economy B can be explained using a partial equilibrium model, in which national economy A (exporting country) produces commodity X with greater technical efficiency than national economy B (importing country).

Now, based on the equilibrium price of commodity X in national economy A, for higher values of the price of commodity X, the difference between the supply (Sa) of commodity X and the demand (Da) of commodity X (Sa-Da) for each higher price level, has a tendency to increase (Williams *et al*., 2004).

According to Williams *et al.* (2004), these excess supplies (ESA) in economy A that are generated for each price level above price (Pa), can be transferred to a



Source: self-elaborated.

Figure 1. Price difference of commodity X in economies A and B.

second scenario that represents part of the international market. Likewise, and drawing a straight line, it is possible to observe the quantities of merchandise X that are offered, which exceed domestic demand in national economy A and that can be destined for the international market (Figure 2). Moreover, based on the equilibrium price of merchandise X in national economy B, for lower values of the price of merchandise X, the difference between the demand for merchandise X: (Db) and the supply of merchandise X: (Sb) (Db-Sb) for each lower price level, has a tendency to increase.

This excess demand (EDB) in economy B, which are generated for each price level below this one (Pb), can be transferred to a second scenario that makes up the international market. In this way, and by drawing a straight line, it is possible to observe the quantities demanded of good X, which exceed the domestic supply in national economy B and which can be supplied to the international market (Figure 3).

Now, in the international market, it is possible to combine the different amounts of excess supply ESA of merchandise X, which are generated for each price level Pa in economy A with the different amounts of excess demand EDB for merchandise X, which are generated for each price level Pb in economy B (Williams *et al*. (2004). In this scenario, there is a price level in which both lines are equivalent and the equilibrium conditions are now fulfilled in the international market, because ESA and EDB converge at that point (Figure 4).

In this sense, and focusing on the equilibrium price level in the international market, this is where PI is generated, causing an excess supply ESA evident

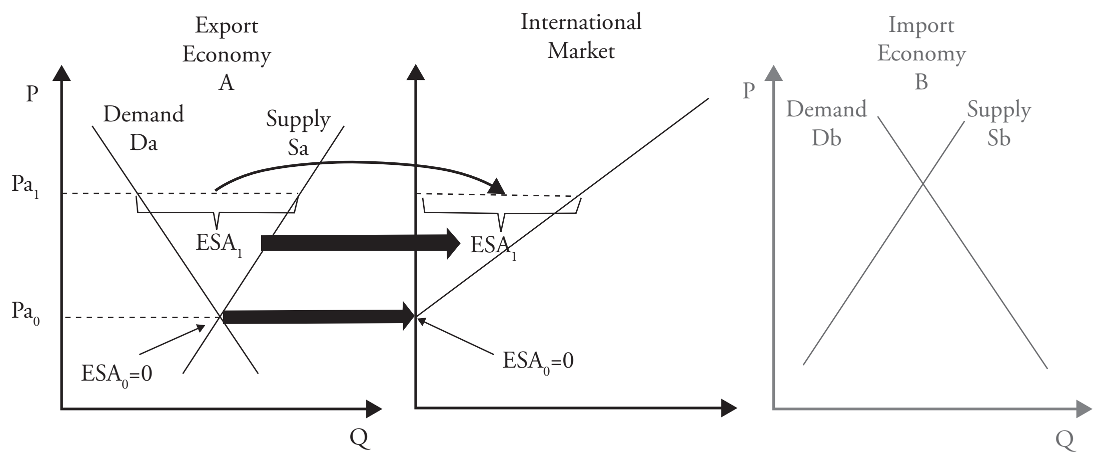


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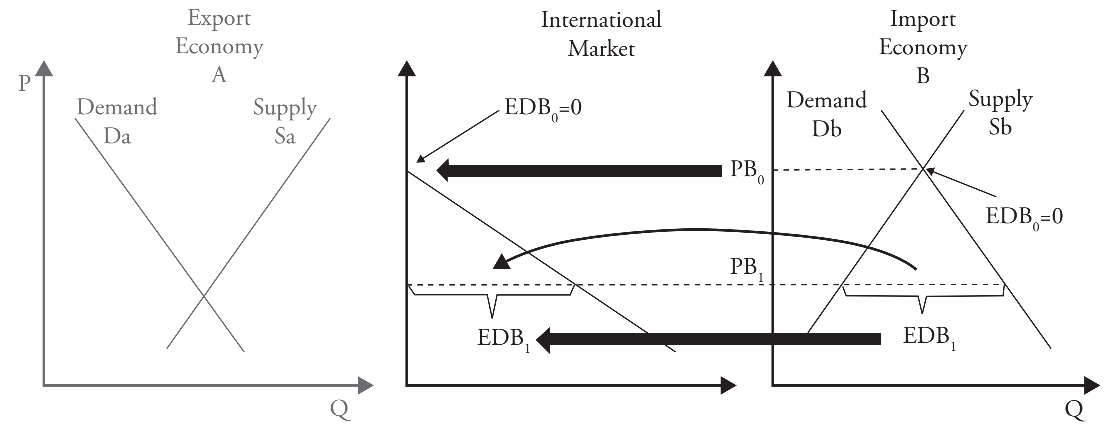
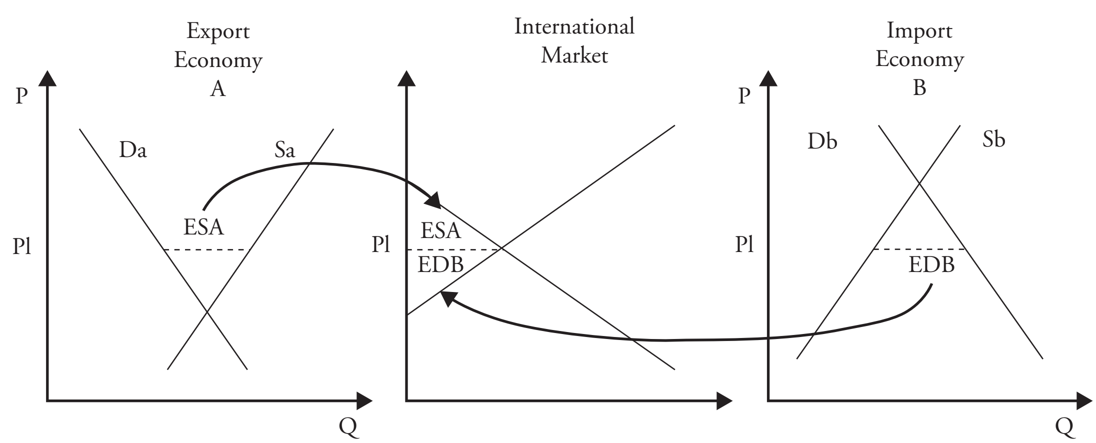
Figure 2. Excess supply of merchandise X destined for the international market.



Source: self-elaborated.
Figure 3. Excess demand for merchandise X, destined for the international market.

in the economy A scenario (exporter) and an excess demand EDB, evident in the economy B scenario (importer).

Thus, at the international price PI, the excess supply Sa-Da (ESA) in economy A is equivalent to the excess demand Db-Sb (EDB) in economy B (Figure 4). In this context, price elasticity related to changes in market demand for a good can be explained with reference to two things: firstly, as the increase in price (measured as a percentage) when the quantity demanded decreases by 1%, and secondly, as the decrease in price (average as a percentage) when the quantity demanded increases by 1%. In this way, price elasticity related to changes in demand can be conceptualized as a good's price reactivity to changes in the quantity of that good demanded by the market (Hernán-dez-Soto *et al*., 2020).



Source: self-elaborated.
Figure 4. International market for merchandise X.

Notably, the partial equilibrium model represents an international trade analysis that makes it possible to identify the effect of a change in the quantity or market price of a good between two national economies. The simulated quantities and prices allow for the establishment of hypothetical scenarios to demonstrate the impact on specific production areas, as well as the feasibility of implementing these changes.

METHODOLOGY

For the purpose of this research, a descriptive study was developed to illustrate the effects of an increase in Mexican cucumber exports to the US market. To do so, the cucumber market between Mexico and the United States was represented by an econometric model. The goal was to calculate price elasticity related to changes in demand and develop a partial equilibrium analysis of the international market for a good between two economies. This calculation allows for the simulation of an increase in the quantity traded.

Thus, it is possible to affirm that the study is explanatory, as in order to carry it out, it is necessary to establish the effect on price of an increase in the quantity of Mexican cucumbers imported into the United States. Therefore, an increase in the quantity traded between the two countries implies two effects, from which it is necessary to determine the overall effect.

In this work, the market is represented by an econometric model, considering the relationship between the variables that influence international trade in cucumbers between Mexico and the United States.

The econometric model of simultaneous equations

The econometric model that represents the cucumber market between two national economies is made up of two principal equations:

The first represents a demand function for Mexican cucumber imports, where the real CIF price per t $LPIPMUSA_t$, is the dependent variable, which in the model is determined by two independent variables: the quantity of Mexican cucumber imported into the United States $LQIPMUSA_t$, multiplied by the United States Gross Domestic Product $LGDPUSA_t$, the price of cucumber produced in Mexico $LPPPM_t$, and the total quantity of cucumber imported into the United States from all export countries $LQIPW_t$. We indicate that these variables were transformed into logarithmic form.

$$LPIPMUSA_t = \beta_{10} - \beta_{11} LQIPMUSA_t + \beta_{12} LGDPUSA_t +$$
$$\beta_{13} LPPPM_t + \beta_{14} LQIPW_t + \varepsilon_t$$

The second is a supply function for cucumber exports from Mexico, for which the real price per t $LPEPM_t$ is the dependent variable and the interior of the model is determined by two independent variables: the price of cucumber produced in Mexico with a double lag period $LPPPML2_t$, and the price of cucumber exports in Mexico with a single lag period $LPEPML_t$. We indicate that these variables were transformed into logarithmic form.

$$LPEPM_t = \beta_{20} + \beta_{21} LPPPML2_t + \beta_{22} LPEPML + \varepsilon_t$$

At this point, we should mention that the Two-Stage Least Squares (2SLS) method was applied to the simultaneous equations model (demand and supply in the international market) in order to calculate the β_{10}-β_{22} coefficients. Thus, the β coefficients were calculated simultaneously, based on the relationship between market variables, represented by the model (Gujarati *et al*., 2019). The calculations were performed using SAS version 9 software.
Notably, the $LPIPMUSA_t$, $LQIPMUSA_t$ and $LQIPW_t$ variables were constructed with information from the Global Agricultural Trade System (GATS) of the United States Department of Agriculture (USDA, 2024); whereas the $LGDPUSA_t$ variable was constructed with data from the United States Department of Commerce (USDC, 2024). The $LPEPM_t$ and $LPEPML_t$ variables were constructed with information from the Food Agriculture Organization (FAO, 2024); while the $LPPPM_t$ and $LPPPML2_t$ variables were constructed using information from the Agricultural and Livestock Information System (SIAP) of the Ministry of Agriculture and Rural Development (SADER, 2025). Significantly, the time series were constructed from 35 observations (1989–2023).

Partial equilibrium analysis

In order to develop the partial equilibrium model, the following assumptions were established:

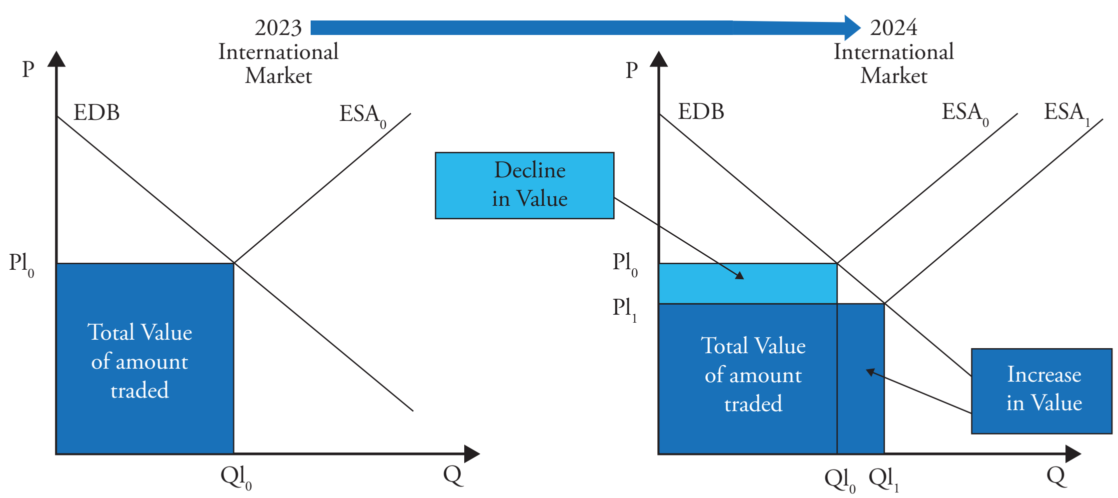
1. The international market of a good: cucumber between Mexico and the United States.
2. An international market between two economies: Mexico (exporting country) and the United States (importing country).
3. For this analysis, cucumber exports from Mexico are equal to the excess supply in the international market.
4. For this analysis, cucumber imports from United States are equal to the excess demand in the international market.
5. Monetary values in United States dollars USD.
6. Values and prices in real terms.

7. A 10% increase in the amount of Mexican cucumber imported into the United States in 2024, relative to the amount imported in 2023.

Thus, an increase in the quantity of Mexican cucumbers imported into the United States is expressed in the international market as a shift in the excess supply curve from ESA_0 to ESA_1. This shift causes the international price to decrease from PI_0 to PI_1, which in turn causes an increase in the quantity traded from QI_0 to QI_1. This decrease in price from PI_0 to PI_1 also causes an increase in excess demand for cucumbers in the international market EDB (Figure 5). The response of a change in price to a change in the quantity traded is expressed by the price elasticity of demand, which can be calculated as follows:

$$E_{QIPMUSA}^{PIPMUSA} = \frac{dPIPMUSA}{dQIPMUSA}$$

Using price elasticity related to changes in demand, the percentage by which the international price decreases when the quantity traded (between both countries) increases by 1% can be calculated. The analysis begins (in the first instance) with the actual international market for Mexican cucumbers imported into the United States in 2023; in this scenario, the international price of imports is PI_0, while the quantity imported is QI_0.
During a second period, the simulated scenario 2024 considers a 10% increase in the quantity of Mexican cucumber imported into the United States, expressed as QI_1 in the international market, while the price PI_1 is under PI_0 (in 2024), at a



Source: self-elaborated.
Figure 5. Changes in the value of the quantity traded, in response to an increase in the quantity exported.

magnitude determined by the price elasticity related to changes in demand. It can be established that an increase in the imported quantity causes an increase in the total value of imports, but at the same time, a decrease in price causes a decrease in the previously quoted total value (Figure 5).

The combined effects of both impacts on the value of Mexican cucumber imports to the United States in the international market have an overall effect. These effects can be calculated as follows:

Increase in overall value of the quantity traded (due to increase in quantity):

$$\text{Increase in value} = (Q_1 - Q_0) * P_1$$

Decrease in overall value of the quantity traded (due to decrease in quantity):

$$\text{Decrease in value} = (P_0 - P_1) * Q_0$$

The overall effect is the result of both impacts combined, that is the difference between the increase in value (of total Mexican cucumber imports into the United States), due to the increase in quantity, less the decrease in value, due to the decrease in price, meaning that the overall effect can be calculated as follows:

$$\text{Increase in value} - \text{Decrease in value} = \text{Overall effect}$$

The calculation of this overall effect is the result of a simulated 10% increase in the quantity of Mexican cucumbers imported into the United States. Therefore, to determine the feasibility of this increase in the quantity traded between Mexico and the United States in the international market, criteria were as follows:

1. If the increase in value exceeds the decrease in value, the difference will have a positive sign, meaning that the total value of the traded quantity will increase. This result indicates that a 10% increase in the quantity of Mexican cucumbers imported into the United States is economically viable.
2. If the increase in value is less than the decrease in value, the difference will have a negative sign, meaning that the total value of the traded quantity will decrease. This result indicates that a 10% increase in the quantity of Mexican cucumbers imported into the United States is not economically viable.

Profitability in producing areas

In order to determine how the simulated changes (10% increase in quantity and the consequent decrease in price) impact the producer in the producing economy, it is necessary to transfer these to the context of farmers in Sinaloa, Sonora and Michoacán, to determine the overall effect on profitability, as ultimately it is these suppliers who have the national comparative advantage in Mexico.

In this regard, it is important to mention that Sinaloa, Sonora, and Michoacán accounted for 50.90% (574,240.00 t) of Mexico's total cucumber production (1.14 million t); and besides this, in 2023 they destined 559,556.56 t to the international market, which represented 63.66% of Mexico's total exports (FAO, 2024).

Profitability in production can be expressed by the B/CR (Benefit/Cost relationship) (Bao-García *et al.*, 2015):

B/CR=Income/Expenses

For the purpose of determining profitability for the producer, criteria can be expressed as follows:

B/CR>1 It is profitable
B/CR=1 There is no profit or loss
B/CR<1 It is not profitable

RESULTS

In order to show the results, the 2-Stage Least Squares (2SLS) method was applied to the simultaneous equations model that represented the Mexican cucumber export market to the United States, that is, the demand and supply equations.

Demand:

$$LPIPMUSA_t = \beta_{10} + \beta_{11} LQIPMUSA_t + \beta_{12} LGDPUSA_t + \beta_{13} LPPPM_t + \beta_{14} LQIPW_t + \varepsilon_t$$

Supply:

$$LPEPM_t = \beta_{20} + \beta_{21} + LPPPML2_t + \beta_{22} LPEPML_t + \varepsilon_t$$

The results of Fisher's F-test and R2 are shown in Table 2.

Table 2. Indicators of model fit and significance.

Equation	Fisher's F test			Coefficient of Determination
	Crítical α F=0.01	F Value	Pr>F	R^2
Demand	4.018	17.80	0.0001	0.71778
Supply	5.348	14.14	0.0001	0.48519

Source: self-elaborated.

To perform the Fisher test, it was necessary to start from the null hypothesis, which states that all the β coefficients of the equation are equal to zero, which would imply that none of the independent variables explains the dependent variable; while the alternative hypothesis states that at least one of the β coefficients of the equation is different from zero, meaning that at least one of the independent variables contributes significantly to explaining the dependent variable. Now, the Fisher test is a one-tailed hypothesis test and to perform it, it was necessary to determine the critical value through the tables of the F values of the Fisher distribution (with a significance level of $\alpha = 0.01$). In the case of demand, the critical value is equal to 4,018, while in the case of supply, the critical value is equal to 5,348.

In this context, for the demand equation, the Fisher F test resulted in 17.80, a value that exceeds the critical value (4.018), so the probability of the F is less than 0.05 (p value). Now, for the supply equation, the Fisher F test resulted in 14.14, a value that exceeds the critical value (5.348), so the probability of the F is less than 0.05 (p value).

This means that in both cases (in the demand equation and in the supply equation), the calculated Fisher F value is within the rejection zone of the null hypothesis Ho, which implies that (in both cases), at least one of the independent variables contributes significantly to explaining the dependent variable.

Furthermore, the coefficient of R^2 determination indicates that, in the case of demand, variations in the independent LQIPMUSA, LGDPUSA, LPPPML2 and LQIPW explain 71.778% of the variations in the dependent variable LPIPMUSA; whereas, in the case of supply, variations in the independent variables LPPPML2 and LPEPML explain 48.519% of the variations in the dependent variable LPEPML.

It is significant that the normality test was performed using the Shapiro-Wilk statistic, calculated for each variable in the econometric model. To perform the hypothesis test, Ho states that the data for the specific variable do not have a normal distribution, whereas the alternative hypothesis states that data for the specific variable have a normal distribution.

In this sense and with a significance level of 0.05, the critical value of the Shapiro-Wilk statistic is equal to 0.934 (Table 3). Results indicate that the values of the Shapiro-Wilk statistic, calculated for the variables LPIPMUSA, LQIPMUSA, LGDPUSA, LQIPW, LPEPM, and LPEPML, were: 0.981413, 0.950248, 0.963941, 0.954918, 0.979352 and 0.973976 respectively.

In this regard, the determination of normality for these variables, with a significance level of 0.05, is established once the corresponding values of the SW statistic for each variable exceed 0.934, which is why they are in the Ho rejection zone. Correspondingly, the probability values of the SW statistic: 0.8042, 0.1153, 0.2992, 0.1604, 0.7380 and 0.5791, exceed the significance level of 0.05 (Table 3).

Now, in the case of the LPPPM variables and the two-period lagged analogous LPPPML2 variable, the Shapiro-Wilk statistic values were 0.931825 and 0.932253, indicating a probability of 0.0317 and 0.0406 respectively, less than 0.05. Results indicate that with a significance level of 0.05, the data for these variables do not have a normal distribution. However, we decided to include both, as they contribute to improving the model comprehensively, but they do not play a critical role in the subsequent analysis.

Furthermore, the heteroscedasticity test was applied by applying the LM statistic (Lagrange multiplier) to the demand equation, as well as to the supply equation.

Now it is significant that in order to carry out the test and be able to create a comparison using the distribution values (chi square), the null hypothesis Ho indicates that there is no heteroscedasticity, whereas the alternative hypothesis Ha indicates that heteroscedasticity exists.

Because the test has a different number of variables and lags for each order, each order has a different critical value (located in the chi-square distribution tables); therefore, the simplified interpretation of the result focuses on the

Table 3. Shapiro-Wilk normality test for the model variables.

Variable	Critical value SW α=0.05	Statistical calculated SW	Pr>SW
LPIPMUSA	0.9340	0.981413	0.8042
LQIPMUSA	0.9340	0.950248	0.1153
LGDPUSA	0.9340	0.963941	0.2992
LPPPM	0.9340	0.931825	0.0317
LQIPW	0.9340	0.954918	0.1604
LPEPM	0.9340	0.979352	0.7380
LPPPML2	0.9340	0.932253	0.0406
LPEPML	0.9340	0.973976	0.5791

Source: self-elaborated.

probability of the LM statistic calculated for each order, with a significance level of 0.05.

Considering demand, results indicate that the values of the calculated LM statistic are less than the critical value, therefore, the probability of the LM statistic in all orders is greater than 0.05, so the null hypothesis Ho is accepted, meaning there is no heteroscedasticity; that is the variance of errors is constant (meaning homoscedasticity exists) (Table 4).

Now, considering supply, results indicate that the values of the calculated LM statistic are less than the critical value, so the probability of the LM statistic in all orders exceeds 0.05, meaning the null hypothesis Ho is accepted, so there is no heteroscedasticity, or in other words, the variance of the errors is constant (meaning homoscedasticity exists) (Table 5).

Furthermore, the Durbin-Watson test was performed on both equations to determine the existence of autocorrelation. The null hypothesis, Ho, states that there is no autocorrelation in the model residuals, while the alternative hypothesis Ha states that there is autocorrelation in the model residuals. Notably, the significance level is 0.05.

Results (Table 6) indicate that considering demand, the calculated DW statistic is 1.9982 and is in the central distribution zone (between du and 4-du), that is, it is in the non-rejection zone of Ho, and the probability exceeds 0.05 (in both directions). Therefore, it is possible to affirm that there is no autocorrelation in the case of equation residuals.

In the case of supply, the calculated DW statistic is 1.9106 and is in the central zone of the distribution (between du and 4-du), that is, it is in the non-rejection zone of Ho; therefore, the probability exceeds 0.05 (in both directions),

Table 4. LM heterocedasticity test for the demand equation.

Order	LM Statistic	Pr>LM
1	3.6901	0.0547
2	3.6969	0.1575
3	3.9058	0.2718
4	4.5008	0.3425
5	6.6708	0.2463
6	7.0151	0.3195
7	9.2601	0.2345
8	9.2606	0.3208
9	9.3701	0.4038
10	9.8489	0.4538
11	9.9950	0.5308
12	10.8876	0.5386

Source: self-elaborated.

Table 5. LM heteroskedasticity test for the supply equation.

Order	LM Statistic	Pr > LM
1	2.5978	0.1070
2	4.2473	0.1196
3	4.2618	0.2345
4	4.7330	0.3158
5	6.5898	0.2530
6	9.2096	0.1621
7	9.3600	0.2278
8	9.3691	0.3121
9	9.6671	0.3781
10	11.6841	0.3068
11	12.2979	0.3417
12	12.9376	0.3736

Source: self-elaborated.

Table 6. Durbin-Watson autocorrelation test.

Equation	dL	du	4-du	4-dL	DW	Pr<DW	Pr>DW
Demand	1.222	1.726	2.274	2.778	1.9982	0.2863	0.7137
Supply	1.343	1.584	2.416	2.657	1.9106	0.2893	0.7107

Source: self-elaborated.

permitting us to state that there is no autocorrelation between equation residuals.

In this context, the values of the β coefficients were calculated (Table 7). To analyze the results of calculating the β_{10}, β_{11}, β_{12} and $\beta_{22,}$ coefficients the critical value of the Student t test, with a significance level of 0.01, is equal to 2.4400.

Table 7. β coefficients calculated for the variables of the econometric model.

Variable	β	Value	Standard Error	T Value	Pr > | t |
Intercept	β_{10}	-24.950400	5.331335	-4.68	0.0001
LQIPMUSA	β_{11}	-2.968630	0.836505	-3.55	0.0014
LGDPUSA	β_{12}	1.305231	0.441091	2.96	0.0062
LPPPM	β_{13}	-0.396550	0.186209	-2.13	0.0421
LQIPW	β_{14}	2.209936	1.011287	2.19	0.0374
Intercept	β_{20}	-2.706080	1.141657	-2.37	0.0244
LPEPML	β_{21}	0.145010	0.069647	2.08	0.0460
LPPPMLAG	β_{22}	0.488281	0.154011	3.17	0.0035

Source: Self-elaborated.

Therefore, for the hypothesis tests, the Student t values for these coefficients are equal to -4.68, -3.55, 2.96, and 3.17, respectively, thus exceeding 2.4400. Therefore, the probabilities of the respective Student t tests (0.0001, 0.0014, 0.0062, and 0.0035) are less than 0.01.

Similarly, for the β_{13}, β_{14}, β_{20} y β_{21}, coefficients, the critical value of the Student t, with a significance level of 0.05, is equal to 1.6905. This means the values of the Student t's for these coefficients are equal to -2.13, 2.19, -2.37 and 2.08 respectively, that is they exceed 1.6905, so the probabilities for the respective Student t's (0.0421, 0.0374, 0.0244 and 0.0460) are less than 0.05 (Table 7).

Results indicate that the estimated values of β_{10}, β_{11}, β_{12} y β_{22} are significant within the econometric model, with a significance level of 0.01; while the estimated values of β_{13}, β_{14}, β_{20} and β_{21} are significant within the econometric model, with a significance level of 0.05.

Thus, it is possible to construct the specific demand equation with the value of the β_{10}, β_{11}, β_{12}, β_{13} y β_{14} coefficients:

$$LPIPMUSA_t = -24.950400 - 2.968630LQIPMUSA_t + 1.305231LGDPUSA_t - 0.396550LPPPM_t + 2.209936LQIPW_t + \varepsilon_t$$

At this point, the partial derivative of the demand equation was calculated, with respect to the $LQIPMUSA_t$ amount, resulting in:

$$\frac{dPIPMUSA}{dQIPMUSA} = -2.968630$$

The estimate for the partial derivative shows that the price of Mexican imported cucumber in the United States is flexible with respect to the quantity demanded, as with a 1% increase in quantity, the price decreases by 2.968630% (more than 1%) and with a 1% decrease in the quantity, the price increases by 2.968630% (more than 1%).

Thus, the percentage response of the price in relation to a 10% increase in quantity, for the simulated 2024 scenario, would be a decrease of 29.68630%, in relation to the 2023 price (Table 8).

Table 8. Price elasticity related to changes in demand.

Increase in the amount of Mexican cucumber imported into the United States	Decrease in the price of Mexican cucumbers imported into the United States
1%	-2.968630%
10%	-29.68630%

Source: self-elaborated.

Notably, increasing the quantity imported into the United States from $\mathbf{Q}_0$ to $\mathbf{Q}_1$ causes an increase in the total value due to the increase in traded volume and also a decrease in the total value due to the decrease in price from $\mathbf{P}_0$ to $\mathbf{P}_1$. The balance of these two changes results in an overall negative effect of $182’388,126.30 USD (Table 9).

Now, calculating the areas shown in Figure 5, the overall effect is a decrease of $182’388,126.30 USD (Table 10).

In order to make a more adequate assessment of this result, and through the elasticity of price related to changes in quantity, the overall effect on the total value of imports was calculated for four hypothetical scenarios for change in quantity: -1%, 0%, 1% and 10% (Table 11).

Results show that for a 10% and 1% increase in quantity, the overall effect of the increase in value due to the increase in quantity combined with the consequent decrease in value due to the decrease in price, is negative, implying a decrease in the overall value ($182’388,126 USD and $16’087,852 USD respectively). For the case of a 1% decrease in quantity, the price increases 2.968630%, causing an

Table 9. Decrease in total value due to a 10% increase in quantity.

Q in t	P in t	Q * P
Q_0 = 878,859.50	P_0 = 916.039889	805’070,359.00
Q_1 = 966,745.45	P_1 = 644.101539	622’682,232.70
Decrease in total value of imports		-182’388,126.30

Source: self-elaborated.

Table 10. Overall effect of a 10% increase in the imported quantity.

Increase in Value due to Increase in Quantity	$(Q_1 - Q_0)*P_1$	56’607,475.70
Decrease in value due to decrease in price	$(P_0 - P_1)*Q_0$	238’995,602.00
Overall combined effect on the total value of imports =		-182’388,126.30

Source: self-elaborated.

Table 11. Final effect on the value of imports due to increases in the quantity imported in 4 hypothetical scenarios.

		Hypothetical scenarios 2024			
	2023	-1% in Q	+ 0% in Q	+ 1% in Q	+ 10% en Q
Quantity t	878,859.50	870,070.90	878,859.50	887,648.09	966,745.45
Price USD/t	916.03989	943.23372	916.03989	888.84605	644.10154
Overall effect		15’609,861	0	-16’087,852	-182’388,126

Source: self-elaborated.

overall effect of an increase of $15’609,861 USD in the total value of the quantity imported. The scenario with a 0% change in quantity and 0% in price shows the threshold at which changes of 0% in quantity have a final effect of $0.00 USD on the total value of imports. Besides this, the B/CR of producers in Sonora, Sinaloa, and Michoacán was estimated for the year 2023. Notably, these three states represented 63.66% (559,556 t) of cucumber exports in Mexico destined for the United States. The estimated B/CR for cucumber producers in Sinaloa, Sonora, and Michoacán in 2023 were 1.7616, 1.5724, and 1.8070, respectively.

Results indicate that producing cucumbers in these three states for export to the US market is profitable (Table 12). A hypothetical scenario was then presented, simulating a 10% increase in the quantity exported by these three states by 2024 (335,733.95 t), compared to the quantity exported in 2023, and also reflecting the resulting decrease in price.

The simulated 2024 scenario shows that the B/CR for producers in Sinaloa, Sonora, and Michoacán would be 1.2387, 1.1056, and 1.2706, respectively (Table 13). In this sense, it is possible to affirm that producing cucumbers for export to the US market would be profitable in all three states, given a 10% annual increase in quantity.

DISCUSSION

Results indicate the simulated scenario, making it possible to observe the consequences of a significant change in the fundamental variables, on the reality represented in the analysis. In this sense, partial equilibrium analysis allows us to identify the feasibility of producing a good for export to a given

Table 12. B/CR for the producer in Mexico in 2023.

State	Quantity t	Price $/t	Unit Cost $/t	Overall benefit $	Total cost $	B/CR
Sinaloa	262,530.16	7,817.22	4,437.53	2,052’256,017	1,164’986,514	1.7616
Sonora	198,103.32	8,401.80	5,343.41	1,664’424,474	1,058’546,690	1.5724
Michoacán	98,923.08	6,879.72	3,807.25	680’563,092	376’625,132	1.8070

Source: SADER, 2025.

Table 13 B/CR for the Mexican producer for the simulated 2024 scenario.

State	Quantity t	Price MXN/t	Unit Cost MXN/t	Overall Benefit MXN	Total Cost MXN	B/CR
Sinaloa	288,783.18	5,496.58	4,437.53	1,587’318,853	1,281’484,007	1.2387
Sonora	217,913.65	5,907.62	5,343.41	1,287’350,274	1,164’401,987	1.1056
Michoacán	108,815.39	4,837.39	3,807.25	526‘382,000	414’287,386	1.2706

Source: SADER, 2025.

market, although it can also be interpreted as a preview of the quantities and prices in the international market, in order to understand how this functions (Abdalla *et al*., 2023).

Once this viability has been established in the sense of the national economy, it is possible to assess the conditions of financial profitability in which it occurs, as besides the comparison between the different producing areas, this analysis makes it possible to observe the B/CR, in order to identify areas of low productivity of the specific merchandise.

While the technical efficiency with which a commodity is produced determines its export potential (Ahmad-Hamidi *et al*., 2022), partial equilibrium analysis allows us to assess the repercussions that the increase in productive capacity entails for the production areas. If the final effect were positive, this result would provide evidence to support policies for the development of production in the different producing areas, in order to increase their export capacity. Williams *et al*. (2004) consider that partial equilibrium analysis can reveal the effect of investment in advertising (as in the orange juice market they analyze). In their work, they show that investment in advertising has positive effects on increasing the demand for orange juice; while also increasing the consumption of fresh oranges for the industry, thus encouraging an increase in price and an increase in the income of fresh product producers. Similarly, Capps *et al*. (2010) show that resources invested in advertising in the lamb export market in the United States cause increases in demand, in addition to increases in price, which represents a positive influence on income for producers.

However, the result might be different, because if the increase in the simulated quantity entails a negative overall effect, that is, causes a decrease in the total value of imports; the proposed change is not viable from an economic perspective, as the overall value would decrease, so it would not be pertinent to carry it out, as indicated by the results of this work. In this sense, Hernández *et al*. (2022) state that the characteristics and conditions of the consumer market, as well as exporters from other nations, are factors that significantly influence the calculation of elasticity in demand in relation to changes in price, so it is necessary to consider among possible results, that an increase in exports is not viable.

Results indicate that Mexican cucumber imports into the United States are at saturation level in terms of consumption capacity, at the current level of imports. That is, at this level of saturation, any increase in the quantity exported would have negative impact on the total value of imports. Based on this, it can be argued that it is necessary to maintain the quantity of Mexican cucumber imported into the United States at a stable level year after year (without increases) in order to maintain (national) economic viability and not undermine the profitability of the producing areas that export to that destination.

This context shows the US market as a market on the verge of viability, requiring continued growth without increases in the coming years. This is intended to ensure the cucumber market grows and matures in the near future, thereby reducing elasticity. Now, regarding the profitability analysis in producing areas, although the B/CR would remain above 1 in the three producing areas analyzed in the simulated scenario, it would decrease considerably with a 10% annual increase. The analysis indicates that it is advisable to maintain the annual export quantity stable in the coming years, so as not to reduce economic viability and undermine the profitability of producers in Mexico.

Furthermore, from the perspective of the Mexican cucumber export market, future growth prospects should be planned with an eye toward other markets such as Canada, Europe, and Latin America, in order to develop the export market.

CONCLUSIONS

Mexico is the fourth largest producer and exporter of cucumbers, while the United States is the world's largest importer of cucumbers, and to supply its domestic consumption, it purchases cucumbers primarily from Mexico.

Results indicate that an increase in the quantity of Mexican cucumbers imported into the United States in 2024, representing annual increases of 10% and 1%, would lead to a decrease in the total market value of the imported quantity. Based on these results, it is possible to affirm that increases in the quantity of Mexican cucumbers imported into the United States, representing a 10% increase in one year, would not be economically viable.

Now, translating both impacts to the producer context in Sinaloa, Sonora, and Michoacán, the estimated B/CR would be 1.2387, 1.1056, and 1.2706, respectively. Results indicate that producing cucumbers in Mexico for export to the United States, given a 10% increase in the exported quantity, would still be profitable for producers in all three states. However, the B/CR decreases considerably, so it is advisable to maintain a stable amount of Mexican cucumbers imported into the United States (without annual increases), in order to avoid oversaturating the market, which would reduce economic viability and profitability for producers in Mexico.

In this context, if the strategy is to develop cucumber production in Mexico for export, it would be advisable to establish operational strategies in order to increase the exportable supply. This would mean establishing mechanisms for producing with the technology, fertilization systems, and food safety measures that allow for the generation of a top-quality product that meets the standards demanded by the international market. However, the international trade strategy must be planned in accordance with other markets such as Canada and Europe, as well as the Latin American market, in order to position Mexican cucumbers in other markets and reduce dependence on the US market. Advisedly, a partial equilibrium analysis of the production of Mexican goods in export markets should be undertaken, in order to determine their viability for increasing the quantity exported and to identify saturation level, so as to prevent these scenarios from undermining economic viability and profitability for producers.

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REFERENCES

Abdalla A, Stellmacher T, Becker M. 2023. Trends and prospects of change in wheat self-sufficiency in Egypt. Agriculture, 13(1). 1-12. https://doi.org/10.3390/agriculture13010007.

Ahmad-Hamidi HN, Khalid N, Karim ZA, Zainuddin MRKV. 2022. Technical efficiency and export potential of the world palm oil market. Agriculture, 12(11). 1-16. https://doi.org/10.3390/agriculture12111918.

Bao-García R, Cárdenas-Lucero L, Rodríguez-Cairo V. 2015. Formulación y evaluación de proyectos. 1ª ed.; Limusa. México. pp: 375-377.

Capps O, Williams GW, Dang T. 2010. Effects of lamb promotion on lamb demand and imports. Texas A&M University. Agribussines, Food and Consumer Economic Research Center. Reports 90492. USA. https://doi.org/10.22004/ag.econ.90492

Carbaugh RJ. 2017. Economía internacional, 13ª ed.; Cengage Learning. México; https://issuu.com/cengagelatam/docs/economia_internacional_carbaugh_13e. 81 p.

Chacholiades, M. 2017. The pure theory of international trade. 1ª ed.; Routledge. México. 450 p.

Gujarati DN, Porter DC, Manoranjal P. 2019. Basic Econometrics, 6ª ed.; McGraw Hill. Estados Unidos; pp: 717-763.

Hernández-Soto D, Casique-Guerrero A, González-Farias JP. 2022. 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/j.ijae.20220704.13.

Hernández-Soto D, López-Chanez FJ, Casique-Guerrero A. 2020. Un análisis de equilibrio parcial de las exportaciones de mango mexicano a los Estados Unidos. Revista Agricultura, Sociedad y Desarrollo. 17(1). 171-199. https://doi.org/10.22231/asyd.v17i1.1327.

Krugman PR, Obstfeld M, Melitz MJ. 2016. Economía Internacional, Teoría y Política, 10ª ed.; Pearson Educación. Madrid, España. 791 p.

FAO (Organización de las Naciones Unidas para la Alimentación y la Agricultura). 2024. FAOSTAT. https://www.fao.org/statistics/es.

Secretaría de Agricultura y Desarrollo Rural. 2025. Sistema de Información Agropecuaria y Pesquera. Disponible en: https://nube.siap.gob.mx.

United States Department of Agriculture. 2024. Foreign Agriculture Service. Disponible en: https://apps.fas.usda.gov/gats/default.aspx?publish=1.

United States Department of Commerce. 2024. Bureau of Economic Analysis. Disponible en: https://www.bea.gov.

Williams GW, Capps-Jr. O. 2019. Advertising with supply control: some implications of Norwegian whitefish export promotion. Agricultural and Resource Economics Review. 49(3). 558-

585. https://doi.org/10.1017/age.2019.25.
Williams GW, Capps O, Bessler DA. 2004. Florida orange grower returns from orange juice advertising. TAMRC Consumer and Product. USA, 66 p.