

STRUCTURAL AND STOCHASTIC BEHAVIOR OF MEXICAN AGRICULTURAL EXPORTS

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ABSTRACT

Mexican agricultural exports have grown faster than the country's economy, suggesting a foreign exchange inflow and the use of production factors in Mexico. This work examines both the structural behavior of the agricultural exports and its stochastic behavior using data from 1993 to 2023. The structural part is modeled with three explanatory behaviors: first, the influence in exports of the U.S. economy through its Gross Domestic Product (GDP); second, the effect of the Mexican economy through its own GDP; and third, the search for a more profitable price abroad was modeled with the real exchange rate. On the other hand, the stochastic behavior was modeled with lags of the actual exports and other explanatory variables. After adjusting an autoregressive distributed lag model and verifying the existence of a long-term relationship between Mexican agricultural exports, U.S. GDP, Mexican GDP, and the real exchange rate, it was found that the behavior of the export growth is largely explained by the U.S. economy.

Keywords: Autoregressive Distributed Lag, cointegration, bounds test.

INTRODUCTION

Mexican agricultural exports had a value of \$442 731 253.9 thousand MXN for 2021, or 0.62 % of the total Gross Domestic Product (GDP) of the country for that year. This contribution in 1994 was 0.028 %, showing their increasing importance to the national economy. Agricultural exports have become increasingly important for the economic activity of the country. The aim of this research is to determine what factors contribute to the increase in Mexican agricultural exports. While the signing of the North American Free Trade Agreement in 1994 was an important factor, this behavior could be due to other reasons such as internal, external, profitability factors, or, of course, a combination of these.

As noted by Macías-Urbe (2019), trade agreements are crucial for increasing exports by removing tariffs and making domestic products more appealing. On the other hand, Lechuga-Montenegro and Vega-Miranda (2018) examine the significance of exchange

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and interest rates, both of which are important factors; specifically, the exchange rate may represent not only a better foreign price but also greater purchasing power after payment due to the terms of the exchange rate. Likewise, Galindo and Ríos (2015) highlight the role of both internal and external factors in driving export growth as a growing economy will consider selling abroad, which might influence domestic exports.

Using a dynamic model, we examined the behavior of Mexican agricultural exports in response to the U.S. economy (Y_{US}), the Mexican economy (Y_{MX}), and the MXN-USD exchange rate (TCR). Within the same model, the behavior of exports (EXP) is examined in relation to their previous values as well as the lagged values of the three variables mentioned. Initially, the hypothesis to be tested is that these three variables (Y_{US} , Y_{MX} , and TCR), their respective lags, and export lags all explain the behavior of Mexican agricultural exports.

MATERIALS AND METHODS

Monthly data on Mexican agricultural exports from the Bank of Mexico website (<https://www.banxico.org.mx/SieInternet/>) from 1993 to 2023 were used. To standardize the frequency with the other series used, these were converted to a quarterly basis. Exports are reported in United States dollar (USD) and were converted to Mexican peso (MXN) using the exchange rate obtained from the Bank of Mexico website. The data was deflated using the implicit GDP index from the National Institute of Statistics and Geography (INEGI) website (<https://www.inegi.org.mx/app/indicadores/>). Quarterly Mexican GDP (Y_{MX}) data from the INEGI portal were also used; the quarterly data for the U.S. GDP (Y_{US}) were obtained from the Bureau of Economic Analysis website (<https://www.bea.gov/>). Both GDPs were deflated using the implicit GDP index at 2013 prices obtained from the INEGI and BEA websites, respectively.

Finally, the MXN-USD exchange rate used, originated from the Bank of Mexico website as a variable indicating how profitable placing a domestic product abroad can be. To account for the different inflation rates in each country, the exchange rate was deflated using the implicit GDP price indices, resulting in an indicator of the real exchange rate. These series show fluctuations, hence the use of the Hodrick and Prescott (1997) filter to separate trend and cyclical behavior and estimate the quarterly growth rate in each case using the following growth model (Brambila-Paz, 2011).

$$Y_t = \theta_0 e^{\theta_1 t} + u_t$$

where Y_t is the variable modeled, θ_0 and θ_1 are parameters to be estimated, e is the natural base, t indicates the time in a linear way, and u_t indicates a random term of error. In this model non-linear least squares were used to estimate the growth rate, denoted by parameter θ_1 . The quarterly growth rates for agricultural exports, Mexican

GDP, U.S. GDP, and the MXN-USD exchange rate were 1.48, 0.505, 0.528, and 1.089 %, respectively (Figure 1). These rates were converted to annual rates using the formula:

$$\tau_{an} = (1 + \tau_{trim})^4 - 1$$

where τ_{an} and τ_{trim} are the annual and quarterly growth rates. The annual growth rates are 6.072 % for exports, 2.037 % for Mexican GDP, 2.123 % for U.S. GDP, and 4.42 % for the MXN-USD exchange rate.

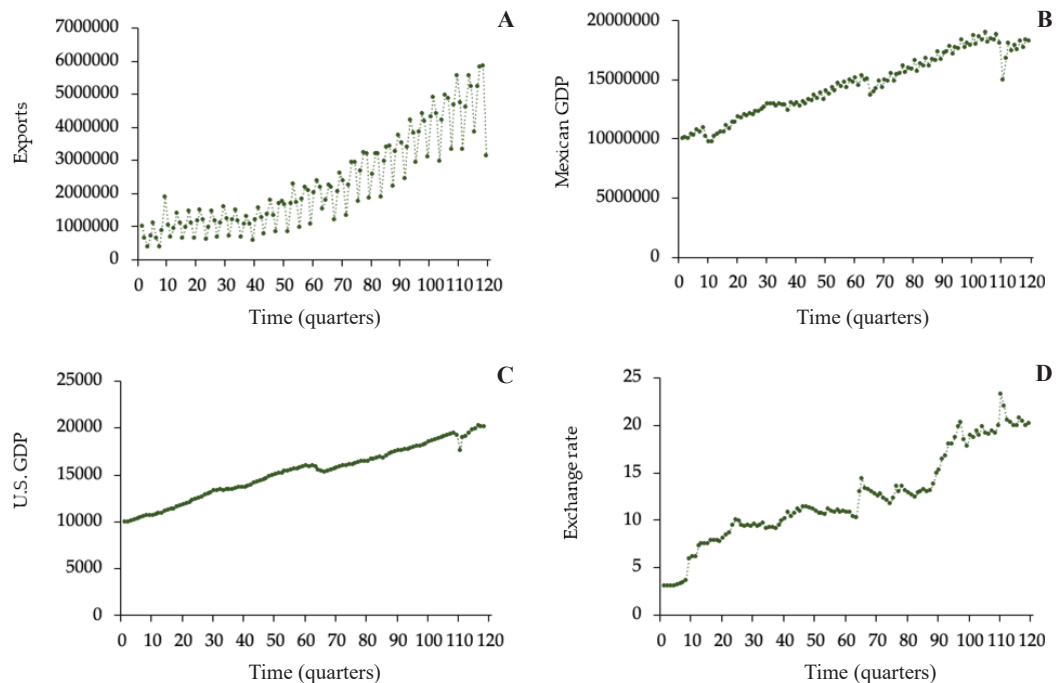


Figure 1. Quarterly growth rates for the economic data used. A: behavior of agricultural exports; B: GDP of Mexico; C: GDP of the U.S.; D: MXN-USD exchange rates.

So, the question is, what can explain export behavior? That is, is the relevant factor domestic economic conditions, or the behavior of the external market, in this case represented by the U.S., Mexico's main export destination, or perhaps the behavior of the exchange rate? The approach is to model Mexican agricultural exports using an autoregressive distributed lag (ARDL). This approach has been used, among others, by Bahmani-Oskooee *et al.* (2016) in the study of Mexico's trade scale with its 13 trade partners; Villarreal-Samaniego (2021), when studying economic growth

and its relationship with stock market capitalization; Valencia-Romero *et al.* (2023), when studying the demand for wheat imports in Mexico; and Gulzar and Li (2018), when examining the leadership between exports and economic growth in China and Pakistan. The ARDL model is formulated as follows:

$$Y_t = \alpha_0 + \sum_{i=1}^p \delta_i Y_{t-i} + \sum_{j=1}^k \sum_{l=0}^{q_j} \theta_{j,l} X_{j,t-l} + \varepsilon_t \quad (1)$$

where Y_t are agricultural exports in time t , Y_{t-i} are the lagged agricultural exports up to p periods, $X_{j,t-l}$ are k explanatory variables (Y_US , Y_MX , and TCR) in period t and its respective lag (q_j), δ_i and $\theta_{j,l}$ are unknown parameters to be estimated, and ε_t is an independent and identically distributed (IID) random error term with expectation $E(\varepsilon_t) = 0$ and $E(\varepsilon_t^2) = \sigma^2$ (zero mean and constant variance). At the time of the analysis, all variables were converted to their natural logarithms, which protects against changes in variance and helps interpret first differences as growth rates.

The model expressed in equation (1) helps explain the behavior of exports (EXP) from their own past as well as other explanatory exogenous variables and their own respective lags. It is worth noting that this is the combination of a structured model and a time series model; the exogenous variables used were the Mexican GDP (Y_MX), the U.S. GDP (Y_US) and the real MXN-USD exchange rate (TCR), as well as their respective lags.

RESULTS AND DISCUSSION

Since the ARDL is a linear regression model and the variables are considered susceptible to contain a unitary root, the problem of a spurious regression may exist. In this regard, Castillo-Ponce and Díaz-Bautista (2002) found an integration order of one for the Mexican GDP, whereas Cushman (2016) found the same for the U.S. GDP. The MXN-USD exchange rate also shows this issue of non-stationarity, according to García *et al.* (2018). Therefore, the data are examined for the presence of a unit root using SAS statistical software. (Table 1).

The set of hypotheses in this test considers that the examined series contains a unit root (non-stationary series). As shown, both the Dickey-Fuller and the Phillips-Perron tests did not reject the presence of a unit root in any of the variables. The null hypothesis is rejected for the version with an intercept for exports (simple mean), with no lags and one lag in the augmented part; if this were the case, an ARDL model is the best approach for extracting long-term behavior because it allows the combination of $I(0)$ and $I(1)$ series.

To recover the coefficients of the model stated in equation (1) and extract a possible long-term component, whether or not the variables that make up the model are

Table 1. Unit root test for: Exports (EXP), Mexico's GDP (Y_MX), US GDP (Y_US) and MXN-USD Exchange Rate (TCR).

			Dickey-Fuller test		Phillips-Perron test	
EXP	Type	Lags	Tau	Pr < Tau	Tau	Pr < Tau
	Mean zero	0	-1.10	0.246	-1.10	0.246
		1	-0.74	0.393	-0.95	0.304
		2	0.83	0.890	-0.27	0.588
	Simple mean	0	-3.20	0.023	-3.20	0.023
		1	-2.81	0.061	-3.10	0.029
		2	-0.72	0.838	-2.44	0.133
Y_MX	Type	Lags	Tau	Pr < Tau	Tau	Pr < Tau
	Mean zero	0	1.05	0.923	1.05	0.923
		1	1.97	0.988	1.60	0.973
		2	2.00	0.989	1.65	0.976
	Simple mean	0	-1.39	0.585	-1.39	0.585
		1	-1.00	0.750	-1.15	0.693
		2	-1.04	0.738	-1.14	0.697
Y_US	Type	Lags	Tau	Pr < Tau	Tau	Pr < Tau
	Mean zero	0	4.04	1.000	4.04	1.000
		1	4.65	1.000	4.56	1.000
		2	4.43	1.000	4.81	1.000
	Simple mean	0	-0.66	0.853	-0.66	0.853
		1	-0.64	0.857	-0.64	0.857
		2	-0.66	0.852	-0.63	0.859
TCR	Type	Lags	Tau	Pr < Tau	Tau	Pr < Tau
	Mean zero	0	2.70	0.998	2.70	0.998
		1	2.20	0.993	2.54	0.997
		2	2.78	0.999	2.68	0.998
	Simple mean	0	0.06	0.962	0.06	0.962
		1	-0.10	0.946	0.01	0.957
		2	0.16	0.969	0.07	0.962

EXP: exports; Y_MX: Mexican GDP; TCR: MXN-USD exchange rate. Elaborated using SAS statistical software (SAS Institute). Pr refers to probability. Tau means a statistic analogous to a t. Type points to a version of the test without intercept (zero mean) or with intercept (simple mean).

examined, the absence of stationary linear combinations would result in a spurious regression (Granger and Newbold, 1974) in the presence of unit roots. One method for testing multivariate cointegration is suggested by Johansen (1991), known as the trace test or maximum eigenvalue test. However, it requires modeling within an autoregressive vector, which in this case and for the number of variables used (four) requires the estimation of 16 parameters for each possible lag of the vector in question, which implies many degrees of freedom.

Therefore, the procedure suggested by Pesaran and Shin (1995) was followed, which proposes a cointegration test under the structure of an ARDL model, namely, the bounds test. The principle of the test is to compare the statistical significance of the coefficients of the explanatory factors considered at level but lagged for a period within a distributed lag regression of the same variables in first difference. This is accomplished using the F-test principle, though if there are unit roots, the statistic follows a different distribution, the percentiles of which were determined by Pesaran and Shin (1995).

The first step is to determine the best order of representation in equation (1), which is how many lags of the endogenous variable to include, as well as the lags of each independent variable. One way to address this is using the AIC statistic, known as the Akaike information criterion. Under this criterion, the best order in which to represent the lags to be modeled is that which minimizes the AIC statistic. For the data used, the best order of representation for the ARDL model considers six lags of the endogenous variable EXP, five lags for both Y_MX and Y_US, and three lags for the TCR variable, this was estimated using R-Software, (Table 2).

Table 2. Autoregressive distributed lag (ARDL) model estimated for Mexican agricultural exports.

	Estimator	<i>t</i> statistic	<i>p</i> value
Exp _{t-1}	0.204	2.188	0.031
Exp _{t-2}	-0.009	-0.096	0.924
Exp _{t-3}	0.117	1.889	0.062
Exp _{t-4}	0.733	11.923	0.000
Exp _{t-5}	-0.080	-0.831	0.408
Exp _{t-6}	-0.163	-1.955	0.054
Y_MX _t	-0.891	-1.474	0.144
Y_MX _{t-1}	-0.020	-0.027	0.979
Y_MX _{t-2}	2.188	3.209	0.002
Y_MX _{t-3}	-0.741	-1.117	0.267
Y_MX _{t-4}	1.030	1.586	0.116
Y_MX _{t-5}	-1.461	-2.556	0.012
Y_US _t	3.198	2.492	0.015
Y_US _{t-1}	0.662	0.397	0.692
Y_US _{t-2}	-4.324	-2.612	0.011
Y_US _{t-3}	0.533	0.321	0.749
Y_US _{t-4}	-1.240	-0.781	0.437
Y_US _{t-5}	2.259	1.777	0.079
TCR _t	1.251	7.458	0.000
TCR _{t-1}	-0.999	-4.376	0.000
TCR _{t-2}	0.565	2.327	0.023
TCR _{t-3}	-0.916	-4.798	0.000
Ordinate	-8.152	-2.798	0.006

Source: own elaboration (R and R-Studio).

Agricultural exports displayed a positive contemporary relation with the U.S. GDP (Y_US) and the real exchange rate (TCR), yet a negative—but not significant—contemporary relation with the Mexican GDP (Y_MX). Out of the 24 coefficients estimated, only nine displayed probability values above 10 %, i.e., not significantly different from zero at that level. Coincidentally, this is also true for the first lag of the respective GDPs of Mexico and the U.S., implying that the effect of the lag on these variables takes at least one quarter to impact exports. On the other hand, a definite impact on the real exchange rate is shown.

One potential issue in this regression with variables that do not rule out the presence of a unit root is the presence of a long-term relationship. If there is no such long-term relationship, there is a model that only reflects short-term behavior; in this case, the Pesaran and Shin (1995) bounds test can help identify a long-term relationship. In particular, the bounds test in its F version resulted in a value of 9.329, which exceeds the critical values of the test for probability values below 10 %, which is 3.2 when the series are integrated of order one. In fact, it exceeds the critical value of 4.66 at a significance of 1 % with three degrees of freedom (taken from results obtained using EViews 12). This has an immediate implication; the variables (exports, GDPs, and the real exchange rate) are cointegrated, meaning that they have a long-term relationship. This implies that a representation of the model can be used in terms of an error correction model:

$$\Delta Y_t = \sum_{i=1}^{p-1} \vartheta_i \Delta Y_{t-i} + \sum_{j=1}^k \sum_{l=0}^{q_{j-1}} \psi_{j,l} \Delta X_{j,t-l} + \sum_{j=1}^k \phi_j \Delta X_{j,t} + \varphi EC_{t-1} + \varepsilon_t$$

where $EC_t = Y_t - \sum_{j=1}^k \gamma_j X_{j,t} - \gamma_0$ represents the long-term relationship or error correction term; Δ represents the difference operator, and Y_t and $X_{j,t-l}$ are as defined in equation (1).

The error correction model estimated with E-Views (Table 3) helps examine short-term relationships. Since the variables used in the model are a transformation into logarithms, this model has an immediate interpretation in terms of growth rates. In this sense, the growth rates of the U.S. GDP (Y_US), Mexican GDP (Y_MX), and real exchange rate (TCR) have a positive contemporary relationship with the growth rate of agricultural exports, whereas their respective lags alternate in signs. Although the long-term relationship shows a contemporary effect on positive levels of both Y_MX and Y_US, despite being negative with the real exchange rate, only the one on Y_US is statistically different from zero.

From both analyses, agricultural exports respond predominantly to the economic activity in the U.S., followed by the economic activity in Mexico. The real exchange rate has expected effects on the short term but little importance in the long term. These results are similar to the findings by Alam and Qazi (2012) for Pakistan, who found

Table 3. Error correction model.

Variable	Coefficient	Estimated error	<i>t</i> statistic	<i>p</i> value
ΔEXP_{t-1}	-0.598	0.084	-7.143	0.000
ΔEXP_{t-2}	-0.607	0.086	-7.038	0.000
ΔEXP_{t-3}	-0.489	0.088	-5.578	0.000
ΔEXP_{t-4}	0.244	0.084	2.910	0.005
ΔEXP_{t-5}	0.163	0.080	2.031	0.045
$\Delta \text{Y_MX}_t$	-0.891	0.580	-1.535	0.128
$\Delta \text{Y_MX}_{t-1}$	-1.016	0.623	-1.629	0.107
$\Delta \text{Y_MX}_{t-2}$	1.179	0.586	2.000	0.049
$\Delta \text{Y_MX}_{t-3}$	0.432	0.565	0.765	0.446
$\Delta \text{Y_MX}_{t-4}$	1.461	0.535	2.733	0.008
$\Delta \text{Y_US}_t$	3.198	1.199	2.665	0.009
$\Delta \text{Y_US}_{t-1}$	2.772	1.259	2.212	0.029
$\Delta \text{Y_US}_{t-2}$	-1.553	1.232	-1.260	0.211
$\Delta \text{Y_US}_{t-3}$	-1.020	1.194	-0.854	0.395
$\Delta \text{Y_US}_{t-4}$	-2.259	1.174	-1.924	0.058
ΔTCR_{-t}	1.251	0.138	9.051	0.000
TCR_{-t-1}	0.351	0.182	1.925	0.057
TCR_{-t-2}	0.916	0.181	5.037	0.000
CointEq(-1)*	-0.198	0.028	-6.981	0.000

Note: CointEq is the Cointegrating equation:

Variable	Coefficient	Estimated error	<i>t</i> statistic	<i>p</i> value
Y_MX	0.529	1.845	0.287	0.775
Y_US	5.487	2.561	2.143	0.035
TCR	-0.497	0.312	-1.593	0.115
Intercept	-41.094	15.843	-2.593	0.011

Source: own elaboration (EViews 12).

a predominant explanation of exports in the income of trade partners. However, this contradicts Bahmani-Oskooee *et al.* (2016), who discovered that currency depreciation benefits exports. In turn, Gulzar and Li (2018) and Sanjuán-López and Dawson (2010) found a leading relationship where exports drive economic growth. The immediate implication for decision-makers in the scope of agricultural exports in Mexico is to focus their attention on the behavior of the economy of its main trade partner, considering the signal from the domestic economy and, to a lesser extent, the real exchange rate.

CONCLUSIONS

Agricultural exports in Mexico have grown since 1994 at a rate that surpasses the growth rate of the economy and of its main trade partner. An examination of the

hypothesis that internal and external factors, as well as the exchange rate, explain this growth in equal parts leads to the rejection of this hypothesis in favor of the fact that this behavior in the long term is predominantly explained by the tendency of the U.S. economy. As a result, it is worth recommending agricultural exporters closely monitor the behavior of the U.S. economy, particularly on the long-term, followed, to a lesser extent, by the behavior of the Mexican economy and the real exchange rate.

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