International Trade Journal

Volume 19, Number 2, Summer 2005, Pages 179-192

An Error Correction Analysis of U.S. – Mexico Trade Flows

JEL Category: F14, Country Trade Studies

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Acknowledgments: Partial financial support for this research was provided by El Paso Electric Company, El Paso Metropolitan Planning Organization, City of El Paso Office of Economic Development, and Wells Fargo Bank of El Paso.

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Abstract

Estimation of bilateral trade elasticities between countries is less well documented than is the case for aggregate trade flows. This study estimates bilateral trade equations for Mexico and the United States. The empirical analysis is carried out using an error correction approach that allows imports and exports to adjust over time to changes in the independent variables that affect the demands for them. Thus, the modeling strategy allows joint examination of both the long-run determinants of U.S.-Mexico trade flows as well as short-run dynamic adjustments to those trade patterns. Empirical results indicate that imports and exports between the two countries react heterogeneously to variations in domestic prices, foreign prices, and the exchange rate. Lag structures for the trade equations also differ from each other. The results suggest that short-run changes in U.S. imports from Mexico are more sensitive to income changes than to price changes. Changes in U.S. exports to Mexico due to price changes are likely to be equal to or greater than those associated with income shocks in Mexico in the short-run. Over the long-run, however, changes in trade flows between the U.S. and Mexico will likely be dominated by the income effect.

I. Introduction

While numerous earlier studies have provided foreign trade price and income elasticity estimates for the United States on an aggregate basis, very few studies have estimated these elasticities on a bilateral basis for the United States and Mexico. This omission is surprising, especially in light of recent trade history involving the North American Free Trade Agreement (NAFTA). Fullerton, Sawyer, and Sprinkle (1997), and Konno and Hukushige (2003) investigate the impact of NAFTA on U.S.-Mexican trade flows. Both studies find that the long-run nature of the tariff reductions embodied within the NAFTA agreement provided either a small initial positive effect or a more gradual shift in the trade flows between the two countries.

Part of the rationale for this paper lies with the importance of bilateral trade between the two countries and how these trade flows respond, both near- and long-term, to changes in relative prices and incomes. Relative price variations may result from changes in national price levels, tariff reductions, and/or exchange rate changes. Previous studies have provided long-run estimates regarding the aggregate effects of changes in domestic incomes and relative prices, on overall trade flows, but relatively little with respect to bilateral trade.

To summarize, the paper has three objectives. First, the price variables in both the import and export demand functions are decomposed into their three respective components in order to determine if trade flows react differently to changes in U.S. prices, Mexican prices, or the exchange rate. Second, elasticities are estimated using 1980 - 2002 bilateral trade flow data between the U.S. and Mexico. Finally, import and export demand functions are specified using an error correction approach that embodies both long-run relationships and short-run dynamic adjustments of the trade flows.

II. Model and Methodology

A fairly straightforward trade flow modeling approach is utilized in examining U.S.-Mexico bilateral trade. Economic theory suggests that the long-run quantity demanded of imports (QM) is related to domestic income or economic activity (GDPUS) in the importing country (U.S.), the foreign currency price of imported goods (WPIMX), the price of domestic goods competitive with imports (WPIUS), and the appropriate bilateral exchange rate (XR). In an analogous manner, the long-run export quantity demanded (QX) should be related to foreign income or economic activity in Mexico (GDPMX), the dollar price of exports (WPIUS), the price of export substitute goods in Mexico (WPIMX), and the exchange rate (XR). Aggregate, country-level empirical evidence in favor of this basic framework is widespread (Sawyer and Sprinkle, 1996).

A frequent practice in this type of research is to assume that the demand function is homogeneous of degree zero in price, in which case import and export prices can then be defined as a relative price (i.e., the relative price of imports RPM=[WPIMX/WPIUS*XR] or the relative price of exports RPX=[WPIUS*XR/WPIMX]). Imposition of the homogeneity assumption is not always a good choice (Murray and Ginman, 1976). Allowing for parameter heterogeneity may be useful for several reasons.

First, a split-price specification is generally less restrictive and is valid even if the demand function in question is in fact homogeneous. Second, in the case of trade between the U.S. and Mexico and the associated reductions in trade barriers (tariffs), a split price specification allows the impacts of import price changes to differ from those generated by domestic price changes. Third, the homogeneity assumption implicitly forces one to define imports and exports in terms of the domestic price of the importing country. As a consequence, a significant amount of information is lost as it becomes impossible to determine the effects of exchange rate changes on trade flows in isolation from changes in relative prices. This is especially important when exchange rate fluctuation effects are different in magnitude than those associated with relative prices. Empirical evidence of the latter has been widely reported for Latin American economies (Fullerton, Sawyer, and Sprinkle, 1999). Accordingly, in order to fully differentiate the individual effects of changes in these series on import and export quantities, price variables in the specifications below are divided into three component parts: import price, domestic price, and the bilateral exchange rate.

In their simplest forms, long-run U.S. imports from and exports to Mexico can be stated as follows:

$$\ln(QM_t) = \alpha_0 + \alpha_1 \cdot \ln(GDPUS_t) + \alpha_2 \cdot \ln(WPIMX_t) + \alpha_3 \cdot \ln(WPIUS_t) + \alpha_4 \cdot \ln(XR_t) + U_t$$

$$\text{and} \quad \alpha_1 > 0, \ \alpha_2 < 0, \ \alpha_3 > 0, \ \alpha_4 > 0$$

$$\ln(QX_t) = \alpha'_0 + \alpha'_1 \cdot \ln(GDPMX_t) + \alpha'_2 \cdot \ln(WPIUS_t) + \alpha'_3 \cdot \ln(WPIMX_t) + \alpha'_4 \cdot \ln(XR_t) + U_t$$

$$\text{and} \quad \alpha'_1 > 0, \ \alpha'_2 < 0, \ \alpha'_3 > 0, \ \alpha'_4 < 0$$

Where

QM	=	the volume of real imports by the U.S. from Mexico
QX	=	the volume of real exports by the U.S. to Mexico
GDPUS	=	real GDP of the United States
GDPMX	=	real GDP of Mexico
WPIUS	=	the Wholesale Price Index of the U.S.
WPIMX	=	the Wholesale Price Index of Mexico
XR	=	the Exchange Rate Index defined as Mexican pesos per U.S. dollar

The data used in our analysis covers the period 1980:I to 2002:IV. Quarterly data on imports and exports are obtained from The Survey of Current Business and all other variables are retrieved from International Financial Statistics.

It is generally agreed that trade flows do not instantaneously adjust to their long-run equilibria following changes in any of their determinants. Thus, if the long-run relationships between the variables are cointergrated, an error correction model should be estimated. Under such an approach, the change in the level of imports (exports) observed in any period, ΔQM_t (ΔQX_t), would be re-expressed as shown below.

$$\Delta \ln(QM_t) = \beta_0 + \beta_1 \cdot \Delta \ln(GDPUS_{t-i}) + \beta_2 \cdot \Delta \ln(WPIMX_{t-i}) + \beta_3 \cdot \Delta \ln(WPIUS_{t-i}) + \beta_4 \cdot \Delta \ln(XR_{t-i}) + \beta_5 \cdot U_{t-1} + V_t$$

and $\beta_1 > 0,\ \beta_2 < 0,\ \beta_3 > 0,\ \beta_4 > 0,\ \beta_5 < 0$

Where $$U_{t-1} = \ln(QM_{t-1}) - \alpha_0 - \alpha_1 \cdot \ln(GDPUS_{t-1}) - \alpha_2 \cdot \ln(WPIMX_{t-1}) - \alpha_3 \cdot \ln(WPIUS_{t-1}) - \alpha_4 \cdot \ln(XR_{t-1})$$

$$\Delta \ln(QX_t) = \beta'_0 + \beta'_1 \cdot \Delta \ln(GDPMX_{t-i}) + \beta'_2 \cdot \Delta \ln(WPIUS_{t-i}) + \beta'_3 \cdot \Delta \ln(WPIMX_{t-i}) - \beta'_4 \cdot \Delta \ln(XR_t) + \beta'_5 \cdot U_{t-1} + V_t$$

and $\beta'_1 > 0,\ \beta'_2 < 0,\ \beta'_3 > 0,\ \beta'_4 < 0,\ \beta'_5 < 0$

Where $$U_{t-1} = \ln(QX_{t-1}) - \alpha'_0 - \alpha'_1 \cdot \ln(GDPMX_{t-1}) - \alpha'_2 \cdot \ln(WPIUS_{t-1}) - \alpha'_3 \cdot \ln(WPIMX_{t-1}) - \alpha'_4 \cdot \ln(XR_{t-1})$$

III. Empirical Results

The first step in the empirical analysis is an assessment of the stationarity characteristics of each of the variables in the sample. This is achieved by conducting unit root tests on the individual series. Results for the Dickey-Fuller unit root tests are shown in Table 1. Lag lengths are determined using an Akaike Information Criterion. The data indicate that the variables are I(1) series and standard regressions in level form may yield spurious correlations.

Given the unit root test results, cointegration tests are conducted to determine if a linear combination of the variables is stationary in level form. Tests for cointegration are shown in Tables 2 and 3. Outcomes for both the Johansen test and the Engle and Granger test indicate that the

Table 1
Unit Root Tests for Import and Export Variables

Variable	Dickey-Fuller Test Statistic	Dickey-Fuller Number of Lags[a]	Dickey-Fuller Test Statistic	Dickey-Fuller Number of Lags[a]
	Levels		First Differences	
Without Constant and Trend				
ln GDPMX	2.832	6	-4.088**	5
ln GDPUS	3.872	5	-2.839**	1
ln QM	3.911	4	-1.588	5
ln QX	1.646	6	-3.805**	4
ln WPIMX	0.255	5	-1.649	4
ln WPIUS	2.207	4	-4.592**	3
ln XR	-1.893	5	-1.659	4
With Constant				
ln GDPMX	0.799	6	-5.093**	5
ln GDPUS	-0.278	3	-4.579**	4
ln QM	0.063	4	-4.743**	3
ln QX	-0.106	5	-4.019**	4
ln WPIMX	-2.104	4	-2.463	4
ln WPIUS	-0.919	4	-5.195**	3
ln XR	-3.365*	3	-3.136*	2
With Constant and Trend				
ln GDPMX	-2.264	6	-5.306**	5
ln GDPUS	-2.568	2	-4.542**	4
ln QM	-1.260	4	-10.519**	1
ln QX	-2.282	0	-4.157**	4
ln WPIMX	-1.374	5	-3.865*	4
ln WPIUS	-2.866	4	-5.074**	3
ln XR	-2.009	3	-4.203**	2

* denotes significance at the 5% level
** denotes significance at the 1% level

[a] The number of lags used for the test was determined by AIC criteria.

Table 2
Johansen Test for Cointergration of U.S.-Mexico Trade

Series: ln QM, ln GDPUS, ln WPIMX, ln WPIUS, ln XR

Unrestricted Cointegration Rank Test
Number of Lags 2

Hypothesized Number of Cointergating Vectors	Eigenvalue	Trace Statistic	Max-Eigen Statistic
None	0.317318	86.50**	35.12*
At most 1	0.232673	51.39*	24.37
At most 2	0.159490	29.68	15.41

Series: ln QX, ln GDPMX, ln WPIMX, ln WPIUS, ln XR

Unrestricted Cointegration Rank Test
Number of Lags 3

Hypothesized Number of Cointergating Vectors	Eigenvalue	Trace Statistic	Max-Eigen Statistic
None	0.410820	95.69**	46.55**
At most 1	0.261141	49.13*	26.63
At most 2	0.126384	22.50	11.89

* denotes significance at the 5% level
** denotes significance at the 1% level

variables are cointegrated. The Johansen test (Table 2) indicates that there is one cointegrating vector at the 0.01 level of significance, and two cointegrating vectors at the 0.05 level of significance for imports to and exports from Mexico. The Engle and Granger procedure (Table 3) indicates that both imports and exports are cointegrated at the 0.01 level of significance using the augmented Dickey-Fuller test statistic.

Table 3 also presents the estimated long-run (cointegrated) equations for imports and exports to and from Mexico. In the model for U.S. import demand, the estimated income coefficient has the correct sign and is statistically significant. The estimated elasticities for the price and exchange rate variables also have the correct signs and are significant. These results indicate that the primary long-run determinants of U.S. import demand from Mexico include changes in the level of U.S. income plus changes in U.S. wholesale prices, Mexico wholesale prices, and variations in the exchange rate. In addition, these results indicate the U.S. imports from Mexico are quite sensitive to changes in U.S. income (economic activity) and changes in U.S. prices for import competing goods.

Fullerton, Sawyer, and Sprinkle (1997) estimate bilateral U.S. import demand elasticities from Mexico using a geometric lag structure. An income elasticity of U.S. import demand from Mexico of approximately 1.82 is obtained and only the U.S. domestic price variable was significant. Table 3 reports an income elasticity of approximately 4.8. Statistically significant parameters are estimated for both price variables as well as for the exchange rate. As such, the results in Table 3 indicate that the income elasticity in the United States for imports from Mexico may be increasing over time.

Similar to the import model, the estimated demand equation for U.S. exports to Mexico in Table 3 indicates that the foreign income elasticity has the correct sign and is significant. Results for the price and exchange rate coefficients all have the correct signs and all but U.S. prices are statistically significant. Primary long-run determinants of U.S. export demand to Mexico thus seem to include changes in the income level in Mexico, plus price variations in Mexico, and movements in the currency value of the peso. In addition, the magnitudes of the different estimated coefficients indicate that U.S. exports to Mexico are very sensitive to changes in Mexican income (economic activity), whereas, price and exchange rate changes impact U.S. exports by much smaller magnitudes.

These estimates of bilateral U.S. export demand elasticities to Mexico are consistent with prior empirical estimates (Fullerton, Sawyer, and Sprinkle, 1997). The export function income elasticity estimate shown in Table 3 is similar in magnitude to that obtained in the previous study. At approximately 2.4, it is easy to see that U.S. exports to Mexico remain sensitive to business cycle fluctuations. Parameter heterogeneity among the three price components is also apparent for both equations in Table3.

Given that the respective import and export demand variables are cointegrated, a set of error correction models is also developed. Error correction models allow for the analysis of the short-run dynamics between imports (exports) and their underlying determinants. Table 4 reports the estimated error correction equations for imports and exports. The models incorporate estimated

Table 3
Estimated Cointergrating Equations for U.S.-Mexico Trade

	U.S. Imports from Mexico	U.S. Exports to Mexico
	ln QM	ln QX
Constant	-20.4848 (-18.232)**	-3.5836 (-1.716)
ln GDPUS	4.8031 (25.594)**	
ln GDPMX		2.4057 (8.135)**
ln WPIMX	-0.3987 (-6.755)**	0.8817 (8.297)**
ln WPIUS	2.0717 (7.042)**	-0.1874 (-0.306)
ln XR	0.1696 (3.321)**	-0.8113 (-8.117)**
ADF Test Statistic	-3.940**	-4.155**
Number of Lags	4 lags	8 lags

* denotes significance at the 5% level
** denotes significance at the 1% level

Table 4
Estimated Error Correction Models for U.S.-Mexico Trade

	U.S. Imports from Mexico	U.S. Exports to Mexico
	$\Delta \ln QM_t$	$\Delta \ln QX_t$
Constant	0.0134 (1.303)	0.0208 (1.714)
$\Delta \ln GDPUS_{t-1}$	2.6751 (3.431)**	
$\Delta \ln GDPMX_{t-1}$		0.0857 (0.455)
$\Delta \ln WPIMX_{t-2}$	-0.2237 (-2.466)*	0.3950 (3.262)**
$\Delta \ln WPIUS_{t-3}$	0.4034 (0.839)	-0.1400 (-0.208)
$\Delta \ln XR_t$		-0.4695 (-6.952)**
$\Delta \ln XR_{t-2}$	0.0875 (1.745)	
Coint Eq. Error $_{t-1}$	-0.1499 (-2.113)*	-0.1187 (-2.084)*
R-Square	0.2109	0.3952
Pseudo R-Square	0.9796	0.9934
Log Likelihood	138.15	108.02
F-statistic	4.545	10.9795
Sample	1980Q1 – 2002Q4	

* denotes significance at the 5% level
** denotes significance at the 1% level

errors of the respective cointegrating equations along with lagged changes of each the independent variables. Equation lag-lengths are allowed to vary in order to maximize individual log likelihood functions. For that reason, model lag structures shown in Table 4 are similar, but not identical.

In the equation for U.S. import demand, the exchange rate and international (Mexican) price lags are identical, but the lag structure for domestic (U.S.) prices differ. The estimated price and exchange rate coefficients all exhibit different magnitudes indicating that the short-run import demand function is not homogeneous with respect to prices. The estimated income effect occurs within 1 quarter, the exchange rate and Mexican prices impact imports within two quarters, and U.S. prices impact imports from Mexico within three quarters. In addition, all of the estimated coefficients exhibit the hypothesized signs, and the estimated income and Mexican price elasticities are statistically significant. The error correction term has the expected negative sign and is significant. The magnitude of the error correction term indicates that approximately 15 percent of the previous period's error is corrected in the current period.

These results indicate that, in the short-run, U.S. import demand from Mexico is affected by changes in U.S. income, changes in Mexico's prices, and error correction term adjustments to deviations about the long-term equilibrium. Given the magnitudes of the estimated coefficients, the response of U.S. imports to changes in prices and the exchange rate are modest when compared to changes in U.S. income. As such, these results suggest that the business cycle plays a more prominent role in short-run changes in U.S. imports from Mexico than do price fluctuations (including tariff changes). Over the long-run, even though price and exchange rate effects increase in statistical significance, the parameter magnitudes indicate that the income effect is still likely to dominate.

In the equation for Mexico's demand for U.S. exports, the exchange rate effect occurs contemporaneously, potentially reflecting heightened sensitivity to currency market fluctuations in the smaller economy. The other price components are included at longer, and different, lags. As with imports, absolute parameter magnitudes are not equal indicating that the short-run export demand function is not homogeneous with respect to prices. The income effect occurs within 1 quarter, Mexican prices impact exports within two quarters, and U.S. prices impact exports to Mexico within three quarters. All of the coefficients exhibit the hypothesized signs, and the estimated exchange rate and Mexican price elasticities are statistically significant. As with the import equation, the error correction term has the expected negative sign and is significant. The size of the error correction term implies that approximately 12 percent of the previous period's error is corrected in the current period.

These results indicate that short-run U.S. export demand by Mexico is significantly affected by currency market fluctuations, changes in Mexico's prices, and error correction term adjustments to deviations from long-run trends. The magnitudes of the estimated parameters suggest that short-run U.S. export responses to cyclical changes Mexico's income are modest relative to those associated with changes in prices (including tariffs) and the exchange rate. Over the long-run, however, even as the price and exchange rate effects increase in significance, the income effect is still likely to dominate.

IV. Summary and Conclusions

This paper targets three objectives. First is estimation of bilateral trade elasticities between the United States and Mexico. Second is allowance for trade flow reaction heterogeneity with respect to the three individual components that influence international pricing fluctuations: domestic prices, foreign prices, and exchange rates. Lastly, the modeling strategy allows joint examination of both the long-run determinants of U.S.-Mexico trade flows as well as short-run dynamic adjustments to deviations away from those trade patterns.

The estimated long-run coefficients for incomes, prices, and the bilateral exchange rate all exhibit the hypothesized signs. Only the United States price parameter in the long-run export equation fails to be statistically significant. In the error correction models estimated for U.S. import demand from Mexico, parameter magnitudes for the price components differ from each other, as do the lag structures for those variables. Consequently, flexible split price model specifications should probably be employed when estimating bilateral trade flow models. In general, the results obtained indicate that bilateral trade flow equations can be successfully estimated for trading partners such as the United States and Mexico. Such tools may provide useful information when countries enter into bilateral and/or regional trade negotiations that carry with them both short- and long-run outcomes.

In summary, evidence reported herein indicates that trade flows between the United States and Mexico can be analyzed by means of a relatively straightforward error correction framework. Trade flows between the two countries respond in heterogeneous manners to changes in income, prices, and the exchange rate. The long-run income elasticities of the equations imply that growth in both economies is likely to be accompanied by large-scale increases in cross-border trade volumes. Estimation of bilateral trade equations such as these can likely benefit from taking advantage of econometric techniques that account for dynamic time series behaviors exhibited by many economic systems.

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