# Short and Long Run Armington Elasticities for the Mexican Economy

**Enrique R. Casares, Lucía A. Ruiz-Galindo and Horacio Sobarzo**

**Abstract** The Armington elasticity is a key element in models with trade flows, either in International Real Business Cycle (IRBC) models or in computable general equilibrium models. In this paper, Armington elasticities at the aggregate level are estimated for Mexico for the 1993–2013 period. The composite good, formed by domestic and imported goods, is defined by means of an aggregate social accounting matrix for Mexico. This composite good is modeled through of a constant elasticity of substitution function. The relative demand for imports to domestic goods is obtained as a function of their relative prices. The two variables of the model, the logarithm of the relative demand for imports to domestic goods and of their relative prices, are integrated of order one and cointegrated. Therefore, an error correction model is used in order to obtain short and long run elasticities. Thus, short and long run elasticities are 0.534 and 0.719, respectively. The estimated elasticities are consistent with those used in IRBC models, which are relatively small elasticities. Also, long run elasticity is higher than short run elasticity, as presented in the literature.

**Keywords** Real business cycles models · Computable general equilibrium models · Armington assumption · Unit root · Cointegration · Error correction model

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E.R. Casares (✉) · L.A. Ruiz-Galindo
Departamento de Economía, Universidad Autónoma Metropolitana
Unidad Azcapotzalco, Av. San Pablo 180, Col. Reynosa Tamaulipas,
02200 Delegación Azcapotzalco, Ciudad de México, D.F., Mexico
e-mail: ercg@correo.azc.uam.mx

L.A. Ruiz-Galindo
e-mail: laruizg@correo.azc.uam.mx

H. Sobarzo
El Colegio de México, Centro de Estudios Económicos, Camino al Ajusco 20,
Tlalpan, Pedregal de Santa Teresa, 10740 Ciudad de México, D.F., Mexico
e-mail: hsobarzo@colmex.mx



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## 1 Introduction

In models with trade flows, one of the key elements to understanding the behavior of the trade variables and macroeconomic aggregates is the elasticity of substitution between domestic and imported goods, also known as Armington elasticity, which essentially posits that goods are different depending on the place they are produced, and therefore, rarely are perfect substitutes when their prices fluctuate [2].

Specifically, the importance of Armington elasticities has been evident in two branches of economic modeling, International Real Business Cycles (IRBC) models and Computable General Equilibrium (CGE) models, which have different perspectives on their values, and, in both cases, the arguments are reasonable.

On the one hand, to account for the volatility of the terms of trade and movements in the balance of trade, in IRBC models, the practice is to use relatively small calibrated elasticity values in a range between 0.5 and 2 [7, 8]. For example, [3] used a value of 1.5 for the Armington elasticity of substitution (also, [18]). In addition, to provide empirical support for the use of these small elasticities, [13] estimate the substitution elasticity between domestic and foreign goods with aggregate data, finding a value of 0.9. Similarly, [4] estimate an elasticity of 1.13 with data at a macro level.

On the other hand, to explain the growth of international trade, in CGE models, it is very common to find values above 3 and up to 6, depending on different estimations ([1]). [22], for example, uses values of 3 and 4 for the goods considered more tradable, such as in agriculture.

Thus, there seems to be a significant discrepancy regarding these key values when studying the flows of trade. Some reasons that help explain these discrepancies are related to aspects such as the level of aggregation of goods. Thus, in IRBC models aggregation levels are high, while CGE models usually operate with higher levels of disaggregation.

This seemingly unsolvable contradiction has, in fact, a very coherent explanation. In this regard, [21] provides an argument that reconciles both approaches. The idea is simply that the elasticities evaluated with high frequency data on prices and quantities, such as in IRBC models, capture responses to transitory shocks to productivity or demand. On the other hand, the elasticities estimated with changes in trade policy, as in CGE models, are capturing responses to permanent shocks. Therefore, as the agents react differently to permanent or temporary changes, it is normal, then, that the elasticities would differ.[1]

The objective of this paper is to quantify the degree of substitution between imported and domestic goods in Mexico, caused by changes in the relative prices of these goods; that is, the Armington elasticities are estimated at the aggregate level, as in IRBC models. This estimation is important, not only for being the first of its kind for Mexico, but, also, because it contributes to a better understanding of

[1] Hertel et al. [15] point out some problems with econometric estimation techniques and the mismatch between the data sample, the source of variation in the econometric estimation and the policy experiment to be performed in CGE models.

macroeconomic fluctuations associated with the phenomena of trade liberalization and changes in the terms of trade. The value of this elasticity is key to measuring social welfare impacts associated with these phenomena.

In this paper, we present an aggregated Social Accounting Matrix (SAM) for Mexico with the purpose of defining the so-called composite good, consisting of domestic and imported goods. The quantity of the composite good is defined by a Constant Elasticity of Substitution (CES) function, which describes the preferences of consumers to substitute imported for domestic goods. More specifically, a representative domestic consumer is considered to minimize the expenditure on domestic and imported goods subject to the CES function. The first order conditions for this optimization problem lead to the relative demand of imported goods to domestic ones as a function of their relative prices, which is the first model to be considered for the estimation of the Armington elasticities. Together with this, alternative models are formulated, like the partial adjustment and error correction models, which make sense when one has analyzed the properties of the data incorporated in the model.

In the estimation of the model, we use quarterly data corresponding to the domestic supply and imports with their respective price indices for the period from the first quarter of 1993 to the fourth quarter of 2013. Therefore, it is essential to study the order of integration of the variables and their possible cointegration in order to choose between alternative models so we can make a proper analysis of the short and long run effects. The specification of the final model also depends on the economic and econometric evaluations. The latter is an important feature of this work, because a detailed assessment of the assumptions of the econometric model is carried out. Most of the literature on the subject confine themselves to analyzing only the statistical significance of the elasticities, or simply presenting their values.

Due to the fact that the two variables of the model, the logarithm of the relative demand of imports to domestic goods and of their relative prices, are integrated of order one and cointegrated, the estimations were made using an error correction model. Thus, Armington short and long run elasticities estimated in this paper are 0.534 and 0.719, respectively. These results are related to the articles of [11, 16], where using cointegration techniques allow them to distinguish between short and long run elasticities. In addition, [11] find that long run elasticities of import demand are usually higher than short run elasticities, as presented in this paper. Also, our results show that the substitution elasticities between domestic and imported goods are less than one, as in [13].[2]

The paper is organized as follows. In Sect. 2, an aggregated SAM is shown to define the composite good, and to explain how the time series used in the econometric estimation were constructed. In Sect. 3, the optimization problem is presented, and the relative demand model is obtained. In Sect. 4, the econometric methodology and the different models that can be estimated according to the statistical properties of empirical information are presented. In Sect. 5, once the stationarity analysis is

[2]Crucini and Davis [5] develop a model where the discrepancy between the values of substitution elasticity, the short and long run, is a result of the frictions in the distribution sector.

completed and the order of integration of the variables is determined, the most appropriate model is chosen, estimated and evaluated. The paper ends with conclusions in Sect. 6.

## 2 Social Accounting Matrix

In this section, the formation of a Social Accounting Matrix (SAM) for Mexico for the year 2003 is described, where all goods are aggregated into only one, which describes in detail how the supply of (and demand) this good is formed. The idea is simply to define the composite good and show where the optimal choice, between domestic and imported goods, is presented. At the same time, we show how the time series used in the econometric estimation are constructed. In addition, the SAM format arrangement tries to act as point of reconciliation between the two approaches alluded in the previous section, a Macro SAM that, eventually, when disaggregated, provides the basis for a CGE model.

The SAM presented here was developed using the information contained in the Mexican Input-Output Matrix for 2003 and in the Mexican National Accounts for the same year (INEGI). The SAM is formed by the productive activities, goods, factors of production, institutions, investment, and the rest of the world accounts (Table 1).

As is well known, a SAM is a square accounting format, where economic activities of the main actors of the economy are recorded in monetary terms for a given period. A row (sales) and a column (purchases) correspond to each agent. The row represents the income, and the column represents expenses, this way reflecting, for each agent, the accounting identity that income is equal to expenditure.

In Table 1, one can observe that the account of productive activities is broken down into two sub-accounts, value added and gross output. The first sub-account corresponds to the net value of the production of goods (column 1), which consists of payments to factors (labor and capital) and tax payments on production. In the second sub-account (column 2), the formation of gross production is described, which is made up of net output and intermediate consumption (row 6, column 2).

The formation of the supply is described in columns 3, 4, 5 and 6. Thus, taxes on products (393) are added to the domestic consumption supply (10,509) to form the internal supply at market prices (10,902). In turn, the supply of imports is recorded in column 5, where purchases from the rest of the world are recorded (2,026). Thus, the two sources of supply, domestic and imported, are shown at market prices. Both are reported in column 6 to form the total supply (12,928) for domestic consumption. As noted, this supply is called composite good, because it brings together the two sources of supply for the country, domestic and imported. This is where the optimal choice between domestic and imported goods arises, modeled through of the Armington assumption. Note that a part of domestic production goes to the rest of the world in the form of exports (row 2, column 4).

**Table 1** Social accounting matrix of 2003 (billions of Pesos)

| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Productive activity | | Goods | | | | Factors | | Institutions | | | | Total |
| | | | Value added | Gross output | Domestic | Exported | Imported | Composite | Labor | Capital | Households | Government | Investment | Rest of the World | |
| 1 | Productive activity | Value added | | 7,168 | | | | | | | | | | | 7,168 |
| 2 | | Gross output | | | 10,509 | 1,915 | | | | | | | | | 12,425 |
| 3 | Goods | Domestic | | | | | | 10,902 | | | | | | | 10,902 |
| 4 | | Exported | | | | | | | | | | | | 1,915 | 1,915 |
| 5 | | Imported | | | | | | 2,026 | | | | | | | 2,026 |
| 6 | | Composite | | 5,256 | | | | | | | 5,048 | 893 | 1,729 | | 12,928 |
| 7 | Factors | Labor | 2,370 | | | | | | | | | | | | 2,370 |
| 8 | | Capital | 4,493 | | | | | | | | | | | | 4,493 |
| 9 | Institutions | Households | | | | | | | 2,370 | 4,493 | | | | | 6,863 |
| 10 | | Government | 304 | | 393 | | | | | | | | | | 697 |
| 11 | Savings | | | | | | | | | | 1,815 | -195 | | 110 | 1,729 |
| 12 | Rest of the world | | | | | | 2,026 | | | | | | | | 2,026 |
| | Total | | 7,168 | 12,425 | 10,902 | 1,915 | 2,026 | 12,928 | 2,370 | 4,493 | 6,863 | 697 | 1,729 | 2,026 | |

To close the supply-demand circuit, note that demand is recorded in row 6, where the various demands, intermediate consumption and final demand (households, government and investment) are registered, so that supply and demand are equal.

The following accounts describe the circular flow of income, which originates in the payment to the factors of production (value added), and is distributed in columns 7 and 8 to households. These, after deducting taxes, spend their income on consumption and savings. Final demand then arises from private incomes of households, government revenues, and savings or investment.

For the purposes of this paper, what is relevant in this section is to show how the so-called composite good is defined as the result of adding the domestic supply and imports. The next section will show that the representative national consumer selects the optimal mix between these two sources, depending on his budget constraint and the prices of domestic and imported goods. In the econometric estimation, quarterly time series were used, corresponding to the national and imported supply, with their respective price indices, as defined in our SAM of 2003.

## 3 The Model

Given that the Armington assumption states that domestic and imported goods are often not perfect substitutes, a CES function, that allows us to model the supply of the composite, $Q$, is specified as

$$Q = \varphi\left[\delta D^{-\rho} + (1-\delta)M^{-\rho}\right]^{-1/\rho}, \tag{1}$$

where $D$ is the good produced domestically, $M$ is the imported good, $\varphi$ is a scale parameter, $\delta$ is the distribution parameter and $\rho$ is a parameter of substitution.

The consumer minimizes his expenditure, $E$, subject to (1):

$$\min E = P_D D + P_M M, \tag{2}$$

$$\text{subject to } \; Q = \varphi\left[\delta D^{-\rho} + (1-\delta)M^{-\rho}\right]^{-1/\rho},$$

where $P_D$ is the price of the domestic good and $P_M$ is the price of the imported one. The solution of the optimization problem consists in choosing $D$ and $M$ so that the first order conditions of problem (2) are satisfied, which may be expressed by the relation between relative demand and relative prices, given by

$$\frac{M}{D} = \left[\left(\frac{1-\delta}{\delta}\right)\frac{P_D}{P_M}\right]^{\varepsilon}, \tag{3}$$

where $\varepsilon = \frac{1}{1+\rho} > 0$ is the Armington substitution elasticity. Linearizing the above expression, the static log - log linear model can be formulated as

$$\ln\left(\frac{M}{D}\right) = \beta + \varepsilon \ln\left(\frac{P_D}{P_M}\right), \tag{4}$$

with $\beta = \varepsilon \ln\left(\frac{1-\delta}{\delta}\right)$. From here the empirical analysis starts.

## 4 Econometric Methodology

The final specification of the model depends on the properties of the empirical information incorporated in the imported and domestic goods and in the relative prices, and of course, of the economic and econometric evaluations. In this case, time series are available for each variable in the static model in (4), which can be formulated in its linear form as

$$\ln Y_t = \beta + \varepsilon \ln X_t + e_t, \tag{5}$$

where $Y_t = \frac{M_t}{D_t}$, $X_t = \frac{P_{Dt}}{P_{Mt}}$, $e_t$ is the stochastic term, which is a Gaussian white noise, $t = 1, \ldots, T$ is an index that runs over the observations, and $T$ is the total number of them.

First, tests of stationarity are conducted and, where appropriate, the order of integration of the variables $\ln Y_t$ and $\ln X_t$ is determined.[3] When these variables are stationary, $I(0)$, the most appropriate model is the Partial Adjustment Model (PAM), which can be specified as

$$\ln Y_t = \beta + \varepsilon_1 \ln X_t + \varepsilon_2 \ln Y_{t-1} + e_t, \tag{6}$$

with the advantage that this model is dynamic and provides the short and long run Armington elasticities. In it, $\varepsilon_1$ is the short run elasticity, and the long run elasticity is given by

$$\varepsilon_{LP} = \frac{\varepsilon_1}{1-\varepsilon_2}. \tag{7}$$

If the variables in log-levels are not $I(0)$, their orders of integration are determined, and they are analyzed to determine if they are cointegrated only if their orders of integration are the same.[4] If cointegration of variables is accepted, an Error Correction Model (ECM) is formulated [14].[5] As in the linear model presented in (5), there are

[3]This is stationary of the second order, or covariance stationary.

[4]According to Engle and Granger [10], a set of variables is cointegrated if they have the same order of integration, $I(d)$, $d > 0$, and if there is a linear combination of them that is $I(d-b)$ (its order of integration is less than $d$). This linear combination is the long run relation. In this manner, the concept of cointegration refers to the existence of long run relationships between variables, so that even if these increase (or decrease), they do so in a completely synchronized way.

[5]The most used ECM formulation is

$$\Delta \ln Y_t = \beta + \varepsilon_1 \Delta X_t + \alpha\left[\ln Y_{t-1} - \gamma ln X_{t-1}\right] + e_t,$$

two variables, if they are cointegrated, there will be only one long run relationship, and if in addition both are $I(1)$, the ECM can be specified as

$$\Delta \ln Y_t = \beta + \varepsilon_1 \Delta \ln X_t + \varepsilon_2 \ln Y_{t-1} + \varepsilon_3 \ln X_{t-1} + e_t, \tag{8}$$

where $\varepsilon_1$ continues being the short run elasticity, and the long run elasticity is determined by

$$\varepsilon_{LP} = -\frac{\varepsilon_3}{\varepsilon_2}, \tag{9}$$

where $\varepsilon_{LP}$ is the long run elasticity.[6] When the variables have the same order of integration, but are not cointegrated, a model in first differences of the log-levels is used:

$$\Delta \ln Y_t = \beta + \varepsilon_1 \Delta \ln X_t + e_t, \tag{10}$$

where, $\varepsilon_1$, as always, represents short run elasticity.

## 5 Estimation and Evaluation of the Armington Elasticities

The methodology presented previously notes that before proceeding to estimate a model, it is necessary to know the properties of the empirical information that is inserted in it. Therefore, first the stationarity of the time series in log-levels is analyzed; if they are not stationary, a transformation is sought (difference) that is stationary to obtain the order of integration. Next, we study whether the series with the same order of integration are cointegrated or not, to finally specify, estimate, and evaluate the appropriate model.

### *5.1 The Data*

The estimation of the models considers quarterly information from INEGI for the period covered by the first quarter of 1993 to the fourth quarter of 2013, at constant prices of 2008. In the relative demand, $M$, represents total imports and $D$,

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(Footnote 5 continued)
where $\Delta$ is the difference operator, $\alpha$ is the speed of adjustment, $\varepsilon_1$ shows the short run effects, $\gamma$ measures the long run effect of a change in the logarithm of relative prices on the logarithm of the ratio of imported to domestic goods. Doing some algebra, we can obtain the model in (8) with $\varepsilon_2 = \alpha$ y $\varepsilon_3 = -\alpha\gamma$. As already mentioned, ECM makes sense only when $\ln Y_t$ and $\ln X_t$ are $I(1)$ and cointegrated, so in this way, it is guaranteed that $\left[\ln Y_{t-1} - \delta ln X_t\right]$ is $I(0)$, and therefore the equation is balanced, as the stochastic term is assumed to be white noise, $I(0)$, and so are $\Delta \ln Y_t$ and $\Delta \ln X_t$.

[6]The difference of the logarithm of the variable $Z_t$, $\Delta \ln Z_t = \ln Z_t - \ln Z_{t-1}$ is its rate of growth.

the domestic demand, which is calculated as the gross value of production, minus exports. Meanwhile, in the determination of relative prices, the corresponding price indices of $D$ and $M$ were used.

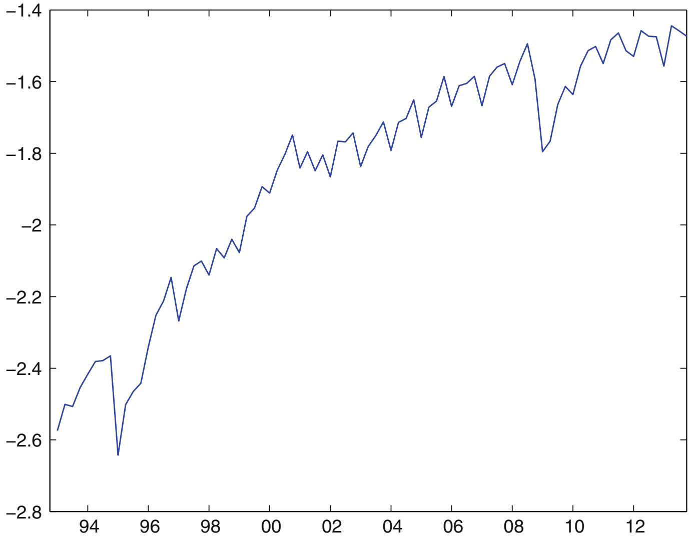


**Fig. 1** Logarithm of the relative demand

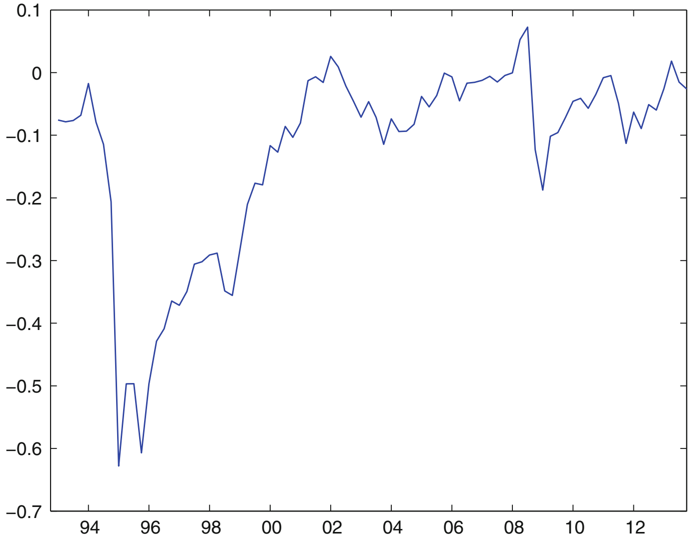


**Fig. 2** Logarithm of the relative price

**Table 2** Stationarity tests

| Variable | ADF | PP | KPSS |
|---|---|---|---|
| $\ln\left(\frac{M_t}{YP_{Dt}}\right)$ | $-3.1542$ | $-2.7090$ | 1.0607 |
| | (0.0569) | (0.0768) | |
| $\ln\left(\frac{P_{YDt}}{P_{Mt}}\right)$ | $-1.9087$* | $-2.0087$* | 0.6495 |
| | (0.3269) | (0.2827) | |
| $\Delta\ln\left(\frac{M_t}{YP_{Dt}}\right)$ | $-3.3331$ | $-13.8929$ | 0.5000 |
| | (0.0168) | (0.0001) | |
| $\Delta\ln\left(\frac{P_{YDt}}{P_{Mt}}\right)$ | $-7.0275$ | $-9.1610$ | 0.0810* |
| | (0.0000) | (0.0000) | |
| Critical values | | | |
| 5% | $-2.9012$ | $-2.8967$ | 0.4630 |
| 10% | $-2.5879$ | $-2.5856$ | 0.3470 |

The numbers in parenthesis are the $p$-values and the * indicates rejection of the null hypothesis at a 5% significance level

## *5.2 Stationarity and Cointegration Analysis*

It is important to point out that regression analysis, in the presence of integrated variables, can lead to spurious relationships [12], so it is necessary to check whether the model variables are stationary; that is to say, if their mean and unconditional variance are time-invariant, and if the unconditional covariance is equal for couples of variables with the same distance in time. In case some of these properties are not satisfied, differences are applied to see the possibility of obtaining a new variable that will satisfy the properties.

Figures 1 and 2 show that neither the logarithm of the relative demand, nor of the relative price, is stationary, both show tendency. Although this is evidence of nonstationarity, statistical tests to support this fact must be performed. Here, the Augmented Dickey and Fuller (ADF), Phillips-Perron (PP) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests are carried out to analyze the stationarity of the variables of the model.[7] All these tests show that the first difference of log-level of demand and relative prices are stationary at a 5% significance level and, therefore, the logarithms of these variables are $I(1)$ (Table 2).

According to the above results, the two variables of the model are $I(1)$ and, therefore, growth rates of the relative demand (substitution rate) and of the prices are $I(0)$, which means that the variables $\Delta\ln Y_t = \Delta\ln\left(\frac{M_t}{D_t}\right)$ and $\Delta\ln X_t = \Delta\ln\left(\frac{P_{Dt}}{P_{Mt}}\right)$, are stationary and, thus, there is a possibility that the variables $I(1)$ are cointegrated.

[7] In the ADF and PP tests ([6, 20], respectively), the null hypothesis is non-stationarity or equivalently, $H_0$: Unit root, while in the KPSS [19], $H_0$: No unit root (Stationarity).

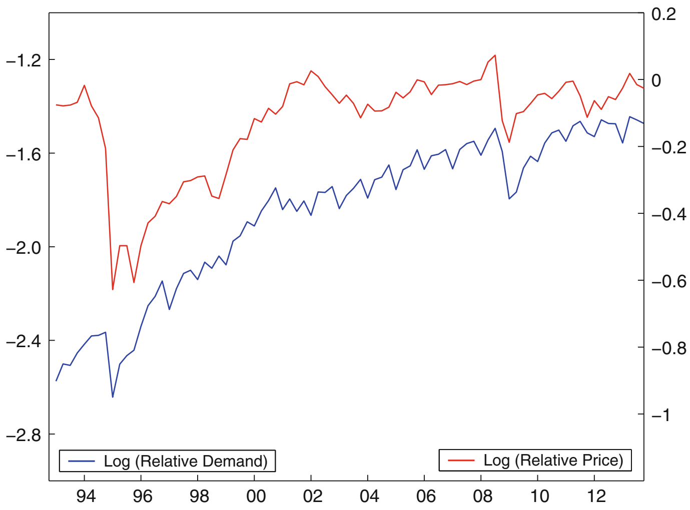


**Fig. 3** Relative demand and relative price (logarithms)

**Table 3** Stationarity tests of the residuals

| Variable | ADF | PP | KPSS |
|---|---|---|---|
| $\hat{u}_t$ | −2.8471 | −3.4496 | 0.3154 |
| | (0.0564) | (0.0119) | |
| Critical values | | | |
| 5% | −2.8987 | −2.8967 | 0.4630 |
| 10% | −2.5866 | −2.5856 | 0.3470 |

The numbers in parentheses are the $p$-values

In Fig. 3 one observes that there could actually be a long run relationship between the logarithm of relative demand and the logarithm of the relative price, as they show very synchronized behavior. However, the graphical evidence is not sufficient to guarantee the existence of cointegration. This is confirmed or refuted by the Engle and Granger test [10] and/or the Johansen test [17], in its two versions: the maximum eigenvalue and trace. All these tests incorporate a tendency because of the dynamics of the series.

In the Engle and Granger test, one should ensure that the residuals of the regression

$$\ln Y_t = \delta_1 + \delta_2 t + \delta_3 \ln X_t + u_t, \tag{11}$$

are stationary, for which the ADF, PP and KPSS tests are carried out. The results, shown in Table 3, do not reject the stationarity of the residuals, given by

$$\widehat{u_t} = \ln Y_t - \widehat{\ln Y_t} = \ln Y_t - \hat{\delta}_1 - \hat{\delta}_2 t - \hat{\delta}_3 \ln Y_t$$

**Table 4** Johansen tests

| Test of the maximum eigenvalue | | | | |
|---|---|---|---|---|
| $H_0$ | $H_1$ | $\lambda_{\text{Max}}$ | Critical value* | $p-$ value |
| $r=0$ | $r=1$ | 23.7713 | 14.2646 | 0.0012 |
| $r\leq 1$ | $r=2$ | 8.6722 | 3.8415 | 0.0032 |
| Trace test | | | | |
| $H_0$ | $H_1$ | $\lambda_{\text{Trace}}$ | Critical value* | $p-$ value |
| $r=0$ | $r=1$ | 32.4436 | 15.4947 | 0.0001 |
| $r\leq 1$ | $r=2$ | 8.6722 | 3.8414 | 0.0032 |

$r$ is the number of relations of cointegration
$*$ 5% significance level

For their part, the versions of the Johansen test presented in Table 4 also provide evidence that the variables are cointegrated, since in both, in the second iteration the hypothesis which establishes the existence of a cointegration relationship, is not rejected.

## 5.3 *Estimation of the Armington Elasticities*

Since the variables $\ln Y_t$ and $\ln X_t$ are $I(1)$ and are cointegrated, the appropriate model to estimate the Armington elasticities is the Error Correction Model (ECM) given by

$$\begin{aligned}\Delta \ln Y_t = \alpha_1 + \varepsilon_1 \Delta \ln X_t + \alpha_2 \big( \ln Y_{t-1} - \hat{\delta}_1 - \hat{\delta}_2 (t-1) \\ -\hat{\delta}_3 \ln X_{t-1} \big) + e_t,\end{aligned} \tag{12}$$

where the term within parenthesis is the residual of the model in (11) and based on it, the least square estimators of $\alpha_1$, $\alpha_2$ and $\varepsilon_1$ are obtained. Once terms have been associated, the model can be expressed as follows

$$\Delta \ln Y_t = \beta_1 + \beta_2 t + \varepsilon_1 \Delta \ln X_t + \varepsilon_2 \ln Y_{t-1} + \varepsilon_3 \ln X_{t-1} + e_t, \tag{13}$$

where $\beta_1 = \alpha_1 - \alpha_2(\hat{\delta}_1 - \hat{\delta}_2)$, $\beta_2 = -\alpha_2 \hat{\delta}_2$, $\varepsilon_2 = \alpha_2$ and $\varepsilon_3 = -\alpha_2 \hat{\delta}_3$, the last specification is the version with tendency of the ECM proposed in (8). In the previous models, Armington short run and long run elasticities are, respectively,

$$\varepsilon_1 = \delta_3 \text{ and } \varepsilon_{LP} = -\frac{\varepsilon_3}{\varepsilon_2}.$$

The ECM estimation was carried out following the Engle and Granger procedure, which consists of two stages. The first is to verify whether the model residuals in (11) are stationary. If so, they proceed to the second stage, where the model proposed in (12) is estimated using the residuals of the regression in (11). The estimation made here is done by adding dichotomous variables (dummies) to the model in (13) to account for significant changes in the level of the series in 1995 and in 2008–2009, to reflect the impact of the 1994–1995 Mexican crises and world crises, respectively, that significantly impacted the behavior of demand and relative prices (see Figs. 1 and 2).[8]

In order to obtain statistically efficient estimation and inference, one may test the weak exogeneity of $\Delta \ln X_t$ for the parameter(s) of interest.[9] Engle and Granger [10] argue that a simple way to check the weak exogeneity of $\Delta \ln X_t$ for the parameters of interest is to estimate an ECM for $\Delta \ln X_t$, and test the significance of the error correction term, using a traditional $t$-test. The weak exogeneity of $\Delta \ln X_t$ is not rejected for the long-run parameter, this means that the speed of adjustment coefficient appears as insignificant in the ECM for $\Delta \ln X_t$ (see Appendix A). Thus, one can conclude that $\Delta \ln X_t$ may be considered as weakly exogenous for the long run parameter.

The first stage of the Engle-Granger procedure was performed when doing the cointegration test, in which the stationarity of the residuals was verified, so we proceed to the second stage, obtaining the estimated model

$$\widehat{\Delta \ln Y_t} = \underset{(0.0053)}{0.0270} + \underset{(0.0596)}{0.534} \Delta \ln X_t - \underset{(0.0094)}{0.095} d_{1t} + \underset{(0.0363)}{0.036} d_{2t}$$
$$\underset{(0.0520)}{-0.052} \left( \ln Y_{t-1} + 2.004 - 0.0001t - 0.719 \ln X_{t-1} \right),$$

where $d_1$ and $d_2$ are dummy variables and the figures in parentheses are the standard errors. The estimated parameters have the expected signs and magnitudes, are significant, and in general, the econometric evaluation is appropriate (Table 5 in the Appendix B).[10] The Armington short and long run elasticities are given by

$$\varepsilon_1 = 0.534 \text{ and } \varepsilon_{LP} = 0.719.$$

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[8]Given the behavior of the log of the demand and of the relative prices, the dummies are defined as

$$d_{1t} = \begin{cases} 1, & t = 1995:1 \text{ to } 1995:4, \\ 0, & \text{in the other quarters,} \end{cases}$$

and

$$d_{2t} = \begin{cases} 1, & t = 2008:1 \text{ to } 2009:3, \\ 0, & \text{in the other quarters,} \end{cases}$$

where 1995:1 indicates the first quarter of 1995 and the other periods are defined in an analogous manner.

[9]The importance of the concept of exogeneity in a conditional econometric model has been pointed out particularly well in [9].

[10]Given that we have a cointegration relationship with $I(1)$ variables, we apply Granger causality test. The null hypothesis of no-causality from $\Delta \ln X_t$ to $\Delta \ln Y_t$ is rejected, but it is not rejected from $\Delta \ln Y_t$ to $\Delta \ln X_t$. Therefore, $\Delta \ln X_t$ is strongly exogenous, since $\Delta \ln X_t$ is weakly exogenous and $\Delta \ln Y_t$ is not Granger causing $\Delta \ln X_t$.

respectively, which implies that relative demand is inelastic in both the short and long run; that is, changes in the relative prices of domestic and imported goods do not have a substantial effect on the relative demand for imports to national goods. Furthermore, the long run elasticity obtained is larger than the short run elasticity, largely due to the longer adjustment time.

# 6 Conclusions

In this paper, short and long run Armington elasticities have been estimated for the Mexican economy. The specification of the final model depended on a detailed assessment of the assumptions of the econometric model. The estimations were made using an Error Correction Model, since the two variables of the model, logarithm of relative demand and logarithm of relative prices, are integrated of order one and are cointegrated. This model has the advantage of providing both the short and long run elasticity estimates, and the estimation is adequate, since on the one hand, elasticities have the expected signs and magnitudes, and on the other, the estimated parameters are individually and jointly significant, and the residuals satisfy the assumptions underlying the stochastic terms of the theoretical econometric model.

In the estimation of the Error Correction Model, the long run Armington elasticity is greater than the short run due to the longer adjustment time. Thus, both elasticities suggest that domestic and imported goods are poor substitutes in Mexico, as in IRBC models. In future research, Armington elasticities will be estimated with disaggregated data, and the discrepancies between the elasticities obtained with aggregated and disaggregated data will be observed. Thus, trade flows in Mexico could be better understood, either using IRBC models, or CGE models.

# Appendix A. Weak Exogeneity Test

The estimated ECM for $\Delta \ln X_t$ is

$$\Delta \ln X_t = \underset{(0.0077)}{0.0050} - \underset{(0.1077)}{0.148}\Delta \ln Y_t + \underset{(0.0772)}{0.087}\big(\ln X_{t-1} - 0.467 - 0.321 \ln Y_{t-1}\big)$$

where the figures in parentheses are the standard errors. The long-run coefficient is insignificant, therefore weak exogeneity is not rejected and one can conclude that $\Delta \ln X_t$ may be considered as weakly exogenous for the long run parameter.

**Table 5** Diagnostic tests for the ECM

| Test | $H_0$ | Statistics | $p -$ value |
|---|---|---|---|
| Normality | | | |
| -Jarque-Bera | Normality | 5.4462 | 0.0656 |
| Autocorrelation | No autocorrelation | | |
| -Lungj-Box | | | |
| 1 lag | | 0.0291 | 0.8650 |
| 4 lag | | 1.3635 | 0.8510 |
| 12 lag | | 10.559 | 0.5670 |
| 32 lag | | 31.846 | 0.4740 |
| -Breusch-Godfrey | No autocorrelation | | |
| 1 lag | | 0.2860 | 0.8661 |
| 4 lag | | 0.3164 | 0.8661 |
| Heteroskedasticity | Homoskedasticity | | |
| -White | | 0.7369 | 0.5696 |
| -White terms Crossed | | 1.0002 | 0.4551 |
| -Breusch-Pagan-Godfrey | | 1.4618 | 0.2219 |
| Correct Specification | Linearity | | |
| -RESET | | 1.3488 | 0.1814 |

## Appendix B. Diagnostic Tests

Table 5 presents the results of diagnostic tests of the estimated model for Armington elasticities. According to the results, it can be concluded that their residuals are a good proxy for the stochastic term of the theoretical econometric model because they are normal, not autocorrelated and homoskedastic, and also, the linear model specification is correct (Table 5).

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