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1 INTRODUCTION

The economic evaluation of regional free trade agreements is difficult because they affect many sectors in several different ways, and have a complex impact on the national economy. It is, however, possible to use computable partial and general equilibrium models to assess their main impacts. In these two types of models, the change in the tariff alters the domestic price of the imported good relative to that of the domestically produced good, and this change in relative price affects the fraction of the demand which is supplied by imports. To analyze this effect, and to try to forecast its intensity, we need estimates of the elasticity of substitution between goods distinguished by their place of origin, known as Armington elasticity in the literature. Furthermore, to take into account the fact that there is a wide variety of situations regarding the substitutability between imports and domestic production, we estimate them by sector.[1]

Estimates of Armington elasticities are not available for the majority of counties, in spite of their crucial importance for evaluating the impact changes in commercial policy in foreign trade. One frequently encounters studies in this area where authors use estimates for other countries to substitute for the required estimates, in many cases completely disregarding important differences that may exist in the structure of production and consumption between it and the home country.[2] Since they are also not available for Brazil, the objective of this study was to estimate them for our country, using the largest available data sample, from 1986 to 2002. We have adopted the same level of aggregation used in the Brazilian input-output matrix, to facilitate the use of the estimated elasticities in disaggregated models.

Furthermore, the approach adopted here is a methodological contribution to the techniques usually employed to estimate the Armington elasticities in the literature, because it advocates the extensive use of the time series properties of the series involved to select of the method of estimation. Depending on the order of integration of the series of relative prices and quantities, we employ one of four approaches: simple regression in levels, equation in first differences, mixed equations, or a vector error correction model of the type proposed by Johansen (VEC).[3]

In the tests of the order of integration, as well as in the estimation of the equations themselves, we consider the possibility of a structural break when Brazilian the foreign trade was liberalized, beginning in 1990, as well as the possibility of the existence of seasonal factors and a time trend. In the estimation, we also consider the possibility that the uncertainty in prices affects the demand for imports. This careful approach to the specification and estimation of the model has clear empirical

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1 Henceforth we will not distinguish between the goods and the sectors that produce them, implicitly assuming that we are referring to the composite commodity produced by the sectors.

2. For example, Sánchez (2001), evaluates the costs and benefits for Mercosul joining ALCA with the use of the GETAP (*Global Trade Analysis Project*), applied general equilibrium model, but arbitrarily multiplies the original elasticities by six. Harrison *et alii* (2002) analyze the impacts of regional and multilateral trade agreements for Brazil while using elasticities estimated for Hong-Kong.

3. We believe this is a pioneering application of the methods developed by Johansen (1988) to the problem of estimating the Armington elasticities.

advantages in the case of Brazil, in the period considered in this analysis, because in this case the identification of the Armington elasticity using simpler methods was very difficult, if not impossible.

There are six sections in the paper, including this introduction. In section 2 we review briefly the concept of elasticity of the Armington elasticity of substitution. In section 3 we describe the database and discuss some empirical problems due to the prevalence, in the period before 1990, of foreign trade regime which was very closed with respect to imports, that was followed by gradual liberalization. Section 4 discusses the tests used to determine the existence of unit roots in the series for prices and quantities. Section 5 presents the different models used for estimation, and the results obtained. Section 6 summarizes the main conclusions.

2 ARMINGTON ELASTICITY: A BRIEF REVIEW

The approach proposed by Armington (1969), initially in a partial equilibrium context, has been widely used to evaluate the impacts of changes in trade policy, in partial equilibrium models as well as in general equilibrium models.[4] It assumes that goods are differentiated by country of origin, and that for each sector the domestic demand is supplied by a composite good that is a CES (Constant Elasticity of Substitution) aggregation of goods produced domestically and imported goods, as shown in equation (1).

$$Q_i = \bar{Q}_i \left[\delta_i M_i^{-\rho_i} + (1-\delta_i) D_i^{-\rho_i} \right]^{-1/\rho_i} \qquad (1)$$

where, for sector *i*, Q_i, M_i e D_i represent, respectively, the quantity index of the aggregate good, of the imported good, and of the domestically produced good, $\overline{Q_i}$ is the scale parameter, and ρ_i and δ_i are parameters. The first one is the distribution parameter, and one can see its role more clearly by setting $\rho_i = 1$, and realizing that the composite good is then only a linear combination of M_i and D_i. The second parameter indicates the degree of substitutability between the domestic and imported good, and determines the shape of the indifference curve that represents the smooth transition between these two good in the taste of the representative consumer.

The solution of the problem of minimizing the cost of supplying the total demand, given the expenditure and the prices of the imported and domestically produced goods gives the optimal composition of the composite good Q_i in terms of these two goods, and is represented by equation (2). It shows that the proportion between the domestic and the imported good depends on the elasticity of substitution $\sigma_i = 1/(1+\rho_i)$ and on the ratio of their prices, represented respectively by PD_i and PM_i

4. A good example is Dervis, Melo e Robinson (1982) that use the Armington specification in a computable general equilibrium model (CGE) which has become almost a standard model. Melo and Robinson (1989). See also Melo and Robinson (1989) for a more detailed discussion of its use in CGE´s. For examples of the use in partial equilibrium models, see the series of studies started by Hufbauer and Elliot (1994) and sponsored by the Institute of International Economics, Washington, D.C., to measure the social cost of protection in several countries.

$$\frac{M_i}{D_i} = \left(\frac{\delta_i}{1-\delta_i} \frac{PD_i}{PM_i} \right)^{\rho_i} \quad (2)$$

The relevant price of the good imported for domestic consumption – the interned price – depends on the price of the good in the foreign market in foreign currency (PE_i), on the exchange rate (e), and on the import tariff (σ_i), as shown in equation (3):

$$PM_i = PE_i \cdot e \cdot (1+\sigma_i) \quad (3)$$

It is useful to explore the behavior of equation (2) for different values of the elasticity of substitution for three extreme cases. If $\rho_i \to \infty$ and $\sigma_i \to 0$, there is no substitution between the two goods, and the ratio of their quantities does not depend on the relative prices. When $\rho_i \to -1$ and $\sigma_i \to \infty$, the two goods are perfect substitutes[5], and small changes in the relative prices are sufficient to produce wide swings in the ratio M_i/D_i. Lastly, when $\rho_i = 0$ and $\sigma_i = 1$, the CES function in equation (1) reduces to the Cobb-Douglas function, and the ratios of the expenditure in the imported and domestically produced goods is constant, and equal to $\delta_i/(1-\delta_i)$. Equation (2) shows also that one estimate of the degree of substitutability between the two goods (σ_i) can be obtained from the time series for the ratios M_i/D_i and PD_i/PM_i

To estimate the elasticity of substitution using equation (2), it is necessary to take into account that a time interval is required for the full adjustment of quantities to the change in prices. In the short run (some months), the impact will probably be small, since a few years are usually necessary the imported quantity to reflect fully the changes in the relative price of imports. The short run and long run elasticities are, therefore, different. In this study we will estimate the long run elasticities of substitution, using the same argument employed by Gallaway, McDaniel and Rivera (2000) to justify the adoption of that same time horizon in their study. They point out that the most frequent use of the Armington elasticity estimates is in comparative static analysis, in partial or general equilibrium models. In this type of analysis we compare the results of the controlled experiment to those in the base case, assuming the economy has had a sufficiently long time to adjust, in such a way that that the results of the experiment reflects the total effect of the policy experiment one is trying to evaluate.

3 SOURCE AND TREATMENT OF THE DATA

This section discusses initially the construction of the time series for the series that appear in equations (1) to (3), and the adjustments to the price series necessary to take into account the effects of the Brazilian foreign trade liberalization, which started in 1990.

5. In this case we consider that the domestic price of good *i* is very sensitive to the imported competitor, and that the ratio between them is approximately constant.

3.1 CONSTRUCTION OF THE DATA BASE

We used quarterly data, disaggregated by sector of the Brazilian input-output matrix (IBGE – level 50), for the period extending from 1986 to 2002.6 The price indexes (PM_i) and the quantum indexes (M_i) are those produced by Fundação Centro do Comércio Exterior (Funcex) [7], following the methodology described in Markwald et alii (1998), and are available in the electronic database system IPEAData (www.ipea.gov.br). The exchange rate (e) corresponds to the monthly average of the official value for sale of dollars. We approximated the index of domestic prices (PD_i) by the corresponding wholesale price index, the *Índice de Preço no Atacado (Oferta Global)* of Fundação Getulio Vargas (IPA-OG-FGV), adopting the correspondence between its sectors and those of the input-output matrix described in Annex 1. We adopted the average price index in the cases where one of the activities of the matrix corresponded to more than one sector of IPA, using the weighted average when the required data was available, or simple averaging, otherwise.

In the estimation, we also used the coefficient of variation of the relative price PD_i/PM_i as an exogenous variable. For each quarter, it is the rate between the standard deviation and the average of this ratio in a "window" 6 months wide, centered in the median month of the period.

The *quantum* index of domestic sales (D_i) was estimated by deflating the value of domestic sales for each sector (VD_i) by the corresponding domestic price index (PD_i). For the period 1986-1990 the value of total domestic sales (VDT_i) was estimated with the help of equation (4). It uses the *quantum* index of domestic production calculated by IBGE (www.ibge.gov.br) for each sector of the matrix, which was adjusted to the aggregation used here in the manner described in Annex 2.

$$VDT_{jt} = (VP_{j85}/12)*(q_{jt}/q_{85})*(P_{jt}/P_{85}) - VE_{jt} \qquad (4)$$

Where:

VDT_{jt} = value of total domestic sales in R$ of sector j in month t;

VP_{j85} = value of production in R$, in base price basis, of sector j in 1985;

q_{jt} = index of physical production of sector j in month t;

q_{85} = index of physical production of sector j, monthly average in 1985;

P_{jt} = index of domestic price of sector j in month t;

P_{85} = index of domestic price of sector j, monthly average in 1985; and

VE_{jt} = value of exports in R$ of sector j in month t.

6. The database in electronic format, Annex 5, is available on demand.

7. The database in this study is different from that in Tourinho, Kume and Pedroso (2002) because in July 2002 a revision of the foreign trade statistics for 1996 was posted (Funcex (2002)). The data for exports did not change significantly, but for several sectors the expenditure with imports suffered important revision, mainly due to changes in the physical quantity imported. Since the price and *quantum* indexes estimated by Funcex are chained in time, using as base period precisely the year of 1996, the data for all series were revised. Therefore, the change in for that year affected the level of the whole series, in spite of the fact that the rates of change were not altered, with the exception of those whose calculated involved the year 1996.

After 1991, the same procedure described above for the reference year of 1985 was used, but using as base the average values of the previous year, because for the period 1991-1996 the value of domestic production is available for each year in the input-output matrix, and in the period 1997-2002 in the National Accounts.

To calculate the nominal tariff of each sector (τ_i), we followed a two-step procedure. Initially, we distributed the products and respective tariffs of the foreign trade classification table – the *Nomenclatura Brasileira de Mercadorias : Sistema Harmonizado (NBM-SH)* and *Nomenclatura Comum do Mercosul (NCM-SH)* – in each sector (level 80) of the input-output matrix. Next, we calculated the average nominal tariff of each activity of the input-output matrix (level 50), weighted by the value of production of each sector (level 80) belonging to each activity (level 50).

3.2 EFFECTS OF THE MORATORIUM AND OF THE LIBERALIZATON

To build the price series for imported products we assume that *before 1990* the following stylized fact was true: the tariff employed in calculating the internalized price of the imports that actually occurred in that period, was null. The rationale for this hypothesis assumes that the imports of that period fall into two broad categories:

a) Non-competitive imports for which the import tariffs were already low, precisely because there was no need to protect the domestic industry. It is the case, for example, of metallurgical coal, petroleum, some fertilizers, and capital goods without a national similar, etc.

b) Competitive imports for which the import tariffs were exceedingly high. In this case, imports were economically viable if done by agents that had access to import tariff reduction or, in most cases, exemption. These import operations were conducted under special fiscal regimes, as those applicable to state-owned enterprises, or those associated to special investment projects that, in spite of being private, were considered of national interest, as for example, the projects supported by Sudam, Sudene, Conselho de Desenvolvimento Industrial (CDI), Zona Franca de Manaus etc..

In both cases, the calculation of the approximate value of the relevant internalized price in equation (3) assumes a null import tariff $(\tau_i = 0)$, in spite of the fact that the nominal legal tariff was very high.[8] This implicitly assumes that very few import operations paid the full (very high) legal tariff. This is a situation of repressed demand were potential importers were expelled from the import market for the goods whose tariff was prohibitive due to the lack of capacity to obtain the tariff exemption.

After 1990, we employed the average legal tariff (calculated as described in section 3.1) in equation (3) because the import liberalization policy reduced the nominal tariffs and extinguished the special regimes, except those associated with the Manaus free trade zone, the *drawback* operations, and the foreign trade agreements.

8. According to Kume (1990), in this period about 70% of imports, excluding petroleum, benefited from special fiscal regimes. Competitive imports were also prohibitive because there was a widespread presence of redundant tariffs.

Lastly, the shift in the demand curve for imports due to the facilitated access to them after the foreign trade liberalization, as long as the full import tariff was paid, was incorporated in the estimated equations by using a dummy variable that is equal to one after the last quarter of 1990.[9]

4 EMPIRICAL ANALYSIS

The first step was to examine the order of integration of the time series involved in the estimation, and choosing the empirical model as a function of the relation between them. This section describes the methodology used in these two steps of the estimation.

4.1 THE ORDER OF INTEGRATION

To implement the unit root test in a systematic way, with regards to the inclusion of the constant and the time trend, we adopted the procedure proposed by Doldado, Jenkinson e Sosvilla-Rivero (1990). In the cases where it indicated the existence of the unit root, we also applied the Perron (1989) test for structural break in the fourth quarter of 1990. In all cases the level of significance adopted in the tests was 10%, and the Akaike information criteria was used to determine number of lags to be used. Annex 3 describes in more detail the methodology employed in implementing the tests.

4.2 THE ESTIMATION METHODOLOGY

The logarithmic transformation of equation (2) is a long-run relation between $x_i^1 = \log(M_i/D_i)$ e $x_i^2 = \log(PD_i/PM_i)$. Since the same methodology applies to all sectors[10], from here on we will drop the product index *i*, to simplify the notation. Letting $x' = (x^1, x^2)$, we can write equation (5) for all periods *t*, where $\beta' = (1, -\sigma)$, $\mu = \log[\delta/(1-\delta)]$, and ε_t is a stochastic error:

$$\beta' x_t - \mu = \varepsilon_t \tag{5}$$

In estimating this equation, we take into account that it is a long-term relation, since the Armington elasticity we are interested in is a structural parameter.

Following Gallaway, McDaniel e Rivera (2000), we choose the specification for the estimated equation taking into account the order of integration of the series x^1 and x^2. When a unit root is not present, the series may be stationary or not but, regardless, the procedure employed is the same, and is based on the assumption that the series is I(0). Table 1 presents the four possible combinations of the order of

9. The official removal of the import restrictions occurred in March 1990, when the new federal government took office. However, the lifting of the non-tariff barriers that in fact controlled most imports happened only in July of that year. Therefore, only in the last quarter did the economic agents effectively perceive and benefited from the new freedom to import.

10. We estimate the elasticity of each good individually and in isolation of the other goods.

integration of the two series, along with the model employed in each case. The following sections discusses each one in more detail.

TABLE 1
DECISION TABLE FOR THE TYPE OF MODEL

Quantities (x^1)	Prices (x^2)	
	I(0)	I(1)
I(0)	A: levels	C: mixed
I(1)	B: levels	D: cointegration

Source: authors.

For estimation, we include other control variables to equation (5), in the case of model A, or to its transformed versions, in the case of models B and C. The first is a dummy variable, to take into account the effects of the foreign trade liberalization that occurred in 1990, as was discussed in section 3.2; its value is $d_t = 1$ for $t \geq 1990:4$ and $d_t = 0$ in the other periods. The second is a time trend (*t*), whose objective is to capture other factors that may have provoked structural changes in the *quantum* of imports, but did not affect the relative price of imports. The third is a vector of seasonal dummies, and the fourth is a measure of the price uncertainty for the importer. These last two effects are included in the vector of other exogenous variables (z_t).

The inclusion of a time trend and of the dummy variable can be rationalized as an attempt to take into account the variations in the quality of the goods, and of the composition of the sector aggregates that cannot be adequately considered in the construction of the quantity index. It is the case, for example, of the imports of electro-electronic goods and of personal computers, which increased significantly in the last years of the period, and where there is wide variation of the characteristics and composition of the aggregate good. That formulation assumes that a part of those changes occurred progressively throughout the period, while others happened in response to the change in the foreign trade regime, and allows the estimation routine to allocate these effects to those variables.

All models include also the coefficient of variation of the ratio of the prices of the domestic and imported varieties of the good as an exogenous variable[11]. This allows for the effect that the uncertainty in that relative price may have on the *quantum* of imports. The expected sign of its coefficient depends on the net effect of the speculative mechanisms, which may be positive or negative. For example, firms that depend heavily on imported inputs may react to an increase in uncertainty in their expected relative costs of imports by increasing their imports (positive effect) or substituting for them (negative effect). Therefore, one cannot be anticipate the significance of this variable in equation (5), or the sign of its coefficient.

In all cases, the estimation process follows the strategy "general to specific", and starts with an equation that includes all the effects already discussed. We then eliminated the non-significant variables and re-estimated the simplified equation.

11. The coefficient of variation is the ratio between the standard deviation and the average of the variable. We chose his measure as an indication of variability because it preserves the non-dimensional nature of equation (2).

4.2.1 Model A

The simplest case occurs when both series are stationary, and we can obtain the long-term elasticity from a regression on the level variables, taking x^1 as endogenous and x^2 as exogenous, as in equation (6).

$$x_t^1 = \mu + \sigma\, x_t^2 + \lambda\, d_t + \xi \cdot \mathrm{z}_t + \gamma\, t + \varepsilon_t \qquad (6)$$

The equation is initially estimated by ordinary least squares and, when the Durbin-Watson statistic indicates the existence of first order serial correlation of the residuals, it is re-estimated using maximum likelihood, assuming a first-order autoregressive structure for the errors. This provides estimates for the coefficients and confidence intervals of the parameters of equation (6), and for the parameter of the autoregressive term (ρ), that allows us to calculate the long term Armington elasticity $\sigma/(1-\rho)$.

In the (rare) case where this procedure suggests the possibility of existence of a unit root on the residuals, that is, the confidence interval of ρ includes one, the equation is re-estimated in first differences, in the form of equation (7), which includes also the lagged values of the price variable among the explanatory variables. The number of lags included in the equation is the same used in the procedure to determine the order of integration of the price series, and may be null.[12]

$$\Delta x_t^1 = \mu + \sigma\, \Delta x_t^2 + \sum_{l=0}^{\tau} \nu_l x_{t-l}^2 + \lambda\, d_t + \xi \cdot \mathrm{z}_t + \gamma\, t + \varepsilon_t \qquad (7)$$

4.2.2 Models B and C

The cases where the order of integration of the two series is not the same are difficult to rationalize, from an economic point-of-view. Besides, the estimation of these unbalanced equations is rather uncomfortable. Maddala e Kim (1998, p. 252) state: "Should one estimate unbalanced equations? Of course not, if it can be avoided. But if it has to be done, one has to be careful in their interpretation and use appropriate critical values." Below we indicate how we treat the two unbalanced cases of Table 1.

When x^1 is I(1) and x^2 is I(0), equation (5) is estimated in first differences, as in equation (7), as is also done in Gallaway, McDaniel e Rivera (2000). This procedure is consistent with the order of integration of the series because the differencing allows us to estimate a regression between series that are I(0).

When x^1 is I(0) and x^2 is I(1), we estimate an equation in levels, including as many lags as those used in the tests of order of integration, plus one, as indicated in equation (8).

$$x_t^1 = \mu + \sigma\, x_t^2 + \sum_{l=0}^{\tau+1} \nu_l x_{t-l}^2 + \lambda\, d_t + \xi \cdot \mathrm{z}_t + \gamma\, t + \varepsilon_t \qquad (8)$$

12. Appendix C shows how we used a sequence of chained tests to obtain endogenously the number of lags used in the ADF test.

If in the estimation of equation (8) there is indication of the existence of serial correlation of the residuals, the same procedure described in the previous section for the occurrence of the same situation in Model A is applied.

4.2.3 Model D

When prices and quantities are integrated, the cointegration relation provides an estimate of the long-term Armington elasticity. Casting equation (5) in the general formulation of Johansen´s VEC, for the particular case when there is no time trend and only one lag is included in the VAR, yields equation (9):

$$\Delta \mathbf{x}_t = \alpha\left(\beta' \mathbf{x}_{t-1} - \mu\right) + \varepsilon_t \qquad (9)$$

where α is a vector that indicates how the cointegration relation is used to incrementally adjust the value of $\mathbf{x}$, which means that it is the vector error correction term. The vector of residuals ε_t must be i.i.d, with zero average e variance Ω. We can write equation (9) in a more general fashion, including the time trend and k lags of the first difference of the vector of variables, as in equation (10):

$$\Delta \mathbf{x}_t - \gamma = \alpha\left(\beta' \mathbf{x}_{t-1} - \beta' \gamma (t-1) - \mu\right) + \sum_{\tau=1}^{k-1} \Gamma_\tau \left(\Delta \mathbf{x}_{t-\tau} - \gamma\right) + \varepsilon_t \qquad (10)$$

The matrices Γ_τ are 2x2 and supply the weights of the auto-regressive components of the process. We chose the number of lags included in the equation, represented by τ, to maximize the likelihood statistic for the system of equations.[13] In equation (10), γ is a 2x1 vector that contains the time trend parameters for the growth of the variables. Therefore, $\beta' \gamma (t-1)$ is a scalar term that shows how the time trend of prices and quantities enters the cointegration.

$$\Delta \mathbf{x}_t - \gamma = \alpha\left[\beta' \mathbf{x}_{t-1} - \left(\beta' \gamma (t-1) + \lambda d_t + \mu\right)\right] + \sum_{\tau=1}^{k-1} \Gamma_\tau \left(\Delta \mathbf{x}_{t-\tau} - \gamma\right) + \varepsilon_t \qquad (11)$$

We can interpret the cointegration relation (the term inside the square brackets in (11)) as the long-run relation between the endogenous and exogenous variables[14]. In it, the term inside the parenthesis shows how that long-term relation between the endogenous quantities (the term $\alpha\beta' \mathbf{x}_{t-1}$, as in equation (1)) shifts due to the time trend, the change in foreign trade regime, and uncertainty in the exchange rate. We interpret this shift as a change in the μ parameter, which is derived from the distribution parameter of the CES demand equation (1), as can be seen in the description of equation (5). We can define this generalized distribution parameter δ_t implicitly by equation (12):

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13. The procedure we adopted was to reduce the number of lags progressively, starting from a maximum arbitrary value of eight quarters, while observing the former criteria to determine their significance. This maximum lag was chosen under the assumption that in two years the larger fraction of the effects of a given shock would have been absorbed by the system.

14. We normalized the cointegration vector with respect to quantities, and the coefficient of the first component of $\mathbf{x}$ in β is one.

$$\log\left[\delta_t/(1-\delta_t)\right]=\beta'\gamma(t-1)+\lambda d_t+\mu \qquad (12)$$

Therefore, equation (11) takes into consideration the important changes that may have occurred in the demand for imports, but only in a limited way, since it is conditioned to the maintenance of the hypothesis that the elasticity of substitution σ was constant through the whole period.

5 RESULTS

We applied the procedure described in the previous sections for the identification of the order of integration of the series and choice of the adequate model for estimation[15] to data for the period 1985 to 2002, for the 28 sectors of the Brazilian input-output matrix where imports were positive in 2002, except for agriculture (and cattle) and the services sectors. It was possible to obtain significant estimates at 10% the level of significance of the Armington elasticity for 24 sectors, and for all of them, except one, the sign is the correct one.

We present in Table 2 the types of series considered in our classification, in terms of their stochastic characteristics, and the code adopted for each. We also show, for each variable of the model, the frequency encountered of each type of series. Only 17 quantum series, and 10 price series, do not have a unit root, but of these only six quantum series, and five price series, are stationary. For 10 quantum series, and 10 price series, we are able to find evidence of a unit root. Finally, there is evidence of a structural break in the fourth quarter of 1990 for 14 quantum series, and 14 price series. Table 3 presents the classification of these two series for each sector.

TABLE 2
TIPOLOGY OF THE *QUANTUM* AND PRICE SERIES

Code	Type	Number of series	
		Quantum	Prices
1	Stationary around a non-zero average	3	-
2	Stationary around a zero average	-	5
3	Stationary around a linear trend	3	-
4	Has a unit root with null time trend	10	10
5	Has a unit root with non-zero time trend	-	-
6	The existence of a unit root cannot be rejected	1	6
7	Does not have a unit root	11	7
-	Evidence of the existence of a structural break in 1990:4	14	14

15. We programmed the estimation routines using the *software* RATS 4.0. The listing, with the estimated equations, is available on demand (Annex 4).

TABLE 3
ARMINGTON ELASTICITY FOR BRASIL: 1986-2002 - Sectors with High Elasticity

Sector			Classification [a]		Structural Break [b]		Model [c]	Estimated coefficients (t-statistic in parenthesis)			
Code	Share [d] (%)	Name	*Quantum*	Price	*Quantum*	Price		Substitution	Variability	Break	Trend
VEI	4.33	Automobiles, trucks and busses	3	7	S	S	A	5.28	-	5.38	0.046
								(4.65)	-	(7.02)	(2.95)
ABA	0.34	Meat preparation and animal slaughtering	7	2	-	-	A	3.80	-	-	-
								(3.33)	-	-	-
OPM	1.89	Other metallurgical products	4	6	-	S	D	3.06	9.00	0.51	-
								(11.09)	(5.15)	(6.22)	-
LAC	0.69	Milk and milk derivatives	7	7	-	-	A	2.68	-	-	-
								(1.37)	-	-	-
DIV	4.34	Other diverse industries	4	6	-	S	D	2.65	2.77	0.57	-
								(12.86)	(3.92)	(9.87)	-
BPV	2.53	Processing of vegetable products and tobacco	7	7	S	S	A	2.47	-	0.76	-
								(3.39)	-	(3.63)	-
TEX	1.96	Textile industry	4	4	-	-	D	2.34	-	0.77	0.008
								(12.54)	-	(11.63)	(6.12)
VES	0.35	Clothing articles and accessories	4	4	-	-	D	2.20	-	0.74	0.016
								(12.89)	-	(8.31)	(7.05)
MEC	12.32	Tractors and machinery	4	6	-	S	D	1.84	-	0.64	-
								(8.78)	-	(13.40)	-
MAD	0.39	Wood products and furniture	4	4	-	-	D	1.58	-	0.17	0.015
								(5.30)	-	(1.26)	(4.32)
ELQ	5.32	Non-petrochemical chemical elements	3	2	S	S	A	1.51	-	0.84	0.029
								(2.41)	-	(3.57)	(5,07)

TABLE 3 (continued)
ARMINGTON ELASTICITY FOR BRASIL: 1986-2002 - Sectors with Average Elasticity

Sector			Classification [a]		Structural Break [b]		Model [c]	Estimated coefficients (t-statistic in parenthesis)			
Code	Share [d] (%)	Name	*Quantum*	Price	*Quantum*	Price		Substitution	Variability	Break	Trend
MNM	0.87	Non-metallic minerals	7	2	S	S	A	1.24	-	0.69	0.018
								(4.29)	-	(5.66)	(5.52)
PLA	0.59	Plastics	4	6	-	S	D	1.22	-	0.40	0.010
								(6.53)	-	(4.37)	(4.12)
MNF	2.15	Metallurgy of non-ferrous materials	7	4	S	-	C	1.15	-	-	0.011
								(3.56)	-	-	(7.42)
OLE	0.51	Vegetable oils and fat for food	7	7	S	S	A	1.15	-	-	-
								(1.87)	-	-	-
BOR	1.29	Rubber industry	4	6	-	S	D	1.08	-	-	0.010
								(7.68)	-	-	(7.90)
OPA	1.88	Other food products and beverages	4	6	-	S	D	0.95	-	0.49	-
								(9.26)	-	(17.27)	-
PET	6.29	Petroleum, natural gas, coal and other fuels	1	7	S	S	A	0.60	-0.99	0.37	-0.025
								(1.80)	(-2.00)	(2.45)	(-6.93)
FAR	3.85	Pharmaceuticals and perfumery	7	4	-	-	C	0.58	-	-	0.046
								(1.79)	-	-	(12.86)
QDV	4.61	Diverse chemicals	7	7	S	S	A	0.56	-	-	0.014
								(1.69)	-	-	(8.85)
PAP	2.03	Paper, pulp and print	4	2	-	-	B	0.51	-	-	-
								(3.33)	-	-	-

(continua)

TABLE 3 (continued)

ARMINGTON ELASTICITY FOR BRASIL: 1986-2002 - Sectors with Low or Null Elasticity

Sector			Classification [a]		Structural Break [b]		Model [c]	Estimated coefficients (t-statistic in parenthesis)			
Code	Share [d] (%)	Name	*Quantum*	Price	*Quantum*	Price		Substitution	Variability	Break	Trend
SID	1.28	Steel	7	4	S	-	C	0.47	-	-	0.019
								(1.27)	-	-	(7.44)
ELE	5.24	Electrical materials	7	4	S	-	C	0.20	-	-	0.010
								(1.96)	-	-	(15.32)
PEC	8.90	Other vehicles, parts and accessories	1	4	S	-	C	0.19	-	0.16	0.010
								(1.48)	-	(3.14)	(8.67)
REF	10.79	Petroleum refining and petrochemical industry	6	2	S	S	B	0.18	-	-	-
								(0.94)	-	-	-
ELT	11.97	Electronic equipment	3	4	S	-	C	0.18	-	-0.14	0.004
								(1.87)	-	(-3.77)	(4.31)
CAL	0.54	Shoes, leather articles and fur	7	4	S	-	C	0.15	-	-	0.019
								(0.36)	-	-	(5.44)
EXM	0.98	Mineral extraction	1	7	-	-	A	-2.38	-	-0.66	-
								(-3.51)	-	(-3.69)	-

[a] Code for the classification of the series: see Table 2.

[b] Code for structural break in 1990:4: Y when there is evidence that it occurs

[c] Code for model estimated: see Table 1.

[d] Share of the sector in the total imports of industrial goods of the period 1997-2002.

Considering the classification of type of model in Table 1, we had ten cases of model A (estimation in levels), and nine of model D (cointegration), totaling nineteen cases where the order of integration of the two series coincides. These are also the cases where the estimate of the Armington elasticity has a smaller standard deviation. There are nine cases of unbalanced equations: two of type B, and seven of type C. In these cases, the estimated elasticity is smaller and more uncertain, as could be expected, because the lack of coincidence of the order of integration is in itself an indication of a weaker association between prices and quantum of imports. The fact that models B and C were not chosen in any of the sectors for which the estimated elasticity is high confirms this interpretation.

Table 3 also presents the estimated coefficients, which show that the point estimate of the elasticity of substitution varies in a wide range of values, reflecting different measures in which the imported good substitutes for the domestically produced good. We frequently encounter this dispersion is in the international literature, and usually it is broader in studies that use a more disaggregated sector classification than the one used here. The point estimates are only indicators of the order of magnitude of the long-run elasticity of substitution in the sectors where the low *t*-statistic implies a large confidence interval.

TABLE 4
CLASSIFICATION OF THE ARMINGTON ELASTICITIES AND NUMBER OF SETORS

Number of sectors	Elasticity	Qualification
3	Larger than 3	Very high
8	Between 1,5 and 3	High
10	Between 0,5 and 1,5	Average
2	Less than 0,5	Low
4	Non-significant	Null
1	Negative	Wrong sign

Source: The authors

Table 4 summarizes the sector variation of the estimated Armington elasticities.[16] Adopting our (arbitrary) classification, in 21 sectors, the elasticity is average, high, or very high, and in only five sectors, it is null or negative.[17] The arithmetic mean and de standard deviation of the estimated elasticities, restricted to the sectors that have positive value are, respectively, 1.47 e 1.43. The weighted average of the elasticities[18], that takes into account the difference in relative importance of the imports of the several goods, is 1.15.

16. These estimates are dependent on the level of aggregation adopted, because the possibility of substitution depends on the similarity between the imported good and the one produced domestically, which itself depends on the aggregation.

17. In these cases, we will provisionally take the long-term elasticity as null, in spite of the possibility of occurrence of specification problems in the application of the Armington hypothesis to these sectors. Some of these sectors seem to have specificities that would lead us to classify them as non-competitive, that is, they are imports of inputs which are essential to production, and are not produced in Brazil, and this would invalidate the use of equation (2) to characterize the imports of these goods.

18. We used as weights the average share of each sector in total imports of goods in the period 1997-2002.

The estimate of the coefficient for the variable that measures the price uncertainty for importers was significant in only three sectors, and is positive in two of them, and negative in one. In those sectors where it is positive we can highlight the speculative motive, whereas in the one where it is negative (petroleum) the important aspect seems to be the import substitution associated to risk aversion. However, is is a bit surprising that this variable was significant in so few cases, because we expected imports to react to an uncertainty in the relative price in a larger number of sectors.

The *dummy* variable for structural break in 1990:4 was significant for 16 goods, which confirms the importance of the considerations made in Section 3 regarding the nature of the economic impacts of the trade liberalization of 1990. For most cases, its coefficient is positive, as expected, and its value is around 0.5. This means that trade liberalization increased the proportion of imports relative to domestic production by about 200%.[19]

The coefficient of the variable that represents the time trend was significant in 17 equations, and had a positive value in all cases, except one. This is consistent with the interpretation that during the period 1986-2002 there was an increase in the relative demand for imports that is not explained by the other three factors, and is possibly related to the modernization and internationalization of the composition of the goods produced and consumed by the domestic industry.

6 CONCLUSIONS

In this paper, we estimated a novel set of Armington substitution elasticities for the 28 industrial sectors of the Brazilian input-output matrix, for the period 1986-2002. They were significant, at the level 10%, for 24 sectors, and the point estimates varies between 0.16 e 5.3, reflecting a broad spectrum of degrees of substitution of the imported product for the domestically produced good. They are larger than unit in 16 sectors, and smaller than unit but significantly different from zero in seven sectors. In one sector (mineral extraction), it is significant but has a negative sign. In the remaining four sectors, the estimated elasticity is not significantly different from zero.

We also tried to employ careful econometric techniques in processing the data. We based the choice of the model to be estimated on the order of integration of the series involved. In the estimation and in the tests of the order of integration we considered the possibility of a structural break when there was a change in foreign trade regime in 1990, as well as the occurrence of seasonal factors and the presence of time trends. We chose endogenously the number of lags to include in the unit root tests, and in the estimation, based on information criteria. When both series are integrated, we used cointegration methods and estimated a vector error-correcting model.

Finally, we believe that the use of these elasticities will allow researchers to evaluate more precisely the economic impacts of a change in trade policy, in partial and general equilibrium models.

19. This is a measure of the repressed demand for competitive imports of the former foreign trade regime.

ANNEX 1

COMPATIBILIZATION OF THE SECTORS OF THE INPUT-OUTPUT MATRIX AND OF THE IPA

Setor da matriz de insumo-produto (nível 50)	Setor do IPA-OG-FGV (coluna)
Extrativa mineral	Extrativa mineral (28)
Petróleo, gás natural, carvão e outros combustíveis	Combustíveis e lubrificantes (54)
Minerais não-metálicos	Calcários e silicatos (30)
Siderurgia	Ferro, aço e derivados (32)
Metalurgia dos não-ferrosos	Metais não-ferrosos (33)
Outros produtos metalúrgicos	Metalúrgica total (31)
Máquinas e tratores	Máquinas e equipamentos industriais (36)
Material elétrico	Material elétrico total (38)
Equipamentos eletrônicos	Material elétrico e outros (41)
Automóveis, caminhões e ônibus	Veículos a motor (43)
Outros veículos, peças e acessórios	Veículos a motor (43)
Madeira e mobiliário	Madeira (45), mobiliário total (46)
Papel e gráfica	Papel e papelão (50)
Indústria da borracha	Borracha (51)
Elementos químicos não-petroquímicos	Química e outros (58)
Refino do petróleo e indústria petroquímica	Química total (53)
Químicos diversos	Química total (53)
Farmacêuticos e perfumaria	Produtos farmacêuticos (81), perfumaria, sabões e velas (82)
Material plástico	Matérias plásticas (56), produtos de matérias plásticas (83)
Indústria têxtil	Tecidos e fios naturais (60), tecidos e fios artificiais e sintéticos (61), malharia (62)
Artigos do vestuário e acessórios	Vestuário (63)
Calçados, artigos de couro e peles	Calçados (64)
Beneficiamento de produtos de origem vegetal, fumo	Produtos alimentares total (71)
Abate e preparação de carnes	Carnes e pescado (78)
Leite e laticínios	Leite e derivados (79)
Óleos vegetais e gordura para alimentação	Óleos e gorduras (74)
Outros produtos alimentares e bebidas	Sal, rações e outros (80), bebidas (66)
Indústrias diversas	Indústria de transformação total (29)
Abate e preparação de carnes	Carnes e pescado (78)

ANNEX 2

COMPATIBILIZATION BETWEEN THE SECTORS OF THE INPUT-OUTPUT MATRIX AND THE INDUSTRY CLASSIFICATION

Classificação	Setor: gênero (g) ou matriz (m) 1986-1990	Setor: gênero (g) ou matriz (m) 1991-1999
Extrativa mineral	Extração de minerais metálicos (m)	Extrativa mineral (g)
Petróleo, gás natural, carvão e outros combustíveis.	Extração de petróleo e gás natural (m)	Extração de petróleo e gás natural (m)
Minerais não-metálicos	Produtos de minerais não-metálicos (g)	Produtos de minerais não-metálicos (g)
Siderurgia	Laminados de aço (m)	Siderurgia (m)
Metalurgia dos não-ferrosos	Metalurgia básica (g)	Metalurgia dos não-ferrosos (m)
Outros produtos metalúrgicos	Outros metalúrgicos (g)	Outros produtos metalúrgicos (m)
Máquinas e tratores	Mecânica (g)	Mecânica (g)
Material elétrico	Material elétrico e de comunicações (g)	Aparelhos e equipamentos elétricos — inclusive eletrodomésticos, máquinas de escritório (m)
Equipamentos eletrônicos	Material elétrico e de comunicações (g)	Material para aparelhos eletrônicos e de comunicação (m) e aparelhos receptores de TV, rádio e equipamentos de som (m)
Automóveis, caminhões e ônibus	Automóveis e camionetas (m)	Automóveis, utilitários, caminhões e ônibus (m)
Outros veículos, peças e acessórios	Motores e autopeças (m)	Motores e peças para veículos (m)
Madeira e mobiliário	Indústria de transformação total (g)	Indústria da madeira (m) e indústria do mobiliário (m)
Papel e gráfica	Papel e papelão (g)	Papel e papelão (g)
Indústria da borracha	Borracha (g)	Indústria da borracha (g)
Elementos químicos não-petroquímicos	Química total (g)	Elementos químicos, não-petroquímicos ou carboquímicos (m) e destilação de álcool (m)
Refino do petróleo e indústria petroquímica	Petroquímica, refino e destilação de carvão de pedra (g)	Refino de petróleo (m), petroquímica básica e intermediária (m) e resinas, fibras e elastômeros (m)
Químicos diversos	Química outros (g)	Adubos, fertilizantes e corretivos para o solo (m) e produtos químicos diversos (m)
Farmacêuticos e perfumaria	Produtos farmacêuticos e veterinários (g) e perfumaria, sabões e velas (g)	Indústria farmacêutica (m) e indústria de perfumaria, sabões e velas (m)
Material plástico	Produtos de matérias plásticas (g)	Produtos de matérias plásticas (g)
Indústria têxtil	Têxtil (g)	Têxtil (g)
Artigos do vestuário e acessórios	Vestuário, calçados e artefatos de tecidos (g)	Artigos do vestuário e acessórios (m)
Calçados, artigos de couro e peles	Calçados (m)	Calçados (m)
Beneficiamento de produtos de origem vegetal, fumo	Produtos alimentares (g)	Beneficiamento de arroz (m), moagem de trigo (m) e beneficiamento de outros produtos de origem vegetal para alimentação (m)
Abate e preparação de carnes	Abate e preparação de carnes (m)	Abate de animais (exclusive aves) e preparação de carnes (m) e abate e preparação de aves (m)
Leite e laticínios	Laticínios (m)	Resfriamento e preparação do leite e laticínios (m)
Óleos vegetais e gordura para alimentação	Refino de óleos e gorduras para alimentação (m)	Óleos vegetais em bruto (m) e refino de óleos vegetais e fabricação de gorduras para alimentação (m)
Outros produtos alimentares e bebidas	Produtos alimentares (g) e bebidas (g)	Outras indústrias alimentares (m) e indústria de bebidas (m)
Indústrias diversas	Indústria de transformação total (g)	Indústria de transformação (g)

ANNEX 3

THE DETERMINATION OF THE ORDER OF INTEGRATION OF THE PRICE AND *QUANTUM* SERIES

This annex describes how we obtain the order of integration of the series involved in the estimation[20], $x_i^1 = \log(M_i/D_i)$ and $x_i^2 = \log(PD_i/PM_i)$. This will allow us to choose systematically the model estimated to obtain the Armington elasticity. For convenience, from now on we will drop the sector index from the notation.

To systematically implement the unit root test, in reference to the inclusion of the Constant and of the time trend, we adopted the procedure proposed by Doldado, Jenkinson e Sosvilla-Rivero (1990), followed by the Perron (1989) test for structural break in the fourth quarter of 1990, in the cases where the first procedure indicates the existence of a unit root. The following shows how we performed these tests.[21]

We initially estimated equation (13), that contains a trend, a constant, and autoregressive components, and we test for the existence of a unit root (γ=0), using the ADF statistic.[22] If we reject that hypothesis, we conclude there is no unit root, and terminate the search.

$$\Delta x_t = a_0 + \gamma x_{t-1} + a_2 t + \sum_{i=1}^{p} \beta_i \Delta x_{t-i} + \varepsilon_t \tag{13}$$

As this test is characterized by low power, if we do not reject the unit root, is is necessary to test the joint hypothesis of its existence and absence of a trend $(a_2 = \gamma = 0)$, using the ϕ_3 statistic of Dickey and Fuller (1981). If we reject this joint hypothesis, we test again γ = 0, using a normal distribution, and the procedure is then ended. If we are not able to reject this joint hypothesis, we assume that we can cast the data generating process in the form of equation (14), and we again test for a unit root with the ADF statistic.

$$\Delta x_t = a_0 + \gamma x_{t-1} + \sum_{i=1}^{p} \beta_i \Delta x_{t-i} + \varepsilon_t \tag{14}$$

If we reject in this specification the null hypothesis of a unit root, we terminate the procedure. If we do not reject it, we test for the joint null hypothesis $c_1 = \gamma = 0$ using the statistic ϕ_2 of Dickey and Fuller (1981). If we reject this joint hypothesis, we test again γ = 0, using the normal distribution and the procedure is finalized. If we do not reject the hypothesis $c_1 = \gamma = 0$, we test for the existence of the unit root in the specification of equation (15), again using the ADF statistic. If we accept (or reject) $\gamma = 0$, we conclude that the series contains (does not contain) a unit root.

---

20. The log variables arise because, for computational convenience, equation (2) is transformed before being estimated.

21. These procedures were implemented using the routines URAUTO, URADF e PERRON of the *software* RATS. They can be downloaded from http://www.estima.com

22. The critical values for the ADF statistics are from Hamilton (1994) for a 10% significance level.

$$\Delta x_t = \gamma x_{t-1} + \sum_{i=1}^{p} \beta_i \Delta x_{t-i} + \varepsilon_t \tag{15}$$

In equations (13), (14) and (15), the number of lags (*p*) was chosen according to the *general to simple* criteria, starting from a maximum number equal to five. We maintain the fifth lag if it is significant at the 5% level. If it is not, we estimate the equation again, with four lags, and again assess the level of significance of the last lag. The procedure continues until de coefficient of the last auto-regressive component is significant at the 5% level.

It is important to emphasize that the results of the tests described above may not be conclusive if there is a structural break in the series, since in that case the ADF statistic has a bias towards the non-rejection of the unit root. To account for this, and take into consideration the likelihood of a structural break in the fourth quarter of 1990, we apply the Perron (1989) test to the series that display a unit root. Using the taxonomy he proposes, we assume the break is of the type represented by the *changing growth model*. Equation (16) describes this model, and accommodates both the null and the alternate hypothesis of the test. In the null, it assumes the existence of a unit root with a change in the intercept of the process in the instant of the structural break. In the alternate is assumes that the process is stationary with a change in the slope of the deterministic trend line in the moment of the break.

$$x_t = \mu + \theta DU_t + \beta t + \gamma DT_t{}^* + \alpha x_{t-1} + \sum_{i=1}^{p} \beta_i \Delta x_{t-i} + \varepsilon_t \tag{16}$$

The null imposes the following restrictions to the parameters of equation (16):

$$\alpha = 1, \gamma = 0, \beta = 0, \theta \neq 0 \tag{17}$$

The alternate hypothesis imposes the following restrictions to the parametres of equation (16):

$$\alpha < 1, \gamma \neq 0, \beta \neq 0, \theta = 0 \tag{18}$$

where:

$T_B =$ Date of the structural break;

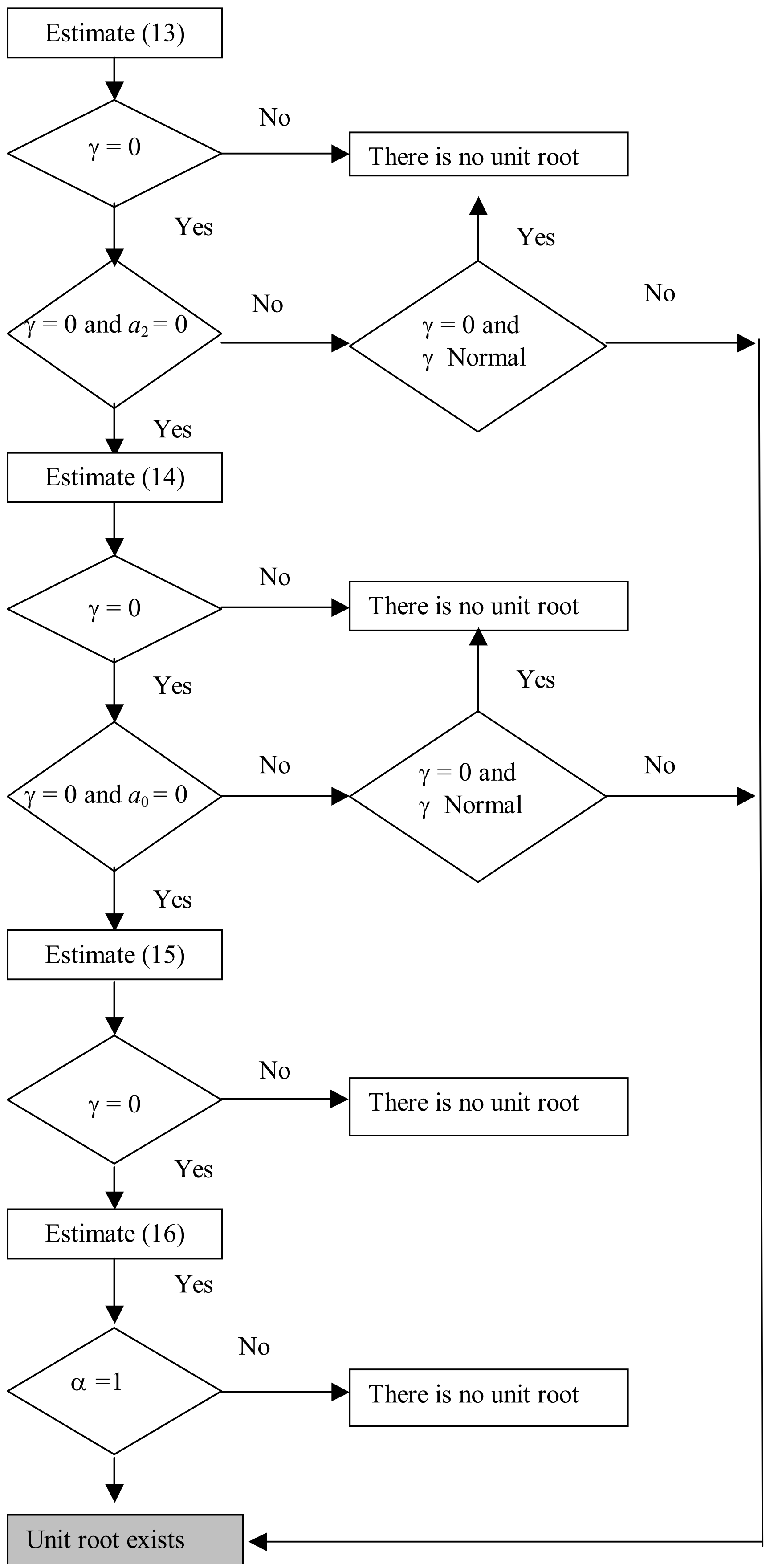
$DU_t = 1$, if $t > T_B$ and $DU_t = 0$, otherwise; and

$DT_t^* = t - T_B$, if $t > TB$ and $DT_t^* = 0$, otherwise.

We assumed the structural break hapened in the fourth quarter of 1990, and the critical values used were those of Perron (1989), with a 10% significance level. We applied the test in a sequential manner, adding autoregressive components until the hypothesis of residual autocorrelation was rejected in the Ljung-Box test, with 5% level of significance.

The following diagram, similar to the one described in Enders (1995), summarizes the testing procedure.

FLUXOGRAM OF THE UNIT ROOT TESTS



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