Aggregating products under different regimes of competition: a source of bias in estimates for substitution elasticities and pass-through effects

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Abstract: This article examines the level of aggregation problem for which Armington price elasticity of substitution and exchange rates elasticities are usually estimated. On the basis of US import data of wood products from Brazil and Mexico, it is argued that the usual levels of aggregation used in the estimates for the elasticity of substitution are too high, since they tend to aggregate perfectly elastic products together with products whose elasticities vary from zero to any negative number. Consequently, these estimates can be seen as attempts to find the mean between zero and infinite. Therefore, the results of these exercises cannot be expected to be fruitful and it should come as no surprise the fact that the literature reveals very different estimates for these elasticities. Since substitution elasticities are often used as parameters in simulations of trade policies and trade agreement, analysts and practitioners should be aware of this bias and should try to obtain more disaggregated data in order to separate products competing under different regimes. Analogously, the elasticity of relative prices with respect to the exchange rate, a measure of the pass-through effect, tends to be underestimated by the presence of homogenous products that follow the law one price. Therefore, pricing-to-market estimates may be grossly overestimated for some industries.

JEL Classifications: F1 (Trade), C1 (Econometric and Statistical Methods)

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Introduction

Assuming that goods are generally traded under imperfect competition, many studies have adopted this hypothesis to estimate substitution elasticities between products from different countries (known as the Armington[1] elasticity) and price elasticities with respect to the exchange rate (known as the degree of pass-through effect) across industries.

Estimates of Armington price elasticity of substitution by sector have been a major parameter for trade policy analysis. In particular, simulation models of trade agreements, be them partial equilibrium or general equilibrium models, almost inevitably apply estimates of Armington elasticities for calculating trade creation and trade diversion effects.

Some attempts to estimate Armington elasticity of substitution covering several industries have appeared in the literature in the last three decades. For U.S. imports, Stern, Francis and Schumacher (1976) made estimates for 28 industries at the 3-digit ISIC level, Shiells, Stern and Deardorff (1986) estimated the elasticities for 163 industries and Reinert and Roland-Holst (1992) covered 163 US mining and manufacturing industries. Schiells and Reinert (1993) broke US imports down into those from Nafta countries and those from other countries, finding estimates for 128 mining and manufacturing industries. The most recent, disaggregated and comprehensive estimates were made by Gallaway, McDaniel and Rivera (2000), covering 311 industries at the 4-digit SIC level.

In the developing world, but along the same lines as in the U.S., Kapuscinski and Waar (1999) estimated substitution elasticities for the Philippines considering 33 industries, while Tourinho, Kume and Pedroso (2002) estimated Armington elasticities for Brazil's imports, covering 28 industries.

In most cases, especially in the most recent ones, substitution elasticities were calculated on the basis of a one level utility that is a function of domestic output and quantities imported by all countries taken together. Shiells and Reinert (1993) is an exception with this regard, as they consider quantities of imported goods from each separate source. They used two-tier utility functions or merger them into a one level utility function, but maintaining imports from different sources[2].

The most recent studies apply cointegration methods, to avoid spurious correlations, and find that statistically significant estimates vary from almost zero to less than five in the US, in Brazil and in the Philippines.

All the above mentioned studies apply time series econometric analyses to estimate the substitution elasticities. Hummels (1999), on the other hand, applies a different methodology, using information on freight rates for a number of importers by different exporters, and his cross-sectional estimates for substitution elasticities are much higher,

[1] Armington (1969) is a reference for most studies of trade agreements.
[2] They refer to two other studies which apply the two-tier utility function: Hamilton and Whalley (1985) and Brown and Stern (1987).

averaging 6.9 at the 3-digit level. Therefore, substitution elasticities tend to be sensitive to the chosen estimation technique.

Typically, however, all these estimates have very high standard deviations, which implies that point estimates should be used with caution and sensitivity analysis is highly recommended.

Nevertheless, McDaniel and Balistrery (2001) point out that there are a few robust findings: "first, long-run estimates are much higher than short-run. Second, the level of aggregation is important; the more disaggregate the sample the higher the estimated substitution elasticity. Finally, single equation time-series approaches identify smaller responses relative to cross-sectional estimation that includes a consideration of supply conditions". They also correctly point out that econometric specifications used in most estimation "suffer from the general critique that they are structurally inconsistent with general equilibrium because they do not consider the supply side of the market".

Among the studies that estimate the degree of pass-through effects in different industries, we can mention Knetter (1993),Yang (1996), (1997) and (1998), Goldberg and Knetter (1997) and Olivei (2002). Industries in these studies are generally defined at the 4-digit level and the pass-through effect is taken as the effect of changes in the nominal exchange rate on the changes in the import price, controlling for changes in domestic price and in prices in other countries. Generally, estimates of pass-through effects are relatively low[3].

We argue here that the fact that within a particular industry there may be products that are traded under different competitive regimes tends to produce an aggregation bias. More specifically, if there are homogenous products that follow the law of one price (LOP) within a particular industry, so that suppliers are price-takers under perfectly competitive markets, applying a specification that assumes imperfect competition will tend to overestimate the substitution elasticities, since individual suppliers of LOP products are confronted with perfectly elastic demand curves. Analogously, it will tend to underestimate the pass-through effect, as suppliers of LOP products are price-takers, therefore, their relative prices are insensitive to changes in the exchange rate.

Modelers may not have been too concerned with that, since most of the literature show that the law of one price tends to be violated for manufacturing products and even for primary commodities defined at very high levels of disaggregation[4]. However, new evidence has appeared in the literature in support of the law of one price and on Purchasing power Parity[5]. Another recent study[6] has shown that the law of one price cannot be rejected for a number of narrowly defined commodities. Furthermore, there are

[3] See Obstfeld (2002) for an excellent discussion on the implications of low pass-through effects on expenditure-switching policies.
[4] Classical articles on the subject are Isard (1977), Kravis and Lipsey (1978) and Richardson (1978). Thursby et al (1986) takes the case of a primary commodity defined at a very high level of disaggregation.
[5] See, for instance, Cecchetti et al. (200) and Goldberg and Verboven (2001).
[6] See Chami Batista and Silveira (2003) and Chami Batista (2003). In fact,

indications that homogeneous goods following the law of one price are more easily found amongst manufactured commodities that go through some basic industrial processing than within the group of primary goods.

The remainder is organized as follows. Section 1 presents the Armington differentiated goods model and contrasts it with the law of one price model. Section 2 describes the methodology applied to classify products as differentiated or homogeneous (LOP) products. Section 3 applies the methodology to Brazil's and Mexico's exports of wood to the US. Section 4 concludes.

1. Armington differentiated goods (DG) model[7]

Armington differentiated good (DG) model assumes that a commodity produced by one country is an imperfect substitute in demand for the "same" commodity produced by another country. He refers to these commodities as goods and to the good produced by a particular country as a product. However, in order to derive his elasticity of substitution he has to make the independence assumption; i.e., marginal rates of substitution between any two products of the same kind must be independent of the quantities of the products of all other kinds; and quantity index functions, relating the quantity of a good to the quantities of its products, must be linear and homogeneous.

He can then relate the relative quantities of two countries or products, according to his convention, to their relative prices. Thus, further assuming that the long-run price elasticity of substitution is constant, it follows that:

$d(Q_i^*/ Q_j^*)/(Q_i^*/ Q_j^*)= \sigma\ d(P_i^*/ P_j^*)/(P_i^*/ P_j^*)$, where σ is Armington's long-run elasticity of substitution between two products.

In point of fact, the independence hypothesis assumed by DG models depends crucially on the level of aggregation. As Armington (1969, pp. 164-165) points out: "in theory, the assumption of independence might be viewed as tautological; for independence could well be taken as a *defining* characteristic of products distinguished by their kind… In practice, however, goods must be identified within the framework of some available classification scheme… Given this constraint, independence is not necessarily tautological…Within the limitation imposed by the available classification scheme, the analyst may attempt to select a vector of goods that renders the independence assumption as realistic as possible".

Note that in contrast with Armington's assumption that products are imperfect substitutes in demand, they may well turn out to be perfect substitutes. In other words, they can be homogeneous products, following the law of one price (LOP)[8]. This law states that homogeneous products must be traded at the same price, regardless of where they are

[7] See Armington (1969).
[8] The next paragraphs on the law of one price are drawn from Chami Batista and Silveira (2003).

sold, as long as prices are expressed in the same currency and taking due account of transfer costs[9]. Any price difference should be rapidly eliminated by commodity arbitrage.

Formally, a strict version of LOP may be expressed as:

$$P_i^* / P_j^* = 1, \quad (1)$$

where P_i^* and P_j^* are the domestic prices paid in a given market for the same good (or perfect substitute goods) imported from countries i and j[10], respectively. These are cif (cost, insurance and freight) prices plus import duties, so they may be written as:

$$P_i^* = (P_i/E_i)\,(1+t_i), \quad (2)$$

where P_i is the cif export price expressed in country i's currency, E_i is the exchange rate relating the value of country i's currency to one unit of the market currency and t_i is the *ad valorem* import tariff (plus any non-tariff *ad valorem* equivalent) for country i.

A weaker version of LOP would allow a price difference (premium), but no variations in relative prices:

$$d(P_i^* / P_j^*)/dt = 0 \quad (3)$$

The presumption behind the law of one price is that suppliers are price takers in perfect competitive markets. The intersection between global demand and supply curves determines the world equilibrium price, which should vary according to the location of delivery, but relative prices from different exporting countries must remain constant at each location. Changes in the costs of suppliers from a particular country, as for instance in the case of an exchange rate devaluation, will in general affect world equilibrium price. A situation in which world equilibrium price is not affected by changes in the cost of suppliers from a particular country is referred to, in the literature, as the small country hypothesis and is based on the assumption that the exporting country is confronted with a perfect elastic demand curve. Aggregate world demand and supply for primary commodities are generally assumed to be rather inelastic, so that changes in either curves have large effects on world prices. Therefore, this assumption is consistent with the high volatility observed for these prices. In any case, the law of one price will remain valid as long as relative prices from different suppliers remain constant.

It should be noted that in both versions of the LOP, the demand side of the importing market plays no part in determining changes in exporting countries' market shares[11]. These changes depend entirely on suppliers' conditions, since the demand price elasticity of substitution is infinite by definition. Therefore, although changes in the

[9] That includes transportation costs, tariff and non-tariff barriers.

[10] Country j may also be the domestic producer in the market. If domestic producers are exporters of the good, then LOP will state that the wholesale price of domestic producers for local buyers must be equal to the export price of these producers.

[11] It is assumed that there exists more than one exporting country.

exchange rate or in cost conditions have no effect on relative prices from different exporting countries, they may well affect the export performance or the relative quantities supplied to the market by these countries[12].

If the chosen definition of an industry is such that it contains some products that are perfect substitutes to each other, then DG models are a misspecification that will lead to bias estimates for the substitution elasticities.

Pass-through effects and pricing-to-market strategies

Under imperfect competition, suppliers may decide to maintain their final prices and market shares relatively stable, despite fluctuations in their costs and, as a result, allow variations in their mark-ups. This pricing-to-market strategy would make particular sense when fluctuations in costs were thought to be temporary rather than permanent. The extent to which changes in cost are actually transmitted into changes in final prices is known in the literature as the pass-through effect. This effect is expected to be greater if products are highly differentiated, marginal production costs is rather stable and import penetration is high.

Assuming a mark-up pricing, we can re-write equation (2) as:

$$P_i^* = \{[c_i (1 + m_i)]/E_i\}(1 + t_i) \qquad (4),$$

where c_i is the total cost of the product from country i and m_i is the mark-up for the same country. If in view of an appreciation of the exchange rate, an exporter maintains its domestic price (P_i) constant, allowing its destination price (P_i^*) to rise in line with the exchange rate appreciation (or any other increase in costs), we have a complete pass-through effect. However, if the exporter decides to change reduce its domestic price in the same proportion of by less than the exchange rate appreciation, or even increase its domestic price, we have a pricing-to-market strategy.

2. Testing if a product is homogenous (LOP) or differentiated

In order to decide if a product is homogenous and follows the law of one price or is a differentiated product, we apply a quite simple test. First, we apply the Augmented Dickey-Fuller test to individual price time series[13]. As commodity prices we expect them to be non-stationary. Second, as long as they are non-stationary, we apply the ADF test to relative prices dividing the prices of pairs of countries. If the time series of relative prices are stationary, we conclude that the products are homogenous and follow the law of one price. Otherwise, they are differentiated products.

In order to estimate the substitution elasticity between differentiated products, we once again apply the ADF test now to relative quantities of the same pairs of countries.

[12] There may be some delay between changes in costs and changes in supply, though this is not the usual rationale for the J Curve.
[13] See Enders (1995) and Hendrick (1995).

Assuming they are non-stationary, we can apply the Johansen cointegration test[14] to find out if relative quantities and prices are cointegrated. If they are, the coefficient of relative prices is the long run Armington elasticity of substitution.

3. Applying a DG model to exporters of wood products to the U.S.

Examining Brazil's and Mexico's exports of wood products to the US, it can be observed that few products, defined by the Harmonised System (HS) at the 10-digit level, account for a large share of total exports of each country[15]. In the case of Brazil, the top eight products responded for almost 60% of export earnings in the industry in 2002. In the case of Mexico, concentration was even higher, since only three products accounted for 66% of the industry export earnings to the US.

On the basis of these products, we have constructed a monthly price index for Brazilian and Mexican wood exports to the US from January 1996 to December 2002[16]. Given that some of these products were not exported in some months, we have used a chained moving base index. As expected, Laspeyres index tended to overestimate the price changes, whereas Paache index did the opposite. Thus, we have constructed a Fisher price index, calculating the geometric mean of the two other indices. Brazil's and Mexico's export price indices are shown in Graph (1) in log form.

The quantity index was indirectly constructed, dividing the export value index of each country by their correspondent price index. Relative price and quantity indices were calculated dividing Brazil's indices by Mexico's. All series of price and quantity indices were transformed into their logarithmic forms and are shown in Graph (2). It can be seen that Brazil's price falls relatively to Mexico's, while export volume from Brazil rises relatively to Mexico's.

Before relating relative quantities to relative prices, we have applied the Augmented Dickey-Fuller (ADF) test[17] to Brazil's and Mexico's series of Fisher price indices. They were both non-stationary, as one would expect. The ADF test was then applied to the relative price between Brazil and Mexico and, again, the series turned out to be non-stationary. Therefore, price behaviour appears to reveal that exports of wood from Brazil and Mexico to the US should be regarded as differentiated products. Had it been stationary, we would have considered that Brazil's and Mexico's exports of wood to the US as homogenous products following the law of one price.

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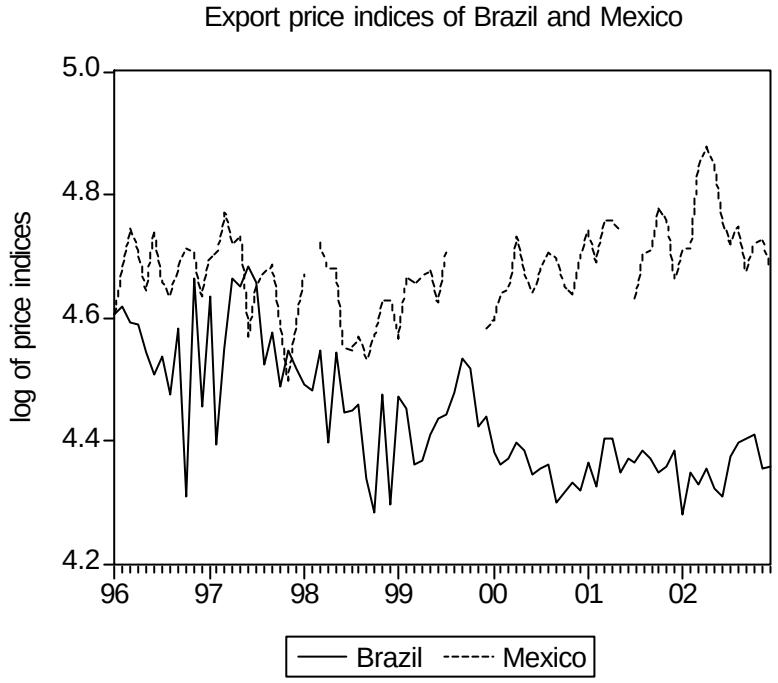
[14] Johansen, S. (1988), (1991) and (1995).

[15] Data are from US International Trade Commission (USITC) and are based on land duty-paid value and first unit quantity.

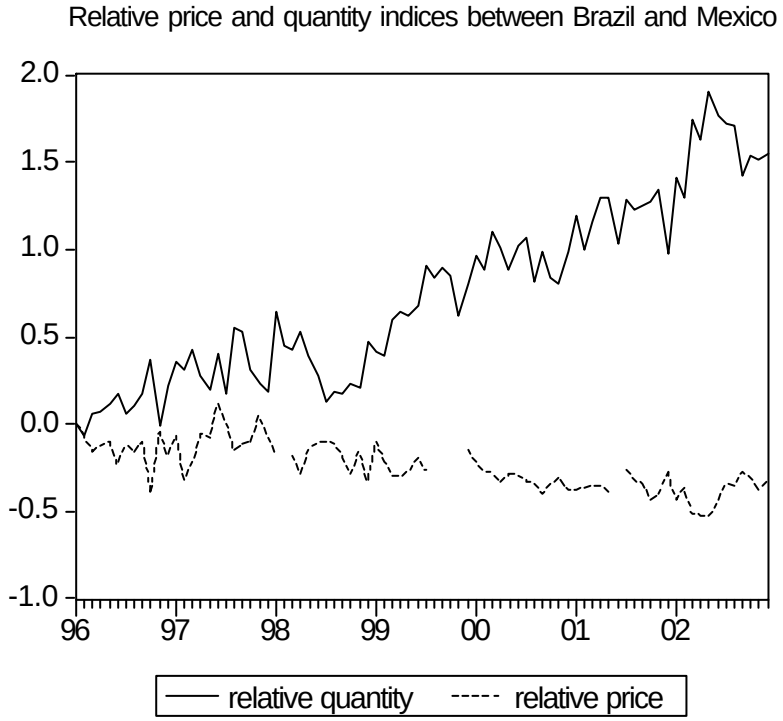
[16] We would have liked to have a longer period of time, but the quality of the data for earlier periods appears to be significantly lower than for this most recent period, due to the increased use of data received through automated collection programs. During the early 1990s, the US Census introduced various programs to reduce reporting errors. In 2001, US Census collected trade statistics on more than 33 million import transactions and approximately 99% of them were received electronically by Customs. See Bureau of the Census (2002). Furthermore, the Harmonised Classification System suffered major changes in 1996.

[17] The ADF tests were run using Eviews 3.0 package.

GRAPH (1):



GRAPH (2):



As it happened, the series of quantity indices were also found to be non-stationary, both individually as well as in relative terms. Thus, we were ready to test if the series of relative prices cointegrates with the series of relative prices. We have applied Johansen cointegration test and found that cointegration between the two series could not be rejected at the 5% level of significance. The long term elasticity of substitution was estimated at -5.08; i.e, a 1% reduction in the price of Brazil's exports of wood relatively to Mexico's export price would increase Brazil's export quantity relatively to Mexico's by 5.08%. This is a relatively high elasticity indeed[18].

Out of the products we considered in constructing the price indices, two of them are exported by both Brazil and Mexico: door and their frames [19] and standard wood moldings[20]. Together these two products account for 35% of the sample of Brazil and 58% of the sample of Mexico. Thus, we have applied the same tests to these products individually. Note that prices and quantities now are not indices, but the logarithm of actual export prices and actual export quantities from each country.

Graph (3) reports the time series of Brazil's and Mexico's export prices of doors and their frames. The ADF test applied to door and their frames revealed that both relative prices and quantities were non-stationary. Graph (4) shows the time series of relative prices and quantities. Note that again Brazil gains market share in quantities as its relative price falls. The Johansen cointegration test indicated one cointegration equation at 5% significance level. But the long term price elasticity of substitution was estimated at -1.81. Therefore, this estimate for the substitution elasticity is much lower than that estimated for the industry as a whole.

However, when the ADF test is applied to Brazil's and Mexico's export prices of standard wood molding, it is found that both series of prices are non-stationary, but the series of relative prices is stationary[21]. Graph (5) reveals the co-movements of Brazil's and Mexico's prices. In other words, this product should be regarded as a homogenous product that follows the law of one price. Therefore, these exports from Brazil and Mexico are perfect substitutes or the price elasticity of substitution is infinite.

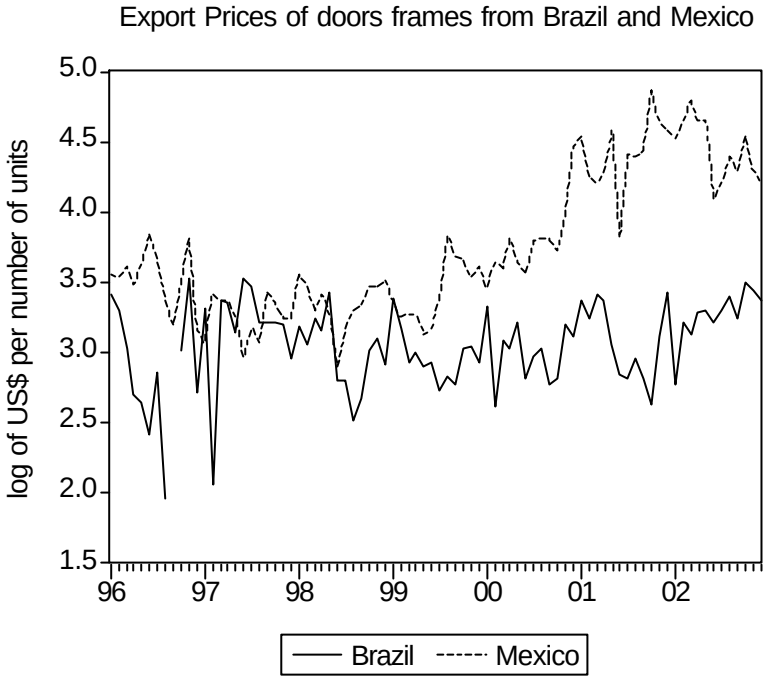
[18] In the US, the long run Armington elasticity for wood products was estimated at 3.195 for softwood veneer and plywood and 1.109 for prefabricated wood buildings, see Gallaway et al.(2000). The substitution elasticity between domestic production and imports of the wood and furniture industry in Brazil was estimated at 2.73, see Tourinho et al (2002).

[19] HS 441820.8060 – doors and theirs frames and thresholds, of wood, nesoi.

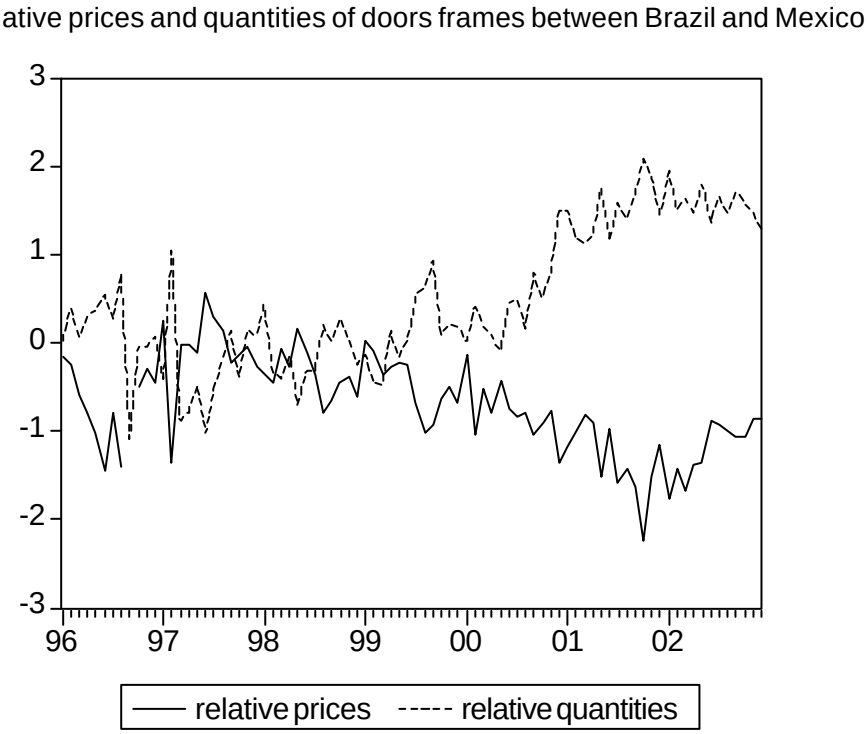
[20] HS 440910.4000 – pine (pinus spp.) standard wood molding.

[21] The series of US import prices of pine standard wood molding from Chile, another major exporter of this product to the US, could also be included in the analysis. ADF test show that relative prices between Chile and Brazil and between Chile and Mexico were also stationary. See Chami Batista and Silveira (2003).

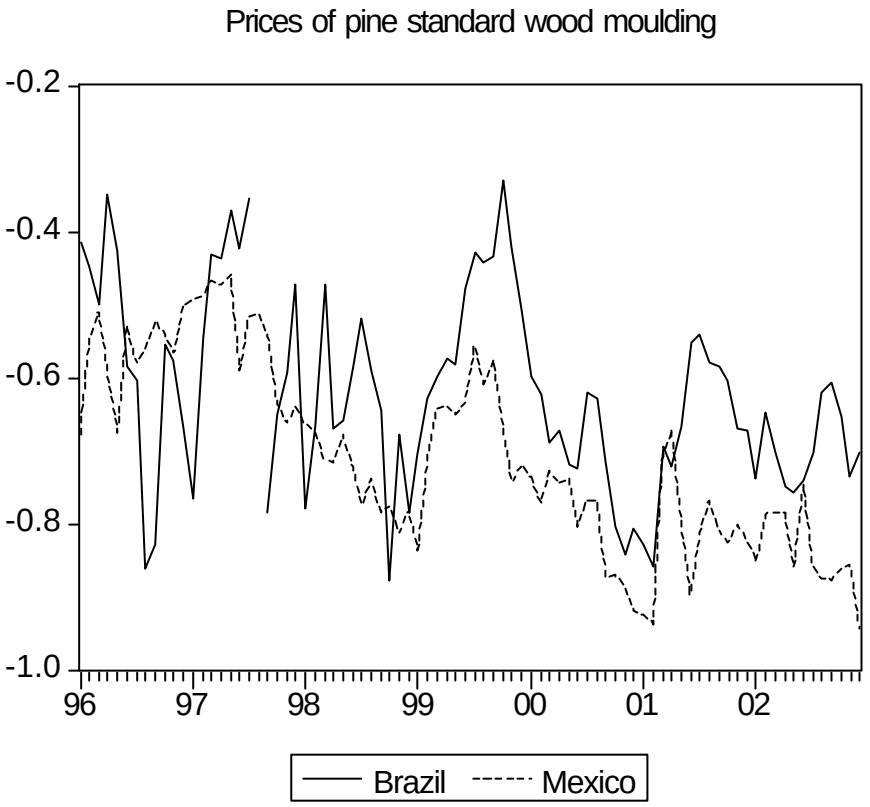
GRAPH (3):



GRAPH (4):



GRAPH (5):



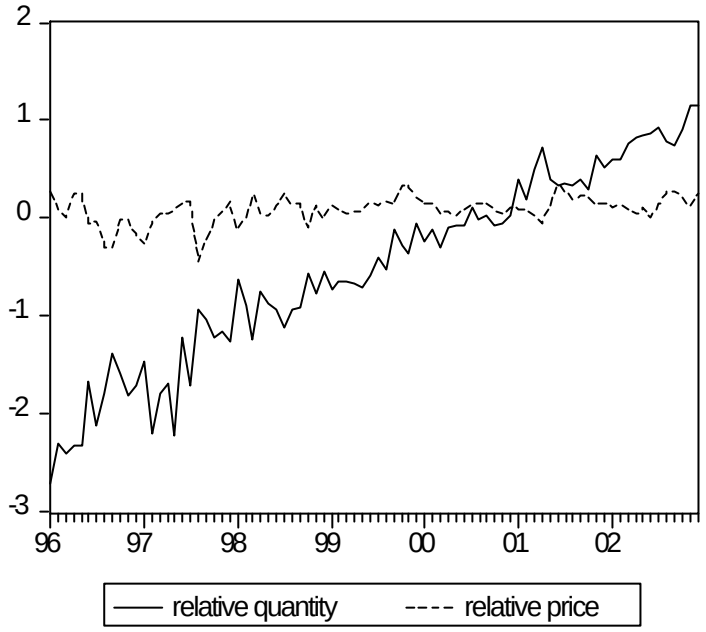
Note in Graph (6) that relative quantities show an increase in Brazilian exports at the expense of a fall in Mexico's exports. However, this market gain of Brazil should be ascribed to supply conditions rather than to demand conditions, since relative prices remain stationary and suppliers ought therefore to be regarded as price takers. Pricing-to-market does not seem to be a plausible hypothesis here, since such a strategy is implemented to avoid changes in market shares in the short run, but in this case Mexico shows a continuous loss of market share to Brazil. Furthermore, the wood industry is characterised as a low technology industry[22] and as having a large number of medium and small suppliers[23].

[22] See, for instance, Hatzichronoglou (1997).

[23] In Brazil, small and family owned enterprises account for 99% of output, see the Brazilian Association of Mechanically Processed Wood Manufacturing – Ambici (Associacao Brasileira da Industria de Madeira Processada Mecanicamente). In the US, see USITC (2002).

GRAPH (6):

Relative prices and quantities of exports of pine standard wood moulding of Brazil and Mexico



The relative price indices of Brazil and Mexico for the wood industry as a whole also cointegrates with the nominal exchange rate (real/peso), with both the consumer price index (CPI) of Brazil and Mexico included as exogenous variables. However, the implied pass-through effect is very low: only 0.28; i.e., a 10% real devaluation of the real against the peso would reduce Brazil's export price of wood by only 2.8% relatively to Mexico's export price.[24]

Now when relative prices of doors and their frames are cointegrated with the nominal exchange rate (real/peso), with both the consumer price index (CPI) of Brazil and Mexico included as exogenous variables, we find a pass-through effect of 198%. In other words, for the differentiated product, the long run effect on relative prices was almost twice the change in the exchange rate[25].

On the other hand, as the series of nominal and real exchange rates are non-stationary, they cannot cointegrate with the series of relative prices of pine standard wood moldings

[24] When the relative price indices of Brazil and Mexico are cointegrated with the real exchange rate (deflated by CPI price indices), the implicit elasticity is only 0.24.

[25] The long run effect of the change in the real exchange rate was 0.79. Therefore, changes in the real exchange rate are almost fully transmitted to relative prices.

which we have found to be stationary. Therefore, the change in relative quantities is entirely explained by the change in the real exchange rate, taken here as a proxy for costs.

Note that the implicit effect of changes in the real exchange rate on the relative quantities exported by Brazil and Mexico for the industry as a whole also seems to have been underestimated, since it was smaller than the same effect for doors and their frames, despite the much larger elasticity of substitution for the industry as a whole[26].

Therefore, the apparent pricing-to-market result for the industry as a whole is simply an aggregation bias that ignores the presence, within the industry, of homogeneous products which follow the law of one price.

4. Conclusions

Some industries defined at the 4-digit level or even more aggregate levels may include homogeneous products that follow the law of one price. When they do, estimates of substitution elasticities for the industry are in fact averaging the elasticities of traded products that compete under different regimes. As products that follow the law of one price have substitution elasticities equal to infinite, the industry's estimated elasticity becomes largely dependent on the weight of these products in the industry. Indeed, they may be regarded as a hopeless attempt to find the mean between zero and infinite.

Typically, elasticities estimates for industries that include LOP products tend to be overestimated due to this aggregation bias, though some narrowly defined products may have substitution elasticities that are much higher than the most common estimated range for industries. Therefore, an effort ought to be made to obtain data, especially on domestic output, at more disaggregated levels and thus obtain more precise estimates of substitution elasticities.

Analogously, the presence of products following the law of one price in a particular industry leads to an underestimation of the exchange rate pass-through effect on relative prices, since the pass-through effect is zero by definition for these products. Therefore, pricing-to-market estimates for these industries may be grossly overestimated.

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[26] The effect of the real exchange rate on relative quantities is estimated as dlnq/dlne=(dlnq/dlnp)(dlnp/dlne), where the last two terms are the elasticities of relative quantities with respect to relative prices and of relative prices with respect to the real exchange rate. For the industry as a whole these elasticities were estimated at 5.08 and 0.24, while for doors and their frames they were 1.81 and 0.79, respectively. Therefore, the elasticity of relative quantities with respect to the real exchange rate is 1.22 for the industry as a whole and 1.43 for doors and their frames.

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