International Competition: is there a place for the law of one price yet?

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This paper provides evidence for the law one price for a set of mining, metal, chemical and wood products imported by the United States. This evidence contrasts somewhat with those of earlier studies, which have shown that the law of one price is violated even for some primary commodities defined at a very high level of disaggregation. However, the methodology and database used in this paper are quite different from previous studies and may account for these contrasting results.

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1. Introduction

There have been a considerable number of studies showing that the law of one price (LOP) tends to be violated for manufactured goods and even for narrowly defined primary commodities, presumed to be homogenous. To the best of our knowledge there has been no recent attempt to show that the LOP holds at least for some products if any at all. Given that trade data can be assumed to have significantly improved in recent years, as electronic information systems have been widely used by traders, and econometric techniques have also been constantly advancing, it should be interesting to apply these techniques to the new data available and test the validity of the LOP for some products. The principal objective of this paper is, therefore, to test the law of one price for a set of mining, metal, chemical and wood products imported by the United States.

In addition to this introduction the paper is organised as follows. The second section discusses the LOP model and contrasts it with a differentiated good model. The third section briefly reviews the empirical evidence on the LOP. The fourth section describes the data used and the methodology applied in this paper. The fifth section presents the results and the last section summarises the main findings.

2. Homogeneous and differentiated goods in international trade

One of the fundamental principles of the classical and neoclassical trade theories is the so-called law of one price. This law states that homogeneous products must be traded at the same price, regardless of where they are sold, as long as prices are expressed in the same currency and taking due account of transfer costs[2]. Any price difference should be rapidly eliminated by commodity arbitrage. Countries would, therefore, specialise either as

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

exporters or importers of these products and would not discriminate between domestic and exporting markets[3].

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[4], 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

[3] The LOP is also a sufficient condition for the aggregate price index of any tradable good to exhibit purchasing power parity and plays a prominent role in some balance of payments adjustment theories. For the role of international pricing and balance of payments adjustment, see Obstfeld, 2002.

[4] 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.

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[5]. These changes depend entirely on suppliers' conditions, since the demand price elasticity of substitution is infinite by definition. Therefore, although changes in the 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[6].

On the other hand, differentiated good (DG) models assume that a commodity produced by one country is an imperfect substitute in demand for the "same" commodity produced by another country. Following Armington's (1969) convention we refer to these commodities as goods and to the good produced by a particular country as a product. Therefore, changes in the price of a product will change both relative prices and relative quantities demanded by the market.

Formally, DG models often assume that[7]:

$$Q_i^*/ Q_j^* = F (P_i^*/ P_j^*), \qquad \text{where } F'<0, \text{ or} \qquad (4)$$

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

[6] There may be some delay between changes in costs and changes in supply, though this is not the usual rationale for the J Curve.

[7] Following Armington (1969) again, we 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.

$$d(Q_i^*/ Q_j^*)/(Q_i^*/ Q_j^*)= f\,[d(P_i^*/ P_j^*)/(P_i^*/ P_j^*)], \text{ where } f'<0. \quad (5)$$

Assuming that the price elasticity of substitution is constant, it follows that:

$$d(Q_i^*/ Q_j^*)/(Q_i^*/ Q_j^*)= \sigma\, d(P_i^*/ P_j^*)/(P_i^*/ P_j^*), \text{ where } \sigma \text{ is the elasticity of substitution.} \quad (6)$$

Moreover, relative prices of different products are often assumed to respond to changes in relative costs. A devaluation, for instance, that reduces the cost of a product valued at the importing market currency, will eventually lower the relative price of the product, thus increasing the quantity sold in that market[8]. The same would happen if one country received a preferential (lower) import tariff in a particular market.

Therefore, suppliers of a particular product (or country) are assumed to face a declining demand curve with respect to their price in the importing market. Devaluations would expand the product supply curve, thus lowering the price and raising the quantity sold in the market by the country whose currency has been devalued. An elasticity of demand greater than one would be, therefore, necessary for an increase in the exporting country's market share in value terms at the market's currency[9].

Note, however, that changes in costs may not be fully transmitted to final market prices, as suppliers may decide to maintain their prices and market shares relatively stable, despite fluctuations in their costs and, consequently, in their mark-ups. This pricing-to-market strategy would make particular sense if fluctuations in costs were thought to be temporary rather than permanent (see Krugman, 1987 and Yang, 1998, who briefly reviews the argument according to various models and authors). 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 cost is rather stable and import penetration is high (see

[8] Time lags are often assumed here and they give rise to the J curve.

[9] $d(P_i^*Q_i^*/ P_j^*Q_j^*)/(P_i^*Q_i^*/ P_j^*Q_j^*)= (\sigma-1)\, d(P_i^*/ P_j^*)/(P_i^*/ P_j^*)$.

Yang, 1998). When products are not differentiated at all, it is as though firms are forced to price to market, since they are price takers, and there is no pass-through effect. Therefore, when the pass-through effect is zero, it is not possible to distinguish a DG model from the LOP model simply through examining the behaviour of countries prices and quantities. One needs to get more detailed information, probably at the firm level, to make such a distinction.

Furthermore, changes in relative costs, even when fully transmitted to prices, may not affect relative quantities in the expected direction if they correspond to changes in the perceived relative quality of the products. Products that are subject to rising relative quality may experience rising relative costs, prices and quantities. From a theoretical viewpoint, quality ladder models deal with this type of vertical (endogenous) technical progress, but tend to assume that products of different qualities are perfect substitutes to each other. Therefore, the state-of-the-art firm becomes a monopoly through Bertrand competition and countries become fully specialised under free trade in these models (see, for instance, Grossman and Helpman (1991) and Barro and Sala-I-Martin,1995). Empirically, the relationship between relative prices (or costs) and relative quantities depends crucially on the level of aggregation of industries or goods. For manufacturing industry as whole, one tends to confirm Kaldor's Paradox[10], but for specific and more disaggregated industries

[10] Kaldor (1978) showed that countries that gained market shares in world exports in the 1950s and 1960s tended to have rising relative unit labour costs. However, as Kaldor analysed exports of manufacturing industry as a whole for a group of advanced countries, it is very likely that changes in the mix of products within exports of each country accounted for cost, prices and market shares moving all in the same direction. As it is well known to trade economists, the decomposition of changes in market shares between product and competitiveness effects that is derived from constant market share analysis depends crucially on the level of disaggregation. A good trade performance at a high level of aggregation may be ascribed to gains of competitiveness when, in fact, at a lower level of aggregation, it is clearly the result of a product effect. In other words, a country may experience an increase in market share simply because its products become more important in the structure of the importing market, though the country market share for each product may have remained the same or may have even declined.

cost or price elasticities tend to be negative (see Chami Batista, 2001 and Carlin et al., 2001)[11].

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".

3. The Empirical Evidence

The vast majority of empirical work on the law of one price and on the relationship between costs or prices and export performance has been undertaken on the basis of rather aggregated data. But the empirical evidence tends to lend no support to the law of one price, even for highly disaggregated primary goods, largely presumed to be homogenous. A traditional reference in the literature is the paper by Isard (1977)[12]. He compared domestic and export prices of a group of industries defined at different levels of aggregation and generally found evidence against the law of one price.

Richardson (1978) did some econometric tests, comparing Canadian and US prices of similar commodities at a reasonable level of disaggregation, including some primary goods, and found that "the law of one price fails uniformly"; i.e., "commodity arbitrage is never

[11] Note that when relative costs are used to explain relative trade performance, it is not possible to know if the transmission mechanism operates through prices and demand effects or through mark-ups and supply effects.
[12] Isard quoted a study by Laurence Rosenberg who found that relative dollar prices of various well-defined steel items (cif for delivery in a common port) charged by different countries were fairly constant over time and were not significantly affected by exchange rate realignments in the 1970s.

perfect". Kravis and Lipsey (1978) also cast doubt on the law of one price both for aggregate as well as disaggregated price indices[13].

Thursby et al (1986) analysed the relative prices of wheat exported by the USA, Australia and Canada to Rotterdam and Japan over a five-year period since 1973. Wheat is regarded as "the more unlikely candidate for a differentiated good model than many other goods", "since it is one of the most narrowly defined products for which trade data are available". However, they found that wheat purchases from different countries were not only imperfect substitutes, as relative prices seem to be correlated with the relevant exchange rates, but trade flows appear to better fit an Armington-type model for differentiated goods than a spatial equilibrium approach consistent with the LOP. They concluded that "there may little published data which will support, in general, the LOP… and may be prudent to follow Richardson's suggestion and treat every country's products as differentiated from those of every other country, even when classified under similar headings" (see Thursby et al., 1986, p. 301).

Armington's trade elasticities of substitution have been estimated for several industries and are often used in trade policy simulation models[14]. To the extent that some products at a high level of disaggregation follow the law of one price, these estimates of Armington's trade price elasticities of substitution of industries defined at a more aggregated level may indeed average out elasticities of products competing under entirely different regimes.

[13] Disaggregated levels meant 4 to 5-digit SITC categories.

[14] Armington trade substitution elasticities have recently been estimated for over three hundred US industries (4-digit SIC level) over the period 1989 to 1995. See Gallaway et al (2000). See Kume et al (2002) for a similar exercise for the Brazilian economy. For a critical analysis of these estimates, see McDaniel and Balistreri (2002).

4. Data and Methodology

The data base consist of monthly observations on US import values, quantities and prices[15] at the 10-digit level from different exporting countries over the period between January 1996 and December 2002[16]. As some countries export only occasionally, we have concentrated on the main exporting countries for which US import data exists for almost every month in the period. Commodities were selected on the basis of a presumption that they were as close as possible to what one could regard as a homogeneous good; i.e., a well defined good with little room for quality differences. Most of the chosen commodities go through some kind of basic industrial processing for their production and may be classified as semi or manufactured goods. The sample also contains a few primary goods (aluminium ore, agglomerated iron ore and non-agglomerated iron ore) and three commodities (three types of silicon) classified as high-tech goods[17].

The first step to find out whether a commodity follows the law of one price is to test if its price series is non-stationary. All price and quantity series were calculated in logarithm. The Augmented Dickey-Fuller (ADF) test[18] was used to detect the presence of unit root processes, which implies that the series is non-stationary. When price series turned out to be non-stationary, we tested if the series of the difference between each pair of products (countries) prices were stationary, using again the ADF test. Given that a stationary series exhibits mean reversion, in that it fluctuates around a constant long-run mean and has a finite variance that is time-invariant, series of product price differences that are stationary

[15] Import prices are cif plus duty payments and are equal to import values divided by first unit quantities (landed duty-paid value/first unit of quantity). The United States International Trade Commission (USITC) is the source of the data.

[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] For a recent classification of high-tech goods, see Hatzichronoglou (1997).

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

already suggests that the prices of each exporting country are determined by the same generating process and it is not possible to reject the LOP[19]. However, in order to test for a short-term relationship between relative prices and quantities, we also tested the quantity series and the differences between quantities for each pair of countries. If the individual quantity series are non-stationary and the differences are stationary, we regress relative quantities on relative prices using OLS. In this case, if the coefficient is significant and negative, we could say that although product prices tend to follow the LOP in the long run, short-term price differences can have some short-term influence in countries' market shares.

5. Results

We have tested the price series of fourteen commodities imported by the US economy. We find evidence in favour of the LOP for nine of these commodities, whereas the price series of five commodities do not appear to follow the LOP. In some cases, a simple examination of a graph showing the series of prices for each exporting country gives a pretty good idea of to what extent they tend to move together along the whole period between January 1996 and December 2002. Given that, generally, exchange rates tended to vary significantly over this period, the observation of prices for a pair of exporting countries moving together means that relative prices remain almost constant over the period, irrespective of changes in the relevant exchange rate, and that could be taken as a first evidence to the LOP. That is why we plot country (or product) prices of each commodity. We next describe the results for each commodity of our sample.

Unwrought tin, not alloyed *-Harmonised System (HS) 800100000.*

This manufactured commodity well illustrates the case of a market evenly distributed among a few countries. There are five main exporting countries to the US: Bolivia, Brazil,

[19] One cannot reject a complete pricing-to-market strategy or a zero pass-through effect either.

Peru, Chile and Indonesia. This was the market that appeared best adjusted to the LOP model. All series of prices of the main five exporting countries are shown to be non-stationary. Figure 1 reveals how these prices in logarithmic form move together over the period[20]. The difference between any pair of price series is shown to be stationary[21] with all means close to zero. This suggests that the strong version of LOP would apply to this commodity. The series of quantity of Bolivia and Peru are stationary, so we cannot test if relative quantities are stationary for all the pairs with these countries. All the other series of relative quantities have shown to be non-stationary and, therefore, cannot be explained by stationary relative prices.

Unwrought Nickel, not alloyed *-HS 7502100000.*

Exports of this manufactured commodity to the US also adjust well to the LOP model, as can be seen in Figure 2. There are four main exporting countries, but Canada supplies about the same quantities as the other three together: Australia, Russia and Norway. All four series of prices are non-stationary[22].

Price differences between Australia & Canada, Russia & Canada, Russia & Australia and Norway & Australia are all stationary, but those between Norway and the two other countries are non-stationary. However, Norway and Russia price difference becomes stationary at 5% level without intercept and Norway and Canada becomes stationary at 10% level without intercept, as shown in Table 1.

The series of quantities of Canada, Australia and Norway are stationary. Therefore, we cannot test if relative quantities are stationary or not. Nevertheless, it looks graphically

[20] One price of Bolivia (September 1997) and two of Peru (March 1997 and September 2001) were excluded as outliers.

[21] See Table (1). In fact, when the outliers of Peru's prices are removed the relative price between Peru and Brazil, Peru and Indonesia and Peru and Bolivia become non-stationary. The low power of the test for series found to be non stationary is likely to account for this result.

[22] The following prices were removed as outliers: Australia (June 1999); Norway (July 2002 and September 2002); and Russia (December 1998 and June 1999).

hard to see any relationship between changes in relative prices and changes in relative quantities between any pair of countries.

Unwrought Zinc, not alloyed - *HS 7901110000.*

Three countries account for most of the exports of this manufactured commodity to the US: Canada, Mexico and Peru. Canada is the main exporter. The series of prices are all non-stationary[23], but relative prices between pairs of countries are all stationary[24]. As shown in Figure 3, Mexican zinc appears to have a "quality discount", as its price is systematically lower than the others, suggesting that the weaker version of LOP applies here.

The series of quantities of Mexico and Peru are non-stationary, but Canada's is stationary. The series of relative quantity between Mexico and Peru is also non-stationary. Therefore, the behaviour of relative prices cannot explain changes in relative quantities between any pair of countries.

Unwrought aluminium, not alloyed *-HS 7901110000.*

Canada is by far the main supplier of this manufactured commodity to the US. Russia is also an important exporter to the US, though its export volumes are quite volatile. Nevertheless, the series of prices of Canada and Russia are both non-stationary[25], but their relative price is stationary (see Table 1), suggesting that they follow the LOP. The series of quantities exported by Canada is non-stationary, but the volatility of Russia's supply makes its series of quantities stationary. In any case, there is no apparent correlation between relative quantities and prices between Canada and Russia. Figure 4 also shows the average price of all other exporting countries to the US together[26]. They together account for

[23] Two prices of each series were removed as outliers: October 1996 and May 2002 from Peru; August and September 2001 from Mexico; and August and September 2001 from Canada.

[24] In fact, relative price between Mexico and Peru is stationary at 10% for lag 2 or at 5% for lag 4. See Table 1.

[25] The following prices of Russia were removed as outliers (December 1996, January 1997, February 1997 and February 2000). In fact, this series of prices is stationary at the 10% level of confidence.

[26] These include Brazil, Venezuela, Australia, China, South Africa, New Zealand, Tajikistan, and Argentina.

between 8% and 17% of the whole market. Even aggregating all other countries together, Figure 4 reveals that prices tend to be more volatile the smaller is the share of the exporting country in the market. However, relative prices between Canada and "Other Countries" and between Russia and "Other Countries" are both stationary, confirming the strict version of LOP for this commodity[27].

Aluminium Ore (bauxite) -*HS 2606000090.*

Four countries account for most of US imports of this primary commodity: Guinea, Brazil, Guyana and Jamaica. After removing a few outliers[28], the series of prices of Brazil, Guyana and Jamaica became non-stationary and are shown in Figure 5. But the series of prices of Guinea, also shown in Figure 5, is quite volatile, has no obvious outliers and is found to be stationary. The relative prices between Brazil and Guyana and between Guyana and Jamaica are both non-stationary (see Table 1), suggesting that the LOP is violated for this commodity. But the series of relative prices between Brazil and Jamaica is stationary (see Table 1), though the price of Jamaica is systematically lower than Brazil's. Looking at the series of quantities we find that all series, but Jamaica's, are stationary. Furthermore, although relative prices and quantities between Brazil and Jamaica were found to be stationary, when relative quantities are regressed on relative prices we find that changes in the latter can explain over 40% of changes in the former. Therefore, the evidence appears not to favour the LOP, since even when relative prices have a constant long run mean, relative quantities seem to respond in the short run to fluctuations of relative prices.

[27] Although Russia dumped the market with low price commodities right after the collapse of the Soviet Union, even if the period between 1991 and 1996 were included into the analysis, the series of relative prices of unwrought aluminium between Russia and Canada would remain stationary.
[28] The following outliers were removed from the price series: Brazil (November 1999); Guyana (February 1998) and Jamaica (February 2001).

***Semi-finished products of iron and non-alloy steel** -HS 7207120050.*

Brazil is the main supplier of this manufactured commodity to the US with a market share of about one third. Mexico comes a close second and Russia is third. Figure 6 shows that all prices roughly follow the same path as Brazil's price, though the prices of Mexico and of Other Countries have a few outliers[29]. We have grouped prices of all other countries together to show that they too follow the same path. All three series of prices are non-stationary. But, when relative prices of each pair of countries are calculated and tested, they are shown to be stationary (see Table 1). Therefore, there are strong indications of the validity of the LOP for this commodity.

As to the series of quantities, Brazil's and Mexico's are stationary, while Other Countries' are non-stationary. All attempts to regress relative quantities on prices between pair of countries, after making all series stationary, failed to show any correlation at all.

***Pig Iron** -HS 7201100000.*

Brazil holds a lion's share of US imports of this intermediary commodity, which is used an input in the manufacturing of steel. From almost 70% of the market of US imports in 1996, Brazil's market share fell to a low 43% in the year to July 1999, but recovered strongly to reach over 75% in 2002. Ukraine, Russia, South Africa, Canada and a few other countries share the remaining of the US market. Since these countries have many months when they do not export to the US and given Brazil's large share of the market, we compare Brazil's price with that of all other countries together in Figure 7. Both the series of price of Brazil and of Other Countries are non-stationary[30]. However, as shown in Figure 7, the series of relative price of Brazil as compared with Other Countries is stationary, suggesting that

[29] None of the outliers were removed, since this would further shorten the series of prices for countries, which already failed to export in a number of months. This would, in turn, weaken the tests.

[30] The following outliers have been excluded from the series of price of Other Countries: January 1996, February 1996, April 1996 and November 2000.

these prices too follow the LOP. The series of quantities exported by Brazil is non-stationary, but the series of quantities exported by Other Countries is stationary. Excluding a few other outliers from this series we have turned it into a non-stationary series. But the series of relative quantities is non-stationary, implying that changes in relative prices cannot explain changes in relative quantities. Taking the first differences of the series of relative quantities, and thus turning it stationary, allows us to regress relative quantities on relative prices. Nevertheless, we find no correlation between these variables, reinforcing the validity of the LOP.

Agglomerated Iron Ore -*HS 2601120030****.***

Canada is the main supplier of this commodity to the US, followed by Brazil. The series of prices of Canada and Brazil, shown in Figure 8, are both non-stationary. The series of relative price is stationary (see Table 1), suggesting the validity of the LOP. The series of quantity of Brazil is non-stationary, but that of Canada is stationary. However, the series of Canada reveals a clear seasonality, which invalidates the ADF test. After excluding the data corresponding to the first quarter of each year, the series of Canada and the relative quantity between Canada and Brazil became non-stationary. Therefore, changes in relative quantities cannot be explained by changes in relative prices.

Non-agglomerated Iron ore *-HS 2601110090.*

Brazil is the main supplier of this commodity to the US. Since all the other exporters competing with Brazil fail to export in a considerable number of months, we have grouped them altogether and calculated their average price. The series of Brazil's prices and of the "Other Countries" are shown in Figure 9. Both series are found to be stationary. An attempt to regress Other Countries' prices on Brazil's prices revealed no correlation at all between them, in addition to the fact that the coefficient has the wrong sign. Therefore, we cannot reject the non-validity of the LOP for this commodity.

Unrefined copper *–HS 7402000000.*

Chile was the main supplier of this commodity to the US in 1996, accounting for 60% of total imports, while Canada was the fourth main exporter with only 5% of the import market. Mexico came third with a share of 23% of US imports. In 2002, Canada accounted for about two thirds of US imports, Chile was second with 15% and Mexico was third with 13%. Therefore, major changes in market shares took place amongst the main exporters of this commodity to the US over the period. However, Figure 10 reveals that the price of Canada remained quite stable over the whole period, whereas the price of Chile and Mexico were volatile, with Chile's price clearly falling relatively to the price of Canada, despite the market share gains of Canada.

The series of price of Chile and Mexico were non-stationary, but Canada's turned out to be stationary. The series of relative prices between Chile and Peru was also non-stationary, suggesting that the LOP is violated for this commodity.

Standard wood mouldings of pine *-HS 4409104000.*

There are three main exporters of this manufactured commodity to the US: Chile, Brazil and Mexico. Prices are all non-stationary as expected[31]. Figure 11 shows that Chilean prices are systematically higher than Mexican and Brazilian prices, whereas Brazilian prices are higher than Mexican prices most of the time and always after 1998[32]. However, despite these price differences, relative prices between any pair of countries are stationary, suggesting the validity of the weaker version of the LOP. The series of quantities are non-stationary, except for Chilean exports. The series of relative quantities between Brazil and Mexico is non-stationary. Therefore, relative quantities cannot be explained by changes in relative prices between any pair of countries.

Silicon less than 99 percent pure *-HS 2804695000.*

Russia has been the main supplier of this commodity to the US, accounting for almost half of total imports in the whole period. Because no other single country has consistently exported on a monthly basis to the US[33], we compare Russia's prices with the average price of all other exporters taken together. As Figure 12 clearly reveals the two series of prices move down together. Indeed, the two series are non-stationary when taken individually, but their difference is stationary, indicating once again the validity of the LOP (see Table 1).

Silicon between 99 and 99.9 percent pure -*HS 2804695000***.**

Brazil finished 2002 as the main supplier of this commodity to the US, with a market share of 40%. However, it had 27% in 1996 and reached a low of 7% in 1998. The series of prices of Brazil is non-stationary. The series of prices of South Africa, another important supplier, is also non-stationary. But relative price between Brazil and South Africa is non-

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[31] The price of Brazil for August 1997 was removed as an outlier.

[32] The price difference in logarithm between Chile and Mexico has a mean equal to 0.289 and standard deviation equal to 0.106. The difference between Chile and Brazil has a mean equal to 0.197 and standard deviation equal to 0.146, whereas between Brazil and Mexico the mean is 0.091 and standard deviation is 0.133.

[33] Even Russia has failed to export in a few months.

stationary too, and so is relative price between Brazil and all other countries together (see Figure 13 and Table 1). Therefore, the evidence suggests that the LOP is violated for this commodity.

Silicon over 99.9 percent pure -*HS 2804610000.*

Germany, with almost 60% of the market in 2002, Japan, Italy and South Korea are the main exporters of this commodity to the US. Germany and Japan have gained market share over the period between 1996 and 2002, while the opposite happened to Italy and Korea.

The series of prices are non-stationary for Germany[34], Japan, Italy and Korea. Relative prices are non-stationary between any pair of countries, except between Japan and Korea and between Italy and Korea whose relative prices are stationary (see Table 1). This suggests that the LOP is violated for this commodity, though Korea seems to follow Japan's and Italy's prices in the long run. Regressing relative quantities on relative prices using OLS, we find some correlation between Italy and Korea (elasticity = -1.39) and between Japan and Korea (elasticity = -0.82), indicating that relative prices tend to explain part of changes in relative quantities in the short term[35]. Therefore, we cannot reject the hypothesis that the LOP is violated for this commodity.

5. Conclusions

As expected, the series of product prices have generally shown to be non-stationary. But the Augmented Dickey-Fuller Unit Root Test shows that for nine out of fourteen commodities relative prices for each pair of countries are stationary. Therefore, we cannot reject the hypothesis that these prices follow the LOP in the long run and that the goods are perfect or quasi-perfect substitutes. On the other hand, for five out of fourteen commodities, relative

[34] Two outliers have been removed from Germany's series: March 1999 and July 2000.
[35] However, the ADF cannot test if the series of relative quantities are stationary because the individual series of quantities for Japan, Italy and Korea are all stationary.

prices proved to be non-stationary, so that is not possible to reject the hypothesis that the LOP is violated for these commodities.

We have tested the LOP for a small sample of mining, metal, chemical and wood products imported by the United States. Therefore, in no way, we are claiming that the LOP applies to a significant number of traded goods. However, given the strong evidence against the LOP that one finds in the recent literature, this paper shows that at least for some narrowly disaggregated commodities it is not possible to reject the LOP.

When we compare the results among the different goods, it appears that the LOP model is best adjusted when the market is not concentrated in just one exporting country, but is rather evenly distributed among a few countries. Although the size of our sample does not allow generalisations, there are indications that homogeneous goods are more easily found amongst manufactured commodities that go through some basic industrial processing than within the group of primary goods[36]. But as the commodity goes through technologically more advanced processing, as in the case of the two purest types of silicon, the LOP tends again to be violated.

[36] This is perfectly consistent with the empirics on primary goods that are generally against the LOP, as in Thursby et al. (1986). Primary goods are more likely to be perceived by consumers as having differences in quality and varieties than do standard metal commodities. Primary agricultural commodities may also generate intra-industry trade because of variations in the time of harvests across countries.

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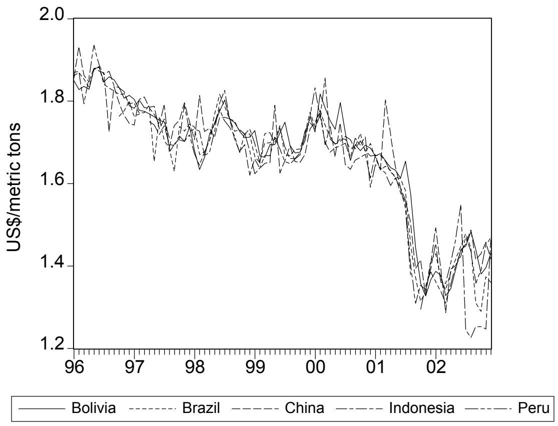
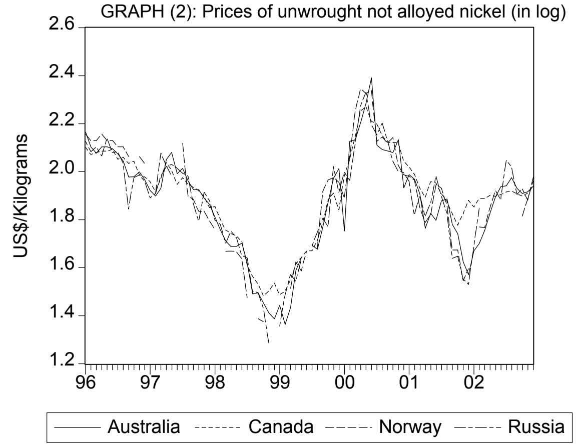
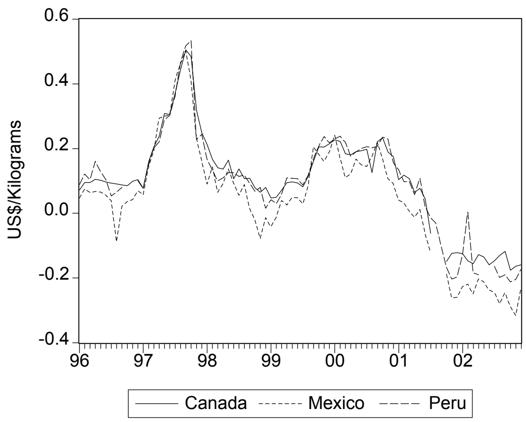
GRAPH (1): Prices of unwrought not alloyed tin (in log)



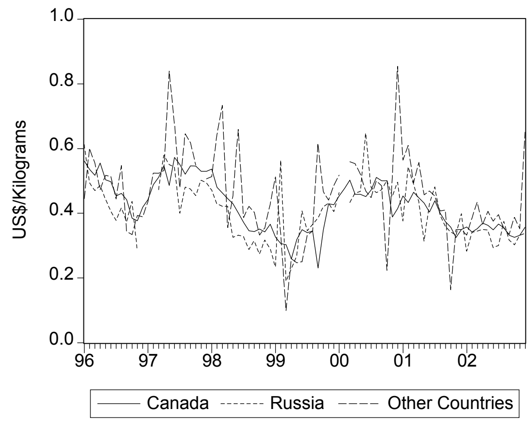
GRAPH (2): Prices of unwrought not alloyed nickel (in log)



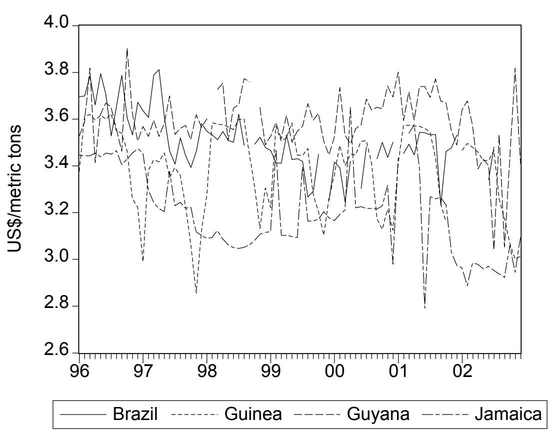
GRAPH (3): Prices of unwrought not alloyed zinc (in log)



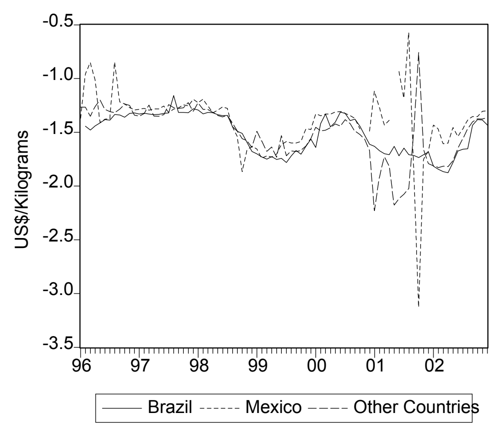
GRAPH (4): Prices of unwrought not alloyed aluminium



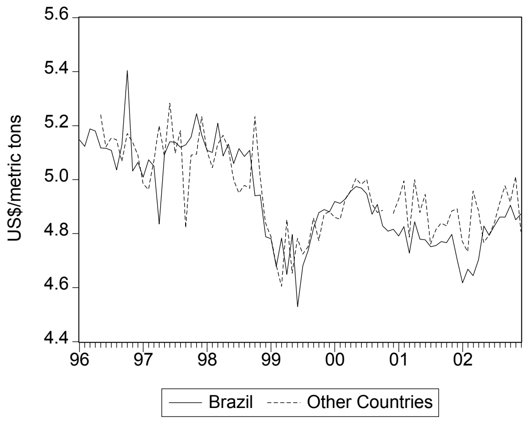
Graph 5): Prices of aluminum ore (in log)



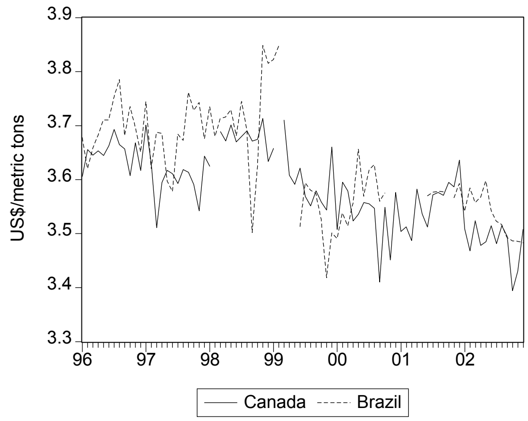
GRAPH(6): Prices of semifinished products of iron and non-alloy steel (in log)



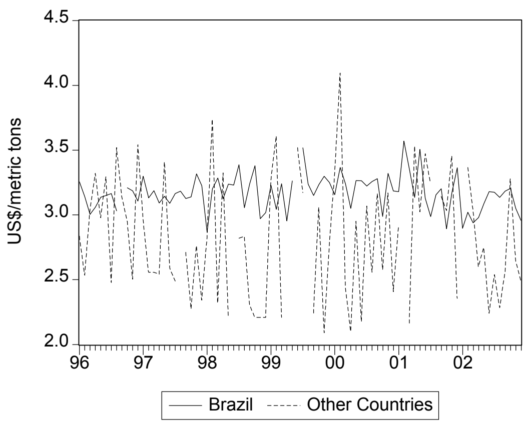
Graph (7): Prices of pig iron (in log)



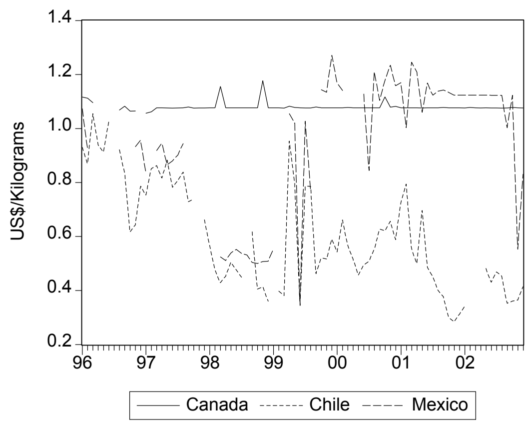
Graph (8): Prices of agglomerated iron ore (in log)



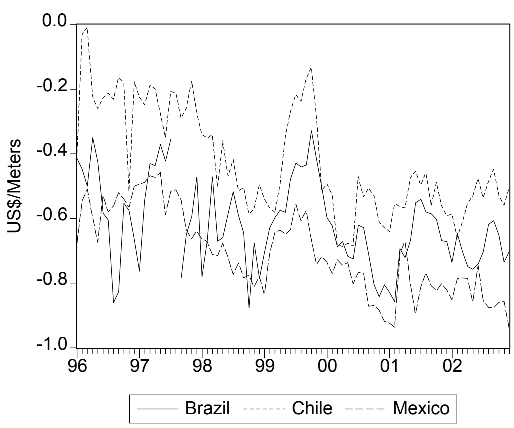
Graph (9): Prices of non-agglomerated iron ore



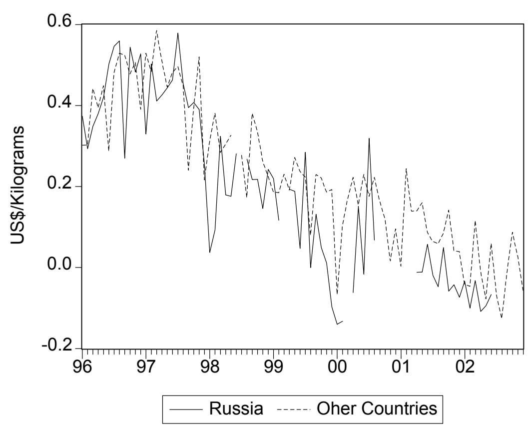
Graph (10): Prices of unrefined copper (in log)



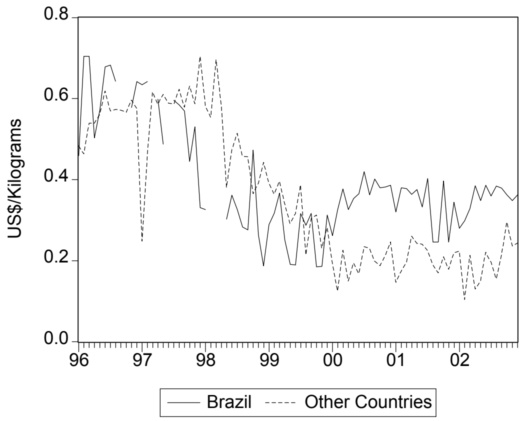
Graph (11): Prices of standard wood moldings of pine (in log)



Graph (12): Prices of silicon less than 99% pure (in log)



Graph (13): Prices of silicon between 99% and 99.9% pure



Graph (14): Prices of silicon over 99.9% pure (in log)

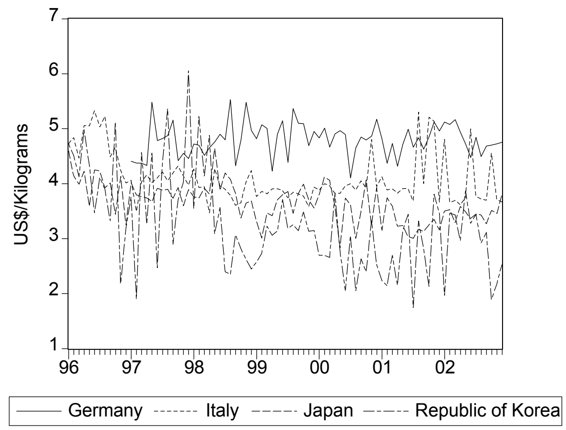


TABLE (1): ADF Test of Relative Prices

1-Unwrought Tin (Not Alloyed)	
C.V.: -3.5164 (1%); -2.8991 (5%); -2.5865 (10%)	
Relative Prices Between	ADF test statistic
Bolivia – Brazil	-5.164107
Bolivia – China	-5.122149
Bolivia – Indonesia	-4.886645
Bolivia – Peru	-5.052507
Brazil – China	-3.760849
Brazil – Indonesia	-4.439421
Brazil – Peru	-4.640361
China – Indonesia	-3.873815
China – Peru	-4.844679
Indonesia – Peru	-3.873815

2-Unwrought Nickel (Not Alloyed)	
C.V.: -2.6227 (1%); -1.9495 (5%); -1.6202 (10%)	
Relative Prices Between	ADF test statistic
Australia – Norway	-3.215839
Australia – Canada	-4.152397
Australia – Russia	-6.137177
Canada – Norway	-1.709113
Canada – Russia	-3.645675
Norway – Russia	-2.386258

3-Unwrought Zinc (Not Alloyed)	
C.V.: -3.5176 (1%); -2.8996 (5%); -2.5868 (10%)	
Relative Prices Between	ADF test statistic
Canada – Mexico	-3.075324
Canada – Peru	-5.180316
Mexico – Peru	-2.807896

4-Unwrought Aluminium (Not Alloyed)	
C.V.: -3.5213 (1%); -2.9012 (5%); -2.5876 (10%)	
Relative Prices Between	ADF test statistic
Canada – Russia	-4.239961
Canada – Other Countries	-5.388471
Russia – Other Countries	-5.144096

5-Aluminum Ore
C.V.: -3.5226 (1%); -2.9017 (5%); -2.5879 (10%)

6-Semifinished Non-Square Products of Iron and Steel	
C.V.: -3.5176 (1%); -2.8996 (5%); -2.5868 (10%)	
Relative Prices Between	ADF test statistic
Brazil – Mexico	-3.101912
Brazil – Other Countries	-3.005538
Mexico – Other Countries	-4.377256

7-Pig Iron	
C.V.: -3.5121 (1%); -2.8972 (5%); -2.5855 (10%)	
Relative Prices Between	ADF test statistic
Brazil – Other Countries	-4.487424

8-Agglomerated Iron Ore	
C.V.: -3.5501 (1%); -2.9137 (5%); -2.5942 (10%)	
Relative Prices Between	ADF test statistic
Canada – Brazil	-2.923880

10-Unrefined Copper	
C.V.: -3.6496 (1%); -2.9558 (5%); -2.6164 (10%)	
Relative Prices Between	ADF test statistic
Chile – Mexico	-1.016153

11-Standard Wood Moldings of Pine	
C.V.: -3.5121 (1%); -2.8972 (5%); -2.5855 (10%)	
Relative Prices Between	ADF test statistic
Mexico – Brazil	-3.172132
Mexico – Chile	-3.987725
Chile – Brazil	-3.329571

12-Silicon less than 99% Pure	
C.V.: -3.5572 (1%); -2.9167 (5%); -2.5958 (10%)	
Relative Prices Between	ADF test statistic
Russia – Other Countries	-2.995831

13-Silicon between 99% and 99.9% pure	
C.V.: -3.5362 (1%); -2.9077 (5%); -2.5911 (10%)	
Relative Prices Between	ADF test statistic
Brazil – Other Countries	-1.285507

Relative Prices Between	ADF test statistic
Brazil – Guinea	-2.539327
Brazil – Guyana	-2.054517
Brazil – Jamaica	-3.882102
Guinea – Guyana	-3.035387
Guinea – Jamaica	-3.768906
Guyana – Jamaica	-2.690773

14-Silicon over 99.9% pure	
C.V.: -3.5121 (1%); -2.8972 (5%); -2.5855 (10%)	
Relative Prices Between	ADF test statistic
Germany – Italy	-2.281505
Germany – Japan	-2.417091
Germany – Korea	-2.521670
Italy – Japan	-2.622062
Italy – Korea	-2.927196
Japan – Korea	-3.206393

C.V. Critical Values.