CEPAL REVIEW 105 • DECEMBER 2011

KEYWORDS

Economic growth
Gross domestic product
Balance of payments
Exports
Imports
Technological change
Production
Economic analysis
Brazil

# Brazil: structural change and balance-of-payments-constrained growth

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This article argues that differences in GDP growth rates are related to differences in income-elasticities; and that these, in turn, depend on the technological intensity of domestic production. Statistical tests were conducted to verify this hypothesis; and the following hypothetical elasticities were estimated to demonstrate its validity for the Brazilian economy: (i) basic; (ii) expanded with capital flows; and (iii) implicit. Co-integration techniques were used in conjunction with vector error correction, to estimate real elasticities for each technological category of output in the Brazilian trade matrix. The results obtained were corroborated by analysing impulse-response functions and the decomposition of the forecast error variance, which confirmed that goods of higher technological intensity have higher income-elasticities. Thus, according to Thirlwall's Law, increasing the domestic production of such goods should promote growth.

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# I
# Introduction

There is a vast literature that highlights the key role of foreign-trade elasticities in determining Brazil's gross domestic product (GDP) (Jayme Jr., 2003; Santos, Lima and Carvalho, 2005; Porcile and Lima, 2006; Vieira and Holland, 2006; Carvalho and Lima, 2008). Although these studies have all acknowledged the external constraint on the country's growth, as proposed in Thirlwall's Law (Thirlwall, 1979), little progress has been made thus far in understanding the mechanisms that determine the elasticities in question. Nonetheless, several recent studies have shown that the productive structure has a major influence (Gouvêa and Lima, 2009; Araujo and Lima, 2007).[1] This article argues that differences in GDP growth rates are related to differences in income-elasticities, which in turn, depend on the technological intensity of domestic output. The article propounds the thesis that structural change, in other words variations in sector GDP shares, also helps ease the external constraint on growth, since the changes are reflected in the country's foreign-trade specialization pattern. Implicit in this argument is the hypothesis that the different sectors produce goods with different elasticities, thereby validating a multi-sector version of Thirlwall's Law, such that changes in their output shares are reflected in national elasticity.[2]

A variety of statistical tests were performed to corroborate these hypotheses. Firstly, the following hypothetical elasticities were estimated using different databases: (i) basic (McCombie, 1997); (ii) expanded with capital flows (Moreno-Brid, 2003), and (iii) implicit (Atesoglu, 1997). Co-integration techniques were used along with vector error correction (VEC) to estimate real elasticities for each technological category of production in Brazil's trade matrix. These categories were constructed from a classification of products by technological level, following Lall (2001). The results of the analyses are corroborated by analysing innovations in the model, through impulse-response functions and the decomposition of the forecast error variance. Lastly, an attempt was made to identify the trend of Brazil's trade elasticities, using the methodology proposed by Gouvêa and Lima (2009).

Following this introduction, the article has another four sections. Section II discusses the Kaldorian-Keynesian theory of balance-of-payments-constrained growth. Section III outlines the recent specialization of Brazil's productive structure in low-technology products, as revealed by the pattern of its trade matrix. Section IV describes the methodology used to test Brazilian data and the results of the estimations; and section V presents the conclusions.

[1] This result was obtained by considering a multi-sector model of Thirlwall's Law, in which each sector's specific production faces a different income-elasticity of demand. The total income-elasticity of the economy is calculated as the sum of the elasticities of the different sectors, weighted by their share of national output. Changes in the composition of the productive structure thus also affect the economy's total income-elasticity of demand.

[2] Theoretically, each country's productive structure determines its pattern of international trade.

# II
# Theoretical framework

Understanding the causes of unequal economic growth was always one of the major topics of study in the Kaldorian-Keynesian theoretical framework (Kaldor, 1966; Thirlwall, 1979; McCombie and Thirlwall, 1994). The cited studies all view demand as driving the economic system, so growth-rate differences between countries are interpreted as the outcome of different rates of growth of demand, which vary from one country to another according to the constraints they face. Thirlwall (1979) stresses the role of the balance-of-payments constraint in economic performance, given the need for long-term external equilibrium. The fact that balance-of-payments deficits cannot be financed indefinitely means that aggregate demand eventually has to be adjusted. As a result, "…Investment is discouraged; technological progress is slowed down, and a country's goods compared with foreign goods become less desirable so worsening the balance of payment still further, and so on. A vicious cycle is started. By contrast, if a country is able to expand demand up to the level of existing productive capacity, without balance-of-payment difficulties arising, the pressure of demand upon capacity may well raise the capacity growth rate by encouraging investment, technological progress and productivity…" (McCombie and Thirlwall, 1994).

This framework envisages demand incentives triggering a virtuous circle of growth that would raise the economy's overall productivity, as factors migrate towards higher-productivity sectors (manufactures), and learning-by-doing intensifies (Kaldor, 1966). Demand growth alters the sectoral mix of incentives in the economy, promoting certain sectors to the detriment of others. The benefited sectors mainly have higher income-elasticities of demand (which, according to the hypothesis of this query, reflects greater technological content). These sectors also tend to display increasing returns, such that an increase in their share of GDP, with a consequent shift of productive factors towards them, raises the productivity of the economy as a whole. Investment is seen as the key variable in propelling growth; while the importance of the balance of payments stems from the scale of the incentive, or disincentive, it provides to investment growth.

This analytical approach led to the formulation of export-led growth theories, in which exports are the only means of raising the growth rate without a deterioration in the balance of payments.

## 1. The balance-of-payments-constrained growth model

Bearing in mind the key importance of external balance for the growth of demand and output, Thirlwall's original 1979 paper developed a growth model under an external constraint in which economic growth is intrinsically related to the income-elasticities of exports and imports.

In this model, balance-of-payments equilibrium in local currency is given by:

$$P_d X = P_f M E \qquad (1)$$

where $E$ is the exchange rate. Imports ($M$) are a function of the ratio between prices weighted by the price-elasticity of demand for imports ($\Psi$<0) and the income-elasticity of demand for imports ($\pi$>0), as shown in the following equation:[3]

$$M = a\left(\frac{P_f E}{P_d}\right)^{\psi} Y^{\pi} \qquad (2)$$

Similarly, exports are a function of the real exchange rate and external income, in which the income-elasticity of demand for exports is denoted by $\varepsilon$ >0, and the price-elasticity of demand for exports is $\eta$ <0, both expressed in foreign currency:

$$X = b\left(\frac{P_d}{P_f E}\right)^{\eta} Z^{\varepsilon} \qquad (3)$$

A linear transformation of the equations, subject to the initial balance-of-payments-equilibrium condition, gives the rate of growth of domestic income that is consistent with balance-of-payments equilibrium (McCombie and Thirlwall, 1994, pp. 234 y 235):

$$y_B = \frac{(1+\eta+\psi)(p_d - p_f - e) + \varepsilon z}{\pi} \qquad (4)$$

Equation (4) has several implications: (i) if domestic inflation is higher than foreign inflation, the balance-of-payments-equilibrium growth rate falls, if $|\Psi + \eta| > 1$; (ii) exchange-rate depreciation ($e$ >0) tends to raise the balance-of-payments-equilibrium growth rate, if $|\Psi + \eta| > 1$ (this is the Marshall-Lerner condition); (iii) a higher rate of growth of world income raises the balance-of-payments-equilibrium growth rate; and (iv) the higher the income-elasticity of demand for imports ($\pi$), the lower will be the balance-of-payments-equilibrium growth rate.

Nonetheless, if purchasing-power-parity (PPP) is accepted as valid in the long run, which means no change in relative prices and domestic inflation equal to international inflation ($p_{dt} - p_{ft} - e_t = 0$), then equation (4) can be reduced to the one initially proposed by Thirlwall (1979), which is equivalent to the growth rule proposed by Harrod (1933):

$$y_B = \frac{\varepsilon z}{\pi} = \frac{x}{\pi} \qquad (5)$$

[3] The price-elasticities of demand for imports and for exports are assumed equal to their cross price-elasticity, namely $\Psi = \phi$ and $\eta = \tau$ respectively.

The empirical evidence presented in McCombie and Thirlwall (1994) confirms this relation, and shows that a pre-requisite for raising a country's growth rate is overcoming the balance-of-payments constraint. This is achieved through policies to stimulate an increase in the income-elasticities of exports and reduce those of imports. Nonetheless, to bring that paradigm closer to the reality prevailing in developing countries, new explanatory factors need to be considered, such as capital flows, exchange-rate variations, and changes in debt-service payments (Thirlwall and Hussain, 1982; McCombie and Thirlwall, 1997).

Firstly, capital flows are very important in developing countries, because they make it possible to run temporary current-account deficits. This means that countries with trade deficits can keep growing provided they can finance the deficit through the capital account. Nonetheless, capital inflows also generate a liability that may depress GDP growth, since they have to be amortized. The model also needs to take account of interest payments abroad, because, at some point, a trade surplus will be needed to service the debt. In other words, an accumulation of external debt can itself generate the need for a contraction in domestic demand (income), to generate a balance-of-payments surplus to pay debt service, which will thus reduce the growth rate (Moreno-Brid, 2003; Barbosa-Filho, 2001).

Moreno-Brid (2003) incorporate these components to obtain the following balance-of-payments-equilibrium condition:

$$P_d X_t + P_d F + P_d R = P_f M_t E_t \tag{6}$$

where $F$ represents capital flows, and $R$ is the real value of capital services. Weighting factors are also included: $\theta 1$ for the share of exports in income, and $\theta 2 = (1\text{-}\theta 1)$ for the income-share of capital. Expressed as growth rates:

$$\begin{aligned} m_t + p_{ft} + e_t = \theta 1(p_{dt} + x) - \theta 2(p_{dt} + r) + \\ (1 - \theta 1 - \theta 2)(p_{dt} + f) \end{aligned} \tag{7}$$

where $r$ is the variation in net interest payments, $f$ is the variation in capital flows, and $\theta 1$ and $\theta 2$ are the following ratios measured in the initial period:

$$\theta 1 = \frac{P_d X}{P_f EM} \tag{8}$$

$$\theta 2 = \frac{P_d R}{P_f EM} \tag{9}$$

Lastly, a sustainable borrowing constraint, $F/Y = k$, is also introduced, which in terms of growth rates is given by:

$$f + p_d = y + p_d \tag{10}$$

Substituting this constraint in (7) and using the same export and import functions, the balance-of-payments-equilibrium growth rate in the presence of capital flows is given by:

$$y_B^* = \frac{(\theta 1\eta + \psi + 1)(p_d - p_f - e) + \theta 1 \varepsilon z + \theta 2 r}{\pi - (1 - \theta 1 + \theta 2)} \tag{11}$$

The first term represents the effect of changes in the terms of trade; the second shows the effect of export demand; the third, the effect of interest payments; and the fourth, by subtracting in the denominator, the effect of capital flows. In the absence of capital flows, $\theta 1 = 1$, which returns us to the initial result of the Harrod (1933) growth rule.

### 2. Productive structure and its effect on elasticities

The fact that elasticities are important for growth calls for deeper research into their determinants.[4] Although an economy's potential output is determined by the rate of growth of demand, the balance-of-payments-constrained growth approach reiterates the importance of the supply characteristics of goods (non-price competitiveness). Thus, if one assumes a country that produces a variety of goods with different elasticities, in which the total income-elasticity of the economy is calculated as the average of the sector elasticities, weighted by each sector's share in the productive structure, then a change in the economy's productive structure will affect the income-elasticity of imports and exports, since different sector-demand growth rates result in different growth rates for the economy as a whole.

Based on this rationale, Araujo and Lima (2007) develop a multi-sector model and reach what the authors

[4] The model developed in the foregoing section implicitly assumes a country that produces a single good with given and unchangeable elasticities.

refer to as the Multi-sector Thirlwall's Law (MSTL). The chief implication of this model is that changes in sector shares in the economy, in other words changes the structure of production, have repercussions on the overall economic growth rate. As a result, "a country can still raise its growth rate even when such a rise in growth of world income does not occur, provided it is able to change the sectoral composition of exports and/or imports accordingly" (Gouvêa and Lima, 2009).

According to Thirlwall's traditional approach, the final equation of the Araujo and Lima (2007) model shows that each country's growth rate is directly proportional to the rate of growth of exports. This proportionality is related inversely to the sector income-elasticity of demand for imports and directly to the sector income-elasticity of demand for exports. In short, the growth rate depends on the sector composition of the economy.

In seeking empirical validity for this sector-formulation of Thirlwall's Law, the aforementioned authors estimate the MSTL elasticities for several Latin American and Asian countries and find that the most technology-intensive sectors have a higher income-elasticity, with smaller differences for imports than for exports. They also conclude that both the original version of Thirlwall's law, and its multi-sector formulation, adequately represent the economy's growth rate. Lastly, with sector income-elasticities estimated as relative weightings, the authors use each sector's foreign-trade share to calculate a weighted average of the annual changes in the elasticities, thus indicating the process of structural change.

This evidence shows that, as industrialization deepens, and, in particular, as higher-technology-intensive sectors gain a larger share of GDP, the elasticities of exports and imports also change, directly affecting output growth rates. Using this framework, this article seeks to identify the relation between the elasticities and the technological content of the goods that comprise the Brazilian trade balance, for the purpose of analysing the effects of structural changes on the country's growth rate.

# III

## External constraint and productive structure in Brazil: 1962-2010

In an empirical study for a group of countries, McCombie and Thirlwall (1994) concluded that terms-of-trade deterioration is a reality for developing countries (although the real effect of this may be very small), whereas capital flows tend to ease the constraint marginally, albeit temporarily. These results are broadly consistent with the structuralist approach adopted by Prebisch (2000a and 2000b), which explains the phenomenon by stressing that: (i) the goods produced in developing countries have a lower income-elasticity of demand; and (ii) the goods produced by central countries have a high income-elasticity of demand.

In an analysis of the Brazilian case, Carvalho and Lima (2008) found that the growth achieved between 1930 and 2004 was compatible with balance-of-payments equilibrium.[5] Moreover, by estimating the share of each of the components considered important in determining the growth rate, they concluded that the real exchange rate is statistically insignificant for observed growth, and also that capital flows do not raise the growth rate in the long run. The ratio of elasticities (Thirlwall's Law) accounted for most of the growth during the period, followed by the terms of trade. In the same study, a structural-break test showed that —in a subsample for the period 1930-1993— the ratio of elasticities fell from 7% to just 1.3% between 1994 and 2004, indicating that the growth slowdown in the Brazilian economy during that period reflected a productive structure that was overly reliant on goods with low income-elasticities of demand (or low-technology products, as will be shown) at a time when world trade patterns were reorganizing (Jayme Jr. and Resende, 2009). Between 1930 and 1993 the terms of trade deteriorated, making a negative contribution to output growth (-0.7%). Thereafter the pattern reverses, and the terms of trade generate average output growth of 1.7%, probably caused by stronger growth in the global economy and the consequent rise in commodity prices.

[5] See also Holland, Vieira and Canuto (2004); Ferreira (2001); Bértola, Higachi and Porcile (2002); López and Cruz (2000); Santos, Lima and Carvalho (2005).

Analysing data both for Brazil and for countries of the Organization for Economic Cooperation and Development (OECD), Jayme Jr. and Resende (2009) note that Brazil has not yet overcome the external constraint on growth, because its balance of trade in medium-and high-technology-intensive products has recorded large deficits since the early 1990s. This reflects the lower level of development of Brazil's National Innovation System (SNI) and weak national competitiveness. Moreover, following the trade liberalization of the 1990s, technological products increased their share in the country's imports, but not in its exports, thereby reflecting a deepening of the peripheral trade pattern. This shows that the Brazilian external sector remains highly vulnerable to fluctuations in international demand, since its exports are based on low-technology goods, in other words products of low income-elasticity. These results are similar to those obtained by Carvalho and Lima (2008).

Figures 1 and 2 illustrate how Brazil's productive structure has gradually evolved since 1962. Whereas the share of commodities in Brazilian exports has declined over time, the share of low-technology products in its exports grew until 1995, when they accounted for 45% of the total. Exports of medium- and high-technology products have also been growing, attaining a 33% share by the end of the period. Nonetheless, of that 33%, less than 10% are high-technology products, which means that medium-and low technology predominates in Brazil's exportable output.

On the import side, the 1981-1990 period was dominated by the oil crisis (particularly the second one in 1979), which fuelled a surge in the value of commodity imports. For the rest of the period, imports of low-technology goods remained broadly stable, with a share of around 25%. Imports of medium-and high-technology goods grew sharply, from a 34% share to 52% by the end of the period, of which about 20% represents high-technology goods.

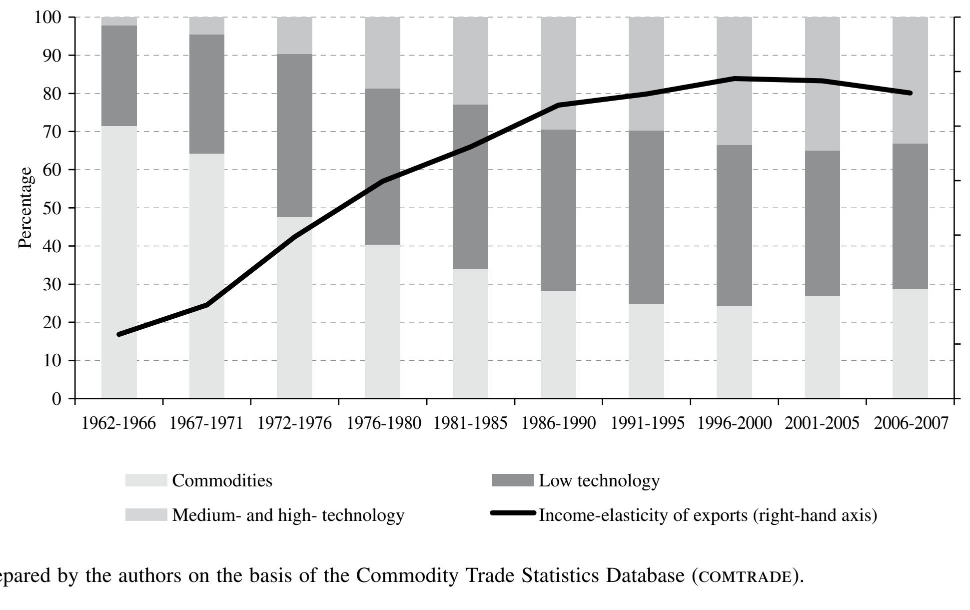
To summarize, figures 1 and 2 show that structural change in the Brazilian economy is not yet complete, so there is still major potential for expanding the production of medium-and, particularly, high-technology goods. Lastly, it should be noted that the black lines in these figures show how changes in income-elasticity have gone hand-in-hand with changes in the sector composition of the economy.[6] Despite the structural change that occurred between 1962 and 1985, figure 1 shows that the Brazilian export basket since 1986 has been based essentially on natural-resource-intensive goods and commodities, whereas medium-and high-technology products have increased their share of imports. In

[6] The estimation of these income elasticities will be presented in the next section.

FIGURE 1

**Brazil: Trend of the sector share of exports**

*(Percentages)*

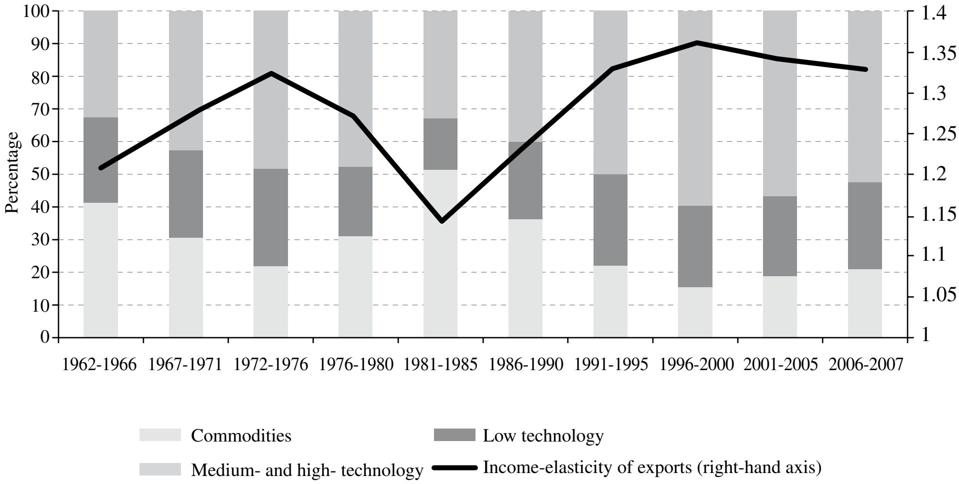



*Source:* Prepared by the authors on the basis of the Commodity Trade Statistics Database (COMTRADE).

FIGURE 2

**Brazil: Trend of the sector share of imports**

*(Percentages)*




*Source:* Prepared by the authors on the basis of the Commodity Trade Statistics Database (COMTRADE).

short, the productive modernization and diversification process that has been unfolding in Brazil since the 1950s and is reflected in the trade pattern, came to a halt in the late 1980s, since when commodity and natural-resource-intensive goods have continued to account for over 50% of total exports. The opposite is true of imports, where high- and medium-technology-intensive products have accounted for over 50% of the total volume imported between 1989 and 2009 (Jayme Jr. and Resende, 2009).

# IV

# Empirical analysis

### 1. Calculation of hypothetical elasticities

In the economic literature, real elasticities have been estimated empirically using various alternative methods. As data relating to certain economies and periods are often incompatible, some studies suggest substitutes for these elasticities, which are also known as hypothetical elasticities. The most frequently used definition is presented by McCombie (1997), who defines "hypothetical income-elasticity" as that which equalizes the observed and theoretical growth rates: $\pi' \equiv x/y$.[7] A second substitute for the elasticities can be obtained in the same way, although following the specifications of the model proposed by Moreno-Brid (2003). Jayme Jr. (2003), estimates an "implicit elasticity", $\pi''$, which is obtained from the co-integration coefficient estimated from the relation $\ln Yt = (1/\pi'') \ln X_t$.

Hypothetical elasticities can thus be expressed as follows:

1) $\pi 1 = x / y$ (Original model)

2) $\pi 2 = (1 - \theta 1 + \theta 2) + \dfrac{\theta 1 x_t - \theta 2 r}{y}$ (Moreno-Brid model)

3) $\pi 3 = 1/\beta$ obtained by the co-integration of $\ln Y_t = \beta \ln X_t$

[7] From this specification, it follows that if and the estimation of are not statistically different, it is impossible to reject the hypothesis that the country's growth rate is balance-of-payments constrained (Santos, Lima and Carvalho, 2005). The estimation of will, in turn, be illustrated in the next subsection.

where $x$, $y$ and $r$ are expressed in the average growth rate for the period analysed; and $\theta 1$ and $\theta 2$ are calculated for the initial period.

To check the appropriateness of these estimations for Brazil, the corresponding elasticities between 1962 and 2007 were calculated.[8] Data on GDP, exports and imports (in dollars) were obtained from the Ipeadata database of the Institute of Applied Economic Research and from the United Nations Commodity Trade Statistics Database (COMTRADE). The values calculated for the hypothetical elasticities are summarized in table 1.

Clearly the results are similar, although the Moreno-Brid model gives slightly higher values than those of the original model —probably because the latter did not include capital flows, which results in the elasticity being underestimated. These estimates provide initial guidance on the expected size of the real elasticities, obtained through the econometric procedures described in the next subsection.

TABLE 1

**Hypothetical elasticities**

| Type | Ipeadata | COMTRADE data |
|---|---|---|
| Original model | 1.112641455 | 1.029140941 |
| Moreno-Brid (2003) model | 1.157374802 | 1.185313709 |
| Implicit elasticity | 1.225173393 | 1.185973163 |

*Source:* Prepared by the authors.
Note: The specifications of the regression model used to calculate the implicit elasticity are the same as those used in the models presented below, and the test statistics were robust.

COMTRADE: United Nations Commodity Trade Statistics Database.
Ipeadata: Economic and financial database maintained by the Institute of Applied Economic Research (IPEA) of Brazil.

## 2. Calculation of real total and sector elasticities

This subsection analyses the methodology used to estimate Brazilian export and import elasticities. By considering the hypothesis, proposed in this study, that the main determinant of elasticities is the technological level of production, the aim was to divide the economy's "total elasticities" between the different sectors of national output, according to their different technological categories. This sector approach —based on a technological classification of traded goods— can be used to test the hypothesis, because the income-elasticities of imports and exports would be higher in more technology-intensive sectors than among low-technology goods and commodities.

The tests performed used sector-level data on Brazilian imports and exports between 1962 and 2007, obtained from the COMTRADE database, according to the two- and three-digit Standard International Trade Classification (SITC). In addition, GDP data were obtained from Ipeadata (values in United States dollars); and the real exchange rate was calculated from the nominal exchange rate provided by the same source, divided by purchasing-power-parity (obtained from the Penn World Table database) during the period analysed.[9] This calculation method proved best suited to the historical analysis of the Brazilian real exchange rate, because, between 1962 and 1990, the usual calculation (*Epf/pd*) produces values very close to zero and hence a loss of explanatory power. The SITC accounts were aggregated as shown in table 2.

Based on this classification, different models were estimated for each of the import and export categories, designated as follows: (i) medium- and high- technology manufactured goods, hereinafter referred to as M1 and X1 for imports and exports, respectively; (ii) low-technology or natural-resource-based manufactures, m2 and x2, respectively; (iii) international commodities, M3 and X3; and (iv) total imports (M0) and exports (X0). The basic equations to be estimated are, therefore, the original import and export demand functions of Thirlwall's Law:

$$\ln M(i) = \beta_0 + \beta_1 \ln R + \beta_2 \ln Y \quad \text{with } i \in (0.3) \quad (12)$$

$$\ln X(i) = \beta_0 + \beta_1 \ln R + \beta_2 \ln Z \quad \text{with } i \in (0.3) \quad (13)$$

where $i \in (0.3)$ represent the different technological categories, M imports, X exports, R the real exchange rate, Y domestic income, and Z foreign income.

— Estimation methodology

A group of series is said to be co-integrated of order p-q [denoted CI(p, q)] if: (i) all of the series are

[8] That period was chosen to ensure that the calculations were compatible with the data used in the tests in the rest of the article.

[9] The same tests were performed using other substitutes for the real exchange rate, such as that used by Hausman, Hwang and Rodrik (2005), r=1/p, and the real exchange rate calculated from the nominal exchange rate multiplied by the quotient between the United States producer price index (PPI) and the Brazilian consumer price index (CPI) (Gouvêa and Lima, 2009). Similar results were obtained in all cases. The choice of the version presented here represents the series that best fits the historical analysis of Brazilian exchange rate, given the recurrent inflationary processes and changes in exchange-rate regimes that occurred during the period under study.

TABLE 2

**Brazil: Aggregation of trade data reported by COMTRADE**

| Commodities | | Natural resource-based manufactures | | | Low technological-intensity manufactures | | Medium technological-intensity manufactures | | High technological-intensity manufactures |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 268 | 12 | 628 | 688 | 611 | 692 | 781 | 721 | 716 |
| 11 | 271 | 14 | 633 | 689 | 612 | 693 | 782 | 722 | 718 |
| 22 | 273 | 23 | 634 | | 613 | 694 | 783 | 723 | 751 |
| 25 | 274 | 24 | 635 | | 651 | 695 | 784 | 724 | 752 |
| 34 | 277 | 35 | 641 | | 652 | 696 | 785 | 725 | 759 |
| 36 | 278 | 37 | 281 | | 654 | 697 | 266 | 726 | 761 |
| 41 | 291 | 46 | 282 | | 655 | 699 | 267 | 727 | 764 |
| 42 | 292 | 47 | 286 | | 656 | 821 | 512 | 728 | 771 |
| 43 | 322 | 48 | 287 | | 657 | 893 | 513 | 736 | 774 |
| 44 | 333 | 56 | 288 | | 658 | 894 | 533 | 737 | 776 |
| 45 | 341 | 58 | 289 | | 659 | 895 | 553 | 741 | 778 |
| 54 | 681 | 61 | 323 | | 831 | 897 | 554 | 742 | 524 |
| 57 | 682 | 62 | 334 | | 842 | 898 | 562 | 743 | 541 |
| 71 | 683 | 73 | 335 | | 843 | 899 | 572 | 744 | 712 |
| 72 | 684 | 98 | 411 | | 844 | | 582 | 745 | 792 |
| 74 | 685 | 111 | 511 | | 845 | | 583 | 749 | 871 |
| 75 | 686 | 112 | 514 | | 846 | | 584 | 762 | 874 |
| 81 | 687 | 122 | 515 | | 847 | | 585 | 763 | 881 |
| 91 | | 233 | 516 | | 848 | | 591 | 772 | |
| 121 | | 247 | 522 | | 851 | | 598 | 773 | |
| 211 | | 248 | 523 | | 642 | | 653 | 775 | |
| 212 | | 251 | 531 | | 665 | | 671 | 793 | |
| 222 | | 264 | 532 | | 666 | | 672 | 812 | |
| 223 | | 265 | 551 | | 673 | | 678 | 872 | |
| 232 | | 269 | 592 | | 674 | | 786 | 873 | |
| 244 | | 423 | 661 | | 675 | | 791 | 884 | |
| 245 | | 424 | 662 | | 676 | | 882 | 885 | |
| 246 | | 431 | 663 | | 677 | | 711 | 951 | |
| 261 | | 621 | 664 | | 679 | | 713 | | |
| 263 | | 625 | 667 | | 691 | | 714 | | |

*Source:* Prepared by the authors on the basis of S. Lall, *Competitiveness, Technology and Skills*, Cheltenham, Edward Elgar. Publishing, 2001.
Note: Products classified according to the Standard International Trade Classification (SITC) at the three-digit level.
COMTRADE: United Nations Commodity Trade Statistics Database.

integrated of order p [denoted I(p)], and (ii) a linear combination of them is integrated of order p-q, (q >0). Accordingly, tests were initially performed to identify the stationarity of the series under study. Although the augmented Dickey-Fuller test (ADF) is usually adopted for this purpose, it is highly sensitive to the number of lags in the model and it assumes a lack of autocorrelation and homoscedasticity in the residuals of its equation. Accordingly, in cases where the residuals of the ADF test equation are non-normal, the Phillips-Perron (PP) test, based on a stochastic process MA(1), gives better results.

Annex 1 of this article summarizes the ADF and PP test statistics for one and three lags of the series expressed in terms of levels and first differences. The number of lags was chosen on the basis of the normality criterion for the ADF equation residuals. Consequently, the PP test gives the best results for one interval, whereas the ADF test is more powerful for three lags. As can be seen, the null hypothesis of no-stationarity is accepted for all variables in the study expressed in level terms; but it is rejected for first differences, which confirms that the series being studied are integrated of order 1, or I(1), so the existence of a long-term relation between them can be tested.

The "Johansen procedure" (Enders, 1995) was used to check the co-integration of the series and to estimate its long-term vector, since this is an easier method to apply (in a single stage); it also avoids spurious regressions and makes it possible to estimate consistent parameters for the model. The specification of the models to be tested was chosen on the basis of minimizing the information criteria most widely used in the literature, namely the Schwartz Information Criterion (SIC); the Akaike Information Criterion (AIQ); the Hannan Quinn Information Criterion (HQC), and the Final Prediction Error (FPE). These criteria were estimated using a maximum number of lags in the sixth interval owing to the small number of degrees of freedom in the models; and their results are summarized in annexes 2 and 3. The trace statistics results (indicating the number of co-integration vectors between the series) are reported for each model in annexes 6 and 7; and the normality tests (autocorrelation and heteroscadasticity) of the residuals are shown in annexes 4 and 5, for each of the specifications posited as a long-term relation.

The results for the co-integration vectors are presented in the next subsection. The following specifications were estimated for all models: (i) without constant; (ii) with trend; and (iii) with constant and co-integration vector. Nonetheless, only the results for the model with the constant in the co-integration vector are reported, since these produced the most robust test results.

A vector-error-correction (VEC) model was developed to identify short-term relations and causality between the variables. Given the structure of the VEC to be estimated, and unlike the vector autoregression model (VAR) from which it is derived, ordinary least squares (OLS) estimation is not appropriate, because cross-equation restrictions have to be imposed. Although the results are not shown, they will be fundamental in analysing the repercussions of innovations in the system

Two tools were used to analyse innovations: impulse-response functions and decomposition of the forecast error variance. The first of these makes it possible to simulate the behaviour of the n variables of the model through time, in response to a shock in the residuals of each of the variables under analysis. This is possible thanks to the partial correlation that exists between the residuals of each of the series in the model, although it is assumed that any change in these residuals will be caused by exogenous shocks. Given the short convergence interval of the series, the graphs of the impulse-response functions cover a period of just 10 years. The second tool, the variance decomposition, complements the first, by making it possible to dynamically analyse the behaviour of the variables subject to shocks; and it shows the weight of the residuals in the final prediction error of the models for each period. Given the annual interval of the data and their relatively rapid convergence, selected results for the first 20 periods will be shown.

### 3. Results

(a) *Income-elasticities of imports*

Initially, the following long-term relation was used: $m(i) = r + y$ (lowercase variables are logarithms). As the information criteria diverged in terms of the ideal model specification for each import category, all of the models suggested for the criteria in question were estimated. Annex 2 shows the ideal number of lags (denoted by "$p$") in the VAR for each criterion. As can be seen, for the most generic model for Brazilian imports as a whole (M0), the ideal varied between one and five lags; so tests were conducted for normality, autocorrelation and heteroscedasticity in the residuals of these estimations (see annex 4). The choice of final specification for the VEC model took account of all of the tests performed for each import category. To ensure standardization and comparable elasticities for each import category, the 3-lag model was adopted ($p=3$). Although the analysis of the foregoing tests can, in some cases, indicate other specifications as the best fit, the fact that the estimated co-integration vector was not very sensitive to the different specifications justifies the decision to standardize the co-integration vectors described. As shown in annex 6, the trace statistics show the existence of at least one co-integration relation between the variables, for all import categories. The normalized co-integration vectors are shown in table 3.

Although interpreting the coefficients of co-integration vectors is always hazardous, the variables were significant in all models, and the coefficients showed that imported goods of high/medium and low technology (M1 and M2) have similar income-elasticities. Only in the case of commodities (M3) is there a significant difference in level, which is compatible with the theoretical paradigm that indicates a lower income-elasticity of demand in the case of commodities. These results might suggest a relative weakness in domestic industry, even in low-technology goods, since income growth is promoting more than proportional increases in the demand for these foreign goods. The estimated elasticities are also fully compatible with the hypothetical ones, calculated previously.

To guarantee the robustness of the parameters, new autoregressive vectors were estimated for each technological category, although restrictions were imposed on the value of the income-elasticities to make them equal to those of the other categories. This made it possible to conduct likelihood-ratio tests[10] for each of the vectors

[10] The likelihood ratio test is conducted by comparing models with and without the restrictions that are being tested. Accordingly, the

TABLE 3

**Co-integration vector**

| Vector | *m* | *y* | *r* | Constant |
|---|---|---|---|---|
| *Income-elasticity of M0* | | | | |
| Coefficient | 1 | -1.39057 | 1.255712 | 12.09121 |
| SD | | 0.104241 | 0.10314 | |
| Alpha | -0.05863 | 0.176316 | -0.2299 | |
| *Income-elasticity of M1* | | | | |
| Coefficient | 1 | -1.45359 | 2.394258 | 13.35274 |
| SD | | 0.101666 | 0.097003 | |
| Alpha | -0.06075 | 0.074304 | -0.12344 | |
| *Income-elasticity of M2* | | | | |
| Coefficient | 1 | -1.47117 | 1.681609 | 15.40699 |
| SD | | 0.097724 | 0.009242 | |
| Alpha | -0.05752 | -0.2162 | 0.093195 | |
| *Income-elasticity of M3* | | | | |
| Coefficient | 1 | -0.84967 | -1.79363 | 1.421589 |
| SD | | 0.116154 | 0.012731 | |
| Alpha | -1.31621 | -0.18706 | -0.0016 | |

*Source:* Prepared by the authors.
Note: 3 lags.

SD: Standard deviation.
Alpha: Speed-of-adjustment coefficient
M0: Total imports
M1: Imports of medium- and high-technology manufactures
M2: Imports of low-technology or natural-resource-based manufactures
M3: Imports of international commodities

estimated, to verify their statistical "singularity" — in other words, guarantee the statistical difference of the elasticities estimated for each technological category. The results of these tests are shown in annex 8. Nonetheless, the *p*-value of the test shows that the null hypothesis of statistical equality between the parameters is not rejected merely by comparing the income-elasticities of imports of high-technology and low-technology manufactured goods (M1 and M2, respectively). In the other cases, parameter equality is rejected at the 5% significance level, thereby confirming different income-elasticities for each level of technological intensity.

As the purpose of this article is to analyse the income-elasticities, the coefficients found for the price-elasticities will be highlighted (effects of the real exchange rate). Nonetheless, these show a decreasing relation with the technological level of traded goods (the sign of the coefficients is reversed). A notable result is the fact that the sign of this elasticity is contrary to expectations only for the commodities vector. Although unusual, this result is broadly consistent with the data and with all of the alternative models estimated: VAR(0), VAR(1), OLS(1). One possible explanation for this behaviour of the parameter is that exchange-rate devaluation could elicit an increase in commodity imports, since these products are needed to produce tradable goods. Another possible hypothesis is that the use of import values is price-biased, so an import volume index might change the result of this parameter. Finding an explanation for this behaviour provides an interesting agenda for future research.

Figure 3 shows the impulse-response functions for the aggregate imports model (M0).[11] The analysis of these innovations makes it possible to visualize the short-run relations between the variables and, thus, also establish their causality relations. It is also possible, along with the variance decomposition, to analyse the dynamic mechanisms that propagate the effects of exogenous shocks on the variables of each model.

Figure 3 shows that an exogenous one-standard-deviation shock to imports has only minor repercussions on the other variables of the model, displaying a positive relation with income and a negative relation with the real exchange rate. Such a shock is almost completely absorbed in the first two periods. In contrast, a real-exchange-rate shock (second column) has a one-period lagged effect, but a large (negative) repercussion on imports and a relatively smaller (positive) one on income. The chaining of the relations between the variables dampens the propagation of the effects of the shock, which are fully dissipated only in the eighth period. An exogenous shock to income (third column) does not have a contemporaneous effect on imports, which only respond (positively) in the subsequent period. In contrast, the real exchange rate has an immediate impact. These effects disappear in the third period in a direct convergence process.

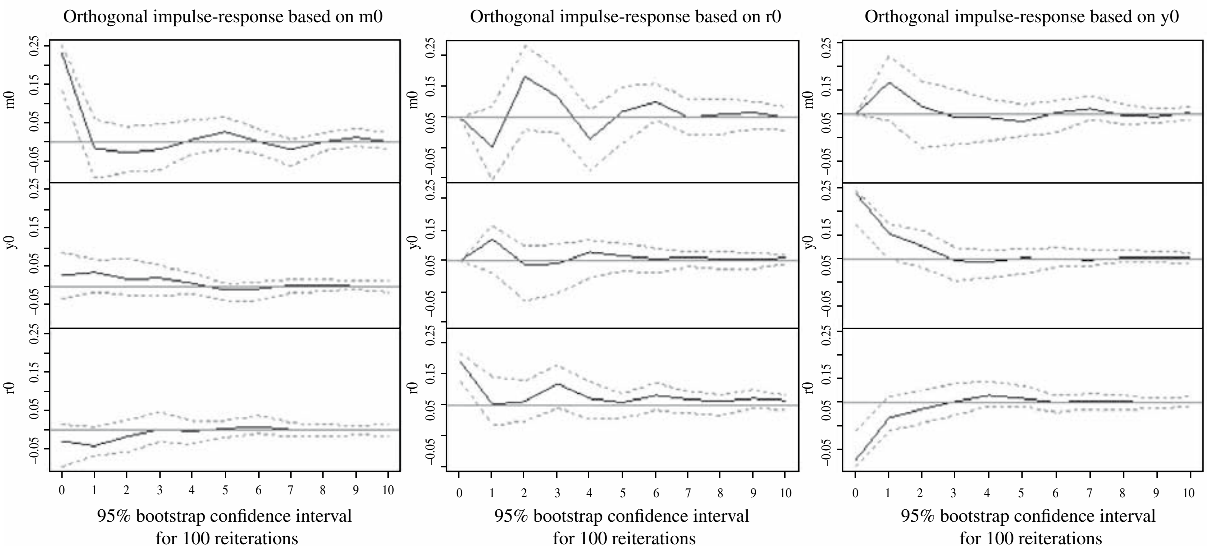
Table 4 shows the results for the analysis of the variance decomposition. Although most of the final prediction error for *m* is due to its own innovations, these lose relative importance through time, both for *r* (one lag) and for *y* (two lags). In the case of *y*, whereas in the current period 71% of its variance stems from the

null hypothesis is that each of the parameters in the test is equal to the predefined value. The test statistic compares the value obtained with that of a chi-squared distribution with *(p-r)rl* degrees of freedom, where *r* is the total number of verified co-integration relations, *p* is the number of lines of the constraint matrix on the betas (equal to 1), and *rl* is the number of columns of that matrix (equal to the number of parameters in the model used).

[11] The grey lines in the impulse-response graphs represent the 95% confidence interval generated from a bootstrap procedure with 100 reiterations.

FIGURE 3

**Brazil: Impulse-response functions for imports**




*Source:* Prepared by the authors.

variation of *r* and just 25% from its own innovations, over 10 periods the proportions change to 58% and 31%, respectively, leaving just a residual part for *m*. The final prediction errors for *r* stem mainly from changes in the real exchange rate itself. Nonetheless, as from the subsequent period there is a significant increase in the relative weight of *m*, which maintains a 12% share in exchange-rate errors through time, whereas *y* is important continuously.

(b) *Elasticity of exports*

The following long-term relation is proposed for exports: $x_{(i)} = r + z$. As was done in the case of imports, tests were performed to select the model (see annex 3) — tests of normality, heteroscedasticity and autocorrelation of the residuals of the estimated models (annex 5), and co-integration tests (annex 7). On the basis of the information thus obtained, the ideal model for all cases would be between the two- and three-lag specifications. Given the similarity of the estimated coefficients in the two models, and to make the analyses between the import and export elasticities compatible, the three-lag specification was chosen. The normalized co-integration vectors for each export category are shown in table 5.

Bearing in mind the hazards of interpreting coefficients in co-integration vectors, the estimated income-elasticity of exports appears to be an increasing function of the technology incorporated in the exported goods. Furthermore, the demand for Brazilian medium- and high-technology goods responds strongly to changes in global income, whereas commodities tend to be income-inelastic. With the disclaimers mentioned above concerning the analysis of co-integration coefficients,

TABLE 4

**Variance decomposition-elasticity of imports**

| Model | Period | Innovations | | |
|---|---|---|---|---|
| | | *m* | *r* | *y* |
| *m* | 1 | 1.00 | 0.00 | 0.00 |
| | 2 | 0.88 | 0.12 | 0.00 |
| | 3 | 0.82 | 0.11 | 0.07 |
| | 4 | 0.81 | 0.12 | 0.07 |
| | 5 | 0.80 | 0.12 | 0.09 |
| | 10 | 0.79 | 0.12 | 0.09 |
| | 20 | 0.79 | 0.12 | 0.10 |
| *r* | 1 | 0.05 | 0.95 | 0.00 |
| | 2 | 0.12 | 0.87 | 0.01 |
| | 3 | 0.13 | 0.86 | 0.01 |
| | 4 | 0.12 | 0.83 | 0.05 |
| | 5 | 0.12 | 0.83 | 0.06 |
| | 10 | 0.12 | 0.81 | 0.07 |
| | 20 | 0.12 | 0.80 | 0.08 |
| *y* | 1 | 0.04 | 0.71 | 0.25 |
| | 2 | 0.08 | 0.60 | 0.32 |
| | 3 | 0.09 | 0.60 | 0.31 |
| | 4 | 0.10 | 0.59 | 0.31 |
| | 5 | 0.10 | 0.59 | 0.31 |
| | 10 | 0.11 | 0.58 | 0.31 |
| | 20 | 0.11 | 0.58 | 0.31 |

*Source:* Prepared by the authors.

TABLE 5

**Co-integration vector**

| Income-elasticity of X0 | | | | |
|---|---|---|---|---|
| Vector | *x* | *r* | *z* | Constant |
| Coefficient | 1 | -0.68115 | -1.14414 | 18.33868 |
| SD | | 0.084565 | 0.035604 | |
| Alpha | -0.02912 | 0.672952 | 0.047245 | |
| *Income-elasticity of X1* | | | | |
| Coefficient | 1 | -2.01321 | -1.9767 | 46.47997 |
| SD | | 0.084257 | 0.036008 | |
| Alpha | 0.047675 | 0.213471 | 0.020072 | |
| *Income-elasticity of X2* | | | | |
| Coefficient | 1 | -0.96508 | -1.28721 | 23.97728 |
| SD | | 0.0869 | 0.00141 | |
| Alpha | 0.002171 | 0.297678 | 0.045457 | |
| *Income-elasticity of X3* | | | | |
| Coefficient | 1 | -0.80188 | -0.74934 | 7.619842 |
| SD | | 0.082212 | 0.033953 | |
| Alpha | 0.062179 | 0.599276 | 0.020581 | |

*Source:* Prepared by the authors.
Note: 3 lags.

SD: standard deviation.
Alpha: Speed-of-adjustment coefficient
X0: Total exports
X1: Exports of medium- and high-technology manufactures
X2: Exports of low technology or natural-resource-based manufactures
X3: Exports of international commodities

in particular because the co-integration vector does not define a causality relation between the variables, this result raises important issues, especially in view of the large differences found between the elasticities of each category of goods. Annex 9 contains the results of the likelihood-ratio tests for the income-elasticities of exports, which show that the elasticity levels for each sector are statistically different: the null hypothesis that the coefficients are equal is rejected (in the case low-technology manufactured goods (X2), the income-elasticity differs from the others only at a 10% significance level).

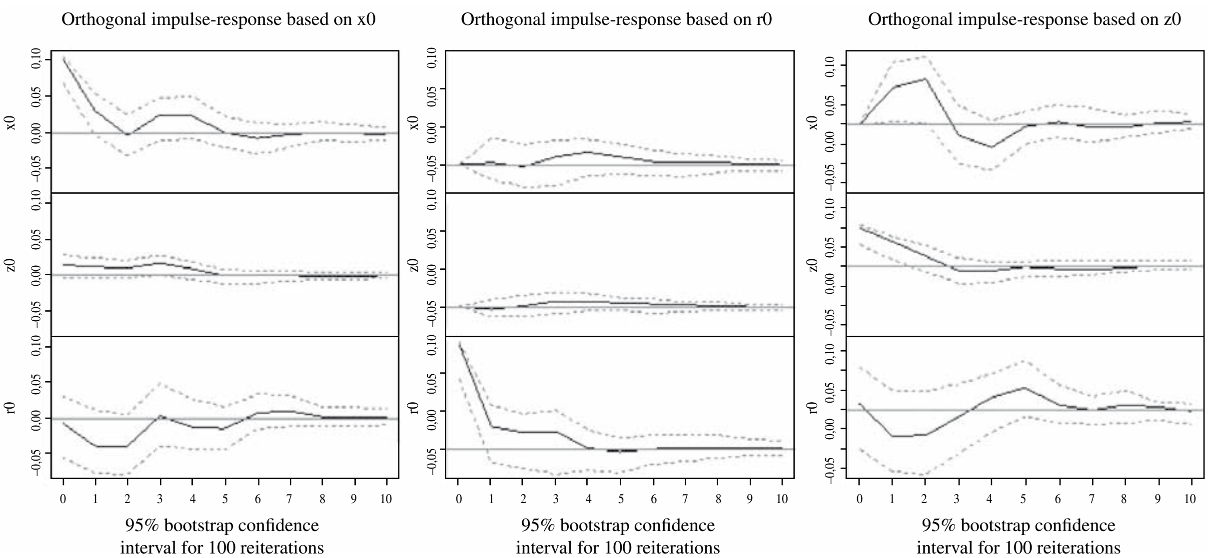
The estimated results suggest that, if the external constraint posited by Thirlwall's Law in any of its versions is valid, an export basket that is biased towards goods with higher technological content could support higher GDP growth rates than one based particularly on commodities, as is the case in Brazil.

In relation to the *price*-elasticities of demand for exports, the same pattern is seen as in the case of imports: the elasticities in question are directly proportional to the level of technology incorporated in the products. This result stands in contrast to the different *income*-elasticities of imports and exports. The impulse-response functions for aggregate exports (X0) are shown in figure 4.

Figure 4 shows that an exogenous shock to exports has an immediate, but relatively insignificant, effect both on external income (positive) and the real exchange rate

FIGURE 4

**Brazil: Impulse-response functions for exports**




*Source:* Prepared by the authors.

(negative). The contrasting and unlagged behaviour of *x* and *r* needs to be emphasized. Variations in the real exchange rate (second column) do not have a significant impact on the other variables. This result is very different from that obtained for imports and shows that the exchange rate behaves asymmetrically, affecting imports more than exports. Moreover, an exogenous shock to external income gradually tends to increase exports, in a proportion peaking at 1:1 in the second period, after which the effect starts to fade. The exchange rate moves in the opposite direction to exports, appreciating as exports grow and depreciating as they decline.

Table 6 shows the variance decomposition for selected periods of the model. The results show the major weight of *z* in the variation of *x* as from the third period, following a shock to *x*. As noted above, variations in the real exchange rate have virtually no effect on the change in exports. The exchange-rate variation, albeit predominantly affected by its own innovation, with time responds to the small variations it caused in *x*. The variance of exports gradually gains importance as an explanatory factor of the final prediction errors for *z*.

TABLE 6

**Variance decomposition-elasticity of exports**

| Model | Period | Innovations | | |
|---|---|---|---|---|
| | | *x* | *r* | *z* |
| *x* | 1 | 1.00 | 0.00 | 0.00 |
| | 2 | 0.89 | 0.00 | 0.11 |
| | 3 | 0.76 | 0.00 | 0.24 |
| | 4 | 0.76 | 0.01 | 0.23 |
| | 5 | 0.73 | 0.02 | 0.25 |
| | 10 | 0.73 | 0.02 | 0.25 |
| | 20 | 0.73 | 0.02 | 0.25 |
| *r* | 1 | 0.00 | 1.00 | 0.00 |
| | 2 | 0.07 | 0.90 | 0.03 |
| | 3 | 0.12 | 0.82 | 0.06 |
| | 4 | 0.11 | 0.82 | 0.06 |
| | 5 | 0.12 | 0.81 | 0.07 |
| | 10 | 0.13 | 0.79 | 0.09 |
| | 20 | 0.13 | 0.78 | 0.09 |
| *z* | 1 | 0.12 | 0.00 | 0.88 |
| | 2 | 0.14 | 0.00 | 0.86 |
| | 3 | 0.16 | 0.00 | 0.83 |
| | 4 | 0.24 | 0.02 | 0.74 |
| | 5 | 0.25 | 0.04 | 0.71 |
| | 10 | 0.24 | 0.05 | 0.71 |
| | 20 | 0.24 | 0.05 | 0.71 |

*Source:* Prepared by the authors.

(c) *Trend of Brazilian elasticities*

According to the original version of Thirlwall's Law ($y = \varepsilon z/\pi$), the greater the income elasticity of demand for a country's exports and the smaller the income-elasticity of its imports, the higher is the growth rate that is compatible with long-term balance-of-payments equilibrium. The tests reported in this study show that the greater the technological content of domestic output, the higher is the income-elasticity of exports and the lower is the income-elasticity of imports. This means lower growth rates compatible with balance-of-payments equilibrium and less easing of the external constraint on growth.

A simple exercise that clearly illustrates this point consists of simulating the trend of Brazilian GDP growth rates that are compatible with external equilibrium, based on the previously estimated elasticities. The latter are used to verify hypothetical GDP growth rates for Brazil, under three different external-trade patterns: (i) a country specialized in high-technology exports and low-technology and commodity imports; (ii) a country specialized in exports of low-technology manufactured goods and imports of all types of goods; and (iii) a country specialized in exports of commodities and imports of all types of manufactures. The average annual growth rate would be on the order of 6.75% in the first case; 3.67% in the second case and 2.03% in the last. In contrast, the actual Brazilian trade pattern produces average annual growth of 3.26%, which shows that the country is closer to the second pattern described above.

The last pattern is very similar to the average growth rates actually delivered by Brazilian GDP in the 1990s, which is unsurprising given the way the country participated in international trade. Moreover, the growth rates that are compatible with balance-of-payments equilibrium differ sharply according to the trade structure adopted; and specialization in exports of high-technology goods clearly relaxes the external constraint on GDP growth.

As proposed by Gouvêa and Lima (2009), the elasticities estimated for the different technology levels can be used to analyse how Brazilian trade elasticities have evolved from year to year (see figure 5). The income-elasticity of imports is practically unchanged from its 1960 level at the end of the period, having risen from 1.2% in 1962 to just 1.3% in 2007. The trend of imports shows a tendency for the income-elasticity to rise at the start of the period, which is consistent with greater need for capital goods imports; but this is reversed in the ensuing period as the import-substitution industrialization model consolidates. The sharp fall in the 1980s reflects the balance-of-payments problems that were being faced by Brazil at that time. As from 1990, the situation is reversed again as income-elasticity climbs back to its initial level.

An evaluation of the trend of the income-elasticity of *exports* makes the picture much clearer. From 1962 until the early 1990s, the elasticity in question rose steadily, suggesting a steady structural shift towards higher-technology-intensive sectors, with exports upgrading particularly from commodities to low- and medium- technology manufactured products. In 1990, the rise in the income-elasticity of exports is interrupted, and it remains broadly constant thereafter (rising from 1.34% in 1990 to 1.36% in 2007).

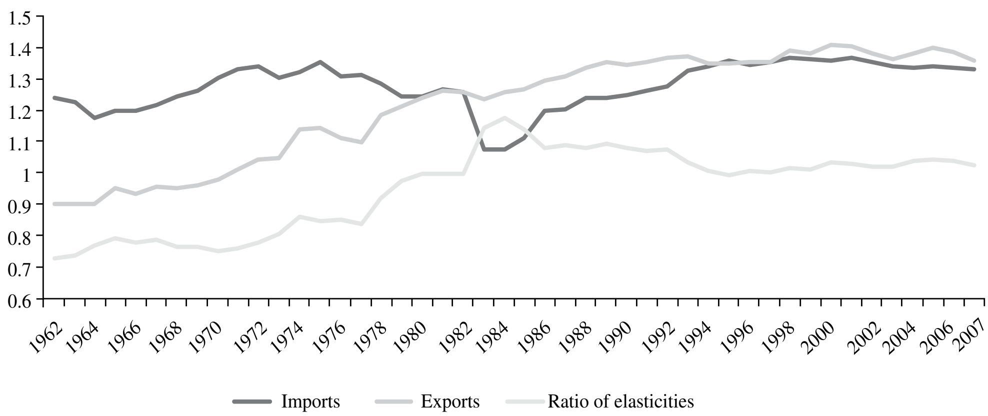
In figure 6, these weighted elasticities are used to calculate the GDP growth rate that is compatible with balance of payments stability (Thirlwall's Law). As a counterpoint to the estimated GDP growth, the actual growth of Brazil's GDP, calculated by the Brazilian Geographical and Statistical Institute (IBGE) is also shown.

Figure 6 shows that annual GDP growth calculated according to Thirlwall's Law, using weighted elasticities, is very similar to the observed behaviour of GDP. Although estimated GDP growth is higher than the growth actually recorded, an analysis of the corresponding trend lines reveals a high degree of similarity. This situation corroborates not only the validity of Thirlwall's Law but also the sector elasticities estimated in this study.[12] It also shows that calculating weighted elasticities is appropriate for analysing the trend of the income-elasticities of imports and exports.

[12] The restriction tests conducted by Gouvêa and Lima (2009) confirm the statistical validity of the Multi-sector Thirlwall's Law for estimating effective GDP growth.

FIGURE 5

**Brazil: Trend of weighted elasticities**

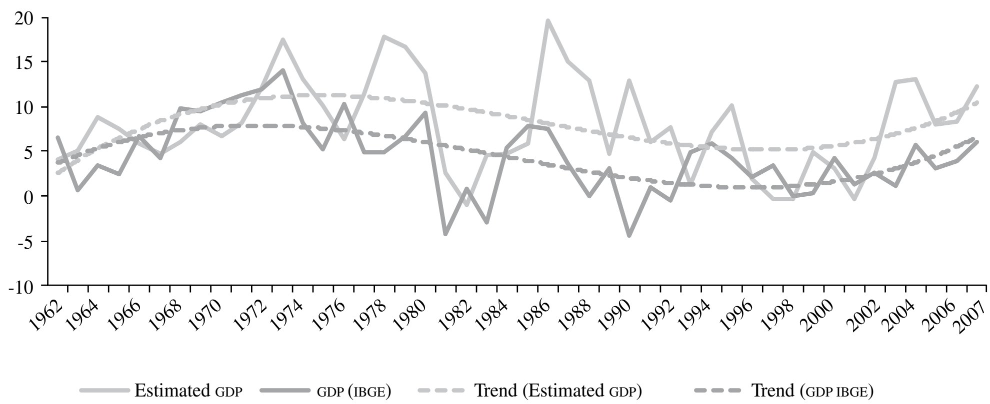



*Source:* Prepared by the authors.

FIGURE 6

**Brazil: Actual and estimated GDP growth**

*(Percentages)*




*Source:* Prepared by the authors.

# V
# Conclusions

This article has attempted to show that structural change favouring sectors that produce technology-intensive goods eases the external constraint on growth by changing the income-elasticities of imports and exports.

Thirlwall's Law is used to show that the growth rate of the domestic economy is ultimately determined by the income-elasticities of demand for imports and for exports. Higher growth rates are associated with a low income-elasticity of imports and a high income-elasticity of exports. Nonetheless, the literature usually treats these variables as exogenous. Araujo and Lima (2007) and Gouvêa and Lima (2009) show that changes in the productive structure of the economy cause changes in the elasticities, which are directly determined via the level of technological development embodied in domestic production. According to Jayme Jr. and Resende (2009), developed countries tend to participate in international trade as exporters of medium- and high-technology manufactured goods and as importers of commodities and low-technology manufactures —the opposite trade pattern to that seen in peripheral countries such as Brazil.

To corroborate that analysis, this study conducted a series of empirical tests to estimate the income-elasticities of technologically different categories of Brazilian tradable goods, based on an adaptation of the classification proposed by Lall (2001), in which the data were reclassified in three groups: (i) commodities; (ii) goods of low technological content and natural-resource-based manufactures; and (iii) medium- and high-technology goods.

The test results corroborate the theoretical framework presented, confirming the existence of an increasing positive relation between the technological level of exports and income-elasticity, and the same for imports. This shows that higher growth rates are obtained by participating in world trade as an exporter of medium- and high-technology goods (high income-elasticity) and as an importer of low-technology goods (commodities, low income-elasticity) which is precisely the pattern identified for OECD countries by Jayme Jr. and Resende (2009). Accordingly, a structural shift is needed to increase the GDP share of sectors producing goods with high technological content.

A separate analysis of the trend of Brazilian elasticities showed the pattern of imports remaining broadly constant, whereas the profile of exports evolved continuously until 1990 (reflecting an increase in the income-elasticity of exports) but not afterwards. The subsequent stagnation of the income-elasticity of exports poses an obstacle to the structural change needed to maintain higher growth rates.

The conclusions stress the importance of technological development as a way to influence the elasticities and thus ease the external constraint. Taking as a basic premise the need to keep demand growing to fuel faster output growth, it was shown that the incorporation of technology in production (or an increase in the share of higher-technology sectors in national output) is essential for sustaining this process and breaking free from balance-of-payments problems.

*(Original: Portuguese)*

**ANNEX 1**

Unit root tests

| Variable (Natural logarithm) | Deterministic terms | ADF p = 1 | ADF p = 3 | PP p = 1 | PP p = 3 | Critical values 1% | 5% | 10% |
|---|---|---|---|---|---|---|---|---|
| Natural logarithm of exports (X0) | Constant | -1.0073 | -1.0856 | -0.9815 | -0.9713 | -3.6 | -2.9 | -2.6 |
| | Constant, trend | -1.702 | -1.9001 | -1.4098 | -1.4612 | -4.2 | -3.5 | -3.2 |
| | Without constant or trend | 3.1482 | 2.2059 | - | - | -2.6 | -2 | -1.6 |
| *p*-value Δ natural logarithm of exports (ΔX0) | | -4.5247 | -1.9133 | -4.7894 | -4.6535 | -3.6 | -2.9 | -2.6 |
| Natural logarithm of medium- and high-technology exports (X1) | Constant | -3.3928 | -1.6306 | -2.4835 | -2.4958 | -3.6 | -2.9 | -2.6 |
| | Constant, trend | -1.7285 | -1.3239 | -1.0913 | -1.0937 | -4.2 | -3.5 | -3.2 |
| | Without constant or trend | 3.4086 | 1.4461 | - | - | -2.6 | -2 | -1.6 |
| *p*-value Δ natural logarithm of exports (ΔX1) | | -4.0831 | -2.1703 | -7.5037 | -6.4918 | -3.6 | -2.9 | -2.6 |
| Natural logarithm of low-technology and natural-resource-based manufactured exports | Constant | -1.5463 | -1.4435 | -1.7223 | -1.7207 | -3.6 | -2.9 | -2.6 |
| | Constant, trend | -1.9023 | -1.5597 | -1.4776 | -1.4891 | -4.2 | -3.5 | -3.2 |
| | Without constant or trend | 2.4001 | 2.1264 | - | - | -2.6 | -2 | -1.6 |
| *p*-value Δ natural logarithm of exports (ΔX2) | | -4.552 | -2.508 | -4.1562 | -3.9967 | -3.6 | -2.9 | -2.6 |
| Natural logarithm of commodity exports (X3) | Constant | -0.1897 | -0.388 | -0.1508 | -0.1512 | -3.6 | -2.9 | -2.6 |
| | Constant, trend | -1.5201 | -1.8119 | -1.507 | -1.5691 | -4.2 | -3.5 | -3.2 |
| | Without constant or trend | 3.4335 | 2.3967 | - | - | -2.6 | -2 | -1.6 |
| *p*-value Δ natural logarithm of exports (ΔX3) | | -4.7922 | -1.6117 | -6.2379 | -6.1631 | -3.6 | -2.9 | -2.6 |
| Natural logarithm of imports (M0) | Constant | -0.8408 | -1.6391 | -0.7095 | -0.68 | -3.6 | -2.9 | -2.6 |
| | Constant, trend | -2.3734 | -2.2357 | -2.3846 | -2.3635 | -4.2 | -3.5 | -3.2 |
| | Without constant or trend | 2.8086 | 3.0893 | - | - | -2.6 | -2 | -1.6 |
| *p*-value Δ natural logarithm of imports (ΔM) | | -5.4268 | -3.4345 | -6.5959 | -6.5873 | -3.6 | -2.9 | -2.6 |
| Natural logarithm of medium- and high-technology imports (M1) | Constant | -1.0652 | -1.9014 | -0.5777 | -0.5922 | -3.6 | -2.9 | -2.6 |
| | Constant, trend | -2.2985 | -3.1387 | -1.9597 | -2.1476 | -4.2 | -3.5 | -3.2 |
| | Without constant or trend | 2.8889 | 2.6019 | - | - | -2.6 | -2 | -1.6 |
| *p*-value Δ natural logarithm of imports (ΔM1) | | -4.5227 | -2.7473 | -5.3069 | -5.2477 | -3.6 | -2.9 | -2.6 |
| Natural logarithm of low technology and natural-resource-based manufactured imports (M2) | Constant | -0.6095 | -1.448 | -0.6711 | -0.6522 | -3.6 | -2.9 | -2.6 |
| | Constant, trend | -2.6197 | -3.0147 | -2.4366 | -2.4935 | -4.2 | -3.5 | -3.2 |
| | Without constant or trend | 2.3578 | 2.4985 | - | - | -2.6 | -2 | -1.6 |
| *p*-value Δ natural logarithm of imports (ΔM2) | | -5.0339 | -3.2973 | -5.9736 | -5.8637 | -3.6 | -2.9 | -2.6 |
| Natural logarithm of commodity imports (M3) | Constant | -0.9294 | -1.2343 | -0.9105 | -0.8048 | -3.6 | -2.9 | -2.6 |
| | Constant, trend | -2.1366 | -1.4751 | -2.2766 | -2.1473 | -4.2 | -3.5 | -3.2 |
| | Without constant or trend | 1.9646 | 2.641 | - | - | -2.6 | -2 | -1.6 |
| *p*-value Δ natural logarithm of imports (ΔM3) | | -5.8363 | -3.7605 | -7.0592 | -7.2128 | -3.6 | -2.9 | -2.6 |
| Natural logarithm of income (*y*) | Constant | -1.2455 | -1.6134 | -1.1976 | -1.1781 | -3.6 | -2.9 | -2.6 |
| | Constant, trend | -2.3293 | -2.5615 | -1.6692 | -1.8223 | -4.2 | -3.5 | -3.2 |
| | Without constant or trend | -2.5966 | 2.1484 | - | - | -2.6 | -2 | -1.6 |
| *p*-value Δ natural logarithm of income (Δ*y*) | | -3.4504 | -3.3783 | -4.2903 | -4.2895 | -3.6 | -2.9 | -2.6 |
| Natural logarithm of the real exchange rate (*r*) | Constant | -1.8862 | -2.2197 | -1.7124 | -1.8856 | -3.6 | -2.9 | -2.6 |
| | Constant, trend | -2.1321 | -2.528 | -1.5413 | -1.813 | -4.2 | -3.5 | -3.2 |
| | Without constant or trend | -1.073 | -1.1633 | - | - | -2.6 | -2 | -1.6 |
| *p*-value Δ natural logarithm of the real exchange rate (Δ*r*) | | -3.5253 | -3.348 | -4.7811 | -4.901 | -3.6 | -2.9 | -2.6 |
| Natural logarithm of world income (*z*) | Constant | -1.2938 | -1.5925 | -1.9428 | -1.7883 | -3.6 | -2.9 | -2.6 |
| | Constant, trend | -1.7455 | -1.396 | -0.9759 | -1.0934 | -4.2 | -3.5 | -3.2 |
| | Without constant or trend | 2.8775 | 2.5457 | - | - | -2.6 | -2 | -1.6 |
| *p*-value Δ natural logarithm of world income (Δ*z*) | | -3.4193 | -2.0366 | -3.3719 | -3.4036 | -3.6 | -2.9 | -2.6 |

*Source:* Prepared by the authors.
Note 1: The critical values of the ADF tests are those reported in D. Dickey and W.A. Fuller "Likelihood ratio statistics for autoregressive time series with a unit root", *Econometrica*, vol. 49, No. 4, New York, Econometric Society, June 1981; and J..D. Hamilton, *Time Series Analysis*, Princeton, Princeton University Press, 1994.
Note 2: H0 (Null hypothesis of the tests: existence of a unit root).
Note 3: The values reported refer to the indicated statistic.

PP: Phillips-Perron test.
MBPP: Commodity- based manufactures.
Δ: difference or variation.
X0: Total exports.
X1: Exports of medium- and high-technology manufactures.
X2: Exports of low-technology or natural-resource-based manufactures.
X3: Exports of international commodities.
M0: Total imports.
M1: Imports of medium- and high-technology manufactures.
M2: Imports of low-technology or natural-resource-based manufactures.
M3: Imports of international commodities.

ANNEX 2

## Choice of the order of the VAR

| Lag | AIC(*p*) | HQC(*p*) | SIC(*p*) | FPE(*p*) |
|---|---|---|---|---|
| *Income-elasticity of X0* | | | | |
| Trend | 2 | 2 | 2 | 2 |
| Intercept | 4 | 2 | 2 | 2 |
| Trend and intercept | 2 | 2 | 2 | 2 |
| None | 2 | 2 | 2 | 2 |
| Choice | 3 lags | | | |
| *Income-elasticity of X1* | | | | |
| Trend | 2 | 2 | 2 | 2 |
| Intercept | 2 | 2 | 2 | 2 |
| Trend and intercept | 3 | 2 | 2 | 2 |
| None | 2 | 2 | 2 | 2 |
| Choice | 3 lags | | | |
| *Income-elasticity of X2* | | | | |
| Trend | 2 | 2 | 2 | 2 |
| Intercept | 2 | 2 | 2 | 2 |
| Trend and intercept | 2 | 2 | 2 | 2 |
| None | 2 | 2 | 2 | 2 |
| Choice | 3 lags | | | |
| *Income-elasticity of X3* | | | | |
| Trend | 6 | 6 | 1 | 6 |
| Intercept | 6 | 6 | 1 | 6 |
| Trend and intercept | 6 | 5 | 1 | 5 |
| None | 6 | 2 | 1 | 6 |
| Choice | 3 lags | | | |

*Source:* Prepared by the authors.
Note: Maximum number of lags = 6.

VAR: Vector autoregression model.
AIC: Akaike information criterion.
HQC: Hannan Quinn information criterion.
SIC: Schwarz information criterion.
FPE: Final prediction error.
X0: Total exports.
X1: Exports of medium- and high-technology manufactures.
X2: Exports of low-technology or natural-resource-based manufactures.
X3: Exports of international commodities.

ANNEX 3

## Choice of the order of the VAR

| Lag | AIC(*p*) | HQC(*p*) | SIC(*p*) | FPE(*p*) |
|---|---|---|---|---|
| *Income-elasticity of M0* | | | | |
| Trend | 5 | 1 | 1 | 2 |
| Intercept | 5 | 2 | 1 | 2 |
| Trend and intercept | 5 | 2 | 1 | 2 |
| None | 5 | 1 | 1 | 2 |
| Choice | 3 lags | | | |
| *Income-elasticity of M1* | | | | |
| Trend | 5 | 2 | 1 | 5 |
| Intercept | 4 | 2 | 1 | 4 |
| Trend and intercept | 6 | 4 | 1 | 4 |
| None | 4 | 2 | 1 | 4 |
| Choice | 3 lags | | | |
| *Income-elasticity of M2* | | | | |
| Trend | 5 | 1 | 1 | 5 |
| Intercept | 5 | 5 | 1 | 5 |
| Trend and intercept | 5 | 5 | 1 | 5 |
| None | 5 | 1 | 1 | 5 |
| Choice | 3 lags | | | |
| *Income-elasticity of M3* | | | | |
| Trend | 5 | 1 | 1 | 2 |
| Intercept | 5 | 2 | 1 | 2 |
| Trend and intercept | 5 | 2 | 1 | 2 |
| None | 2 | 2 | 1 | 2 |
| Choice | 3 lags | | | |

*Source:* Prepared by the authors.
Note: Maximum number of lags = 6.

VAR: Vector autoregression model.
AIC: Akaike information criterion.
HQC: Hannan Quinn information criterion.
SIC: Schwarz information criterion.
FPE: Final prediction error.
M0: Total imports.
M1: Imports of medium- and high-technology manufactures.
M2: Imports of low technology or natural-resource-based manufactures.
M3: Imports of international commodities.

**ANNEX 4**

## Diagnostic evaluation of the residuals

| Model | JB | *p*-value | Q | *p*-value | ARCH | *p*-value |
|---|---|---|---|---|---|---|
| *Diagnosis of residuals of income-elasticity of M0* | | | | | | |
| $p = 3$ | 24.2956 | 0.0004607 | 101.818 | 0.7221 | 82.0855 | 0.1951 |
| $p = 2$ | 19.1771 | $2.51x10^{4}$ | 99.842 | 0.9096 | 95.4263 | 0.03381 |
| $p = 1$ | 38.7853 | $7.89x10^{7}$ | 107.595 | 0.915 | 100.0163 | 0.01617 |
| *Income-elasticity of M1* | | | | | | |
| $p = 3$ | 14.1097 | 0.02843 | 91.0622 | 0.9166 | 62.7236 | 0.7742 |
| $p = 2$ | 18.8462 | $4.43x10^{3}$ | 103.18 | 0.8638 | 69.9512 | 0.5464 |
| $p = 1$ | 25.1554 | $3.20x10^{4}$ | 116.412 | 0.779 | 73.3348 | 0.4341 |
| *Income-elasticity of M2* | | | | | | |
| $p = 3$ | 6.0231 | 0.4206 | 103.307 | 0.6857 | 89.8549 | 0.0757 |
| $p = 2$ | 12.7499 | 0.04718 | 101.144 | 0.8932 | 95.6307 | 0.03276 |
| $p = 1$ | 21.5636 | 0.001452 | 110.03 | 0.8854 | 106.9891 | 0.004691 |
| *Income-elasticity of M3* | | | | | | |
| $p = 3$ | 24.9692 | 0.000346 | 111.948 | 0.4569 | 86.4326 | 0.1179 |
| $p = 2$ | 29.839 | $4.22x10^{5}$ | 109.363 | 0.7469 | 120.7874 | 0.000281 |
| $p = 1$ | 58.9255 | $7.44x10^{11}$ | 104.191 | 0.9468 | 118.1968 | 0.000493 |

*Source:* Prepared by the authors.
Note: The results refer to the best model with intercept in the co-integration vector.

Jarque-Bera (JB): Jarque-Bera test of normality of the residuals (H0: Normal residuals).
Portmanteau (Q): Test for autocorrelation in the residuals (H0: No autocorrelation).
ARCH: Test for autoregressive conditional heteroscedasticity in the residuals (H0: homoscedasticity).
M0: Total imports.
M1: Imports of medium- and high-technology manufactures.
M2: Imports of low-technology or natural-resource-based manufactures.
M3: Imports of international commodities.

**ANNEX 5**

## Diagnostic of the residuals

| Model | JB | *p*-value | | *p*-value | ARCH | *p*-value |
|---|---|---|---|---|---|---|
| *Income-elasticity of X0* | | | | | | |
| $p = 3$ | 6.2999 | 0.3904 | 105.107 | 0.6397 | 76.529 | 0.3354 |
| $p = 2$ | 10.8343 | 0.09364 | 98.5533 | 0.924 | 59.0846 | 0.8626 |
| $p = 1$ | 9.5393 | $1.45x10^{1}$ | 104.955 | 0.9406 | 82.9702 | 0.1771 |
| *Income-elasticity of X1* | | | | | | |
| $p = 3$ | 1.7535 | 0.941 | 90.9865 | 0.9175 | 59.843 | 0.8461 |
| $p = 2$ | 3.8717 | 0.694 | 96.6295 | 0.9424 | 51.5521 | 0.9672 |
| $p = 1$ | 9.4118 | $1.52x10^{1}$ | 83.0726 | 0.9994 | 78.4628 | 0.2815 |
| *Income-elasticity of X2* | | | | | | |
| $p = 3$ | 5.3618 | 0.4983 | 109.938 | 0.5107 | 72.3643 | 0.4658 |
| $p = 2$ | 11.212 | 0.08204 | 90.9576 | 0.9777 | 68.3158 | 0.6012 |
| $p = 1$ | 8.7636 | 0.1873 | 90.6287 | 0.9958 | 86.4695 | 0.1174 |
| *Income-elasticity of X3* | | | | | | |
| $p = 6$ | 3.0402 | 0.8038 | 99.9439 | 0.113 | 65.6792 | 0.6869 |
| $p = 3$ | 2.4965 | 0.8689 | 101.418 | 0.7316 | 67.873 | 0.616 |
| $p = 2$ | 7.6678 | 0.2635 | 99.2726 | 0.9162 | 82.3719 | 0.1892 |

*Source:* Prepared by the authors.
Note: The results refer to the best model with intercept in the co-integration vector.

Jarque-Bera (JB): Jarque-Bera test got normality of the residuals (H0: Normal residuals).
Portmanteau (Q): Test for autocorrelation in the residuals (H0: No autocorrelation).
ARCH: Test for autoregressive conditional heteroscedasticity in the residuals (H0: homoscedasticity)
X0: Total exports.
X1: Exports of medium- and high-technology manufactures.
X2: Exports of low-technology or natural-resource-based manufactures.
X3: Exports of international commodities.

**ANNEX 6**

Co-integration test

| HO | Test statistics | | | Critical values | | |
|---|---|---|---|---|---|---|
| | $p = 1$ | $p = 2$ | $p = 3$ | 90% | 95% | 99% |
| *Income-elasticity of M0* | | | | | | |
| $r = 0$ | 39.07 | 34.12 | 36.75 | 32 | 34.91 | 41.07 |
| $r = 1$ | 16.86 | 17.67 | 17.73 | 17.85 | 19.96 | 24.6 |
| $r = 2$ | 6.52 | 4.14 | 6.12 | 7.52 | 9.24 | 12.97 |
| *Income-elasticity of M1* | | | | | | |
| $r = 0$ | 35.81 | 36.47 | 46.42 | 32 | 34.91 | 41.07 |
| $r = 1$ | 15.37 | 17.59 | 20.99 | 17.85 | 19.96 | 24.6 |
| $r = 2$ | 4.79 | 2.35 | 6.07 | 7.52 | 9.24 | 12.97 |
| *Income-elasticity of M2* | | | | | | |
| $r = 0$ | 39.83 | 40.01 | 42.37 | 32 | 34.91 | 41.07 |
| $r = 1$ | 17.59 | 21.14 | 20.41 | 17.85 | 19.96 | 24.6 |
| $r = 2$ | 7.72 | 4.45 | 7.51 | 7.52 | 9.24 | 12.97 |
| *Income-elasticity of M3* | | | | | | |
| $r = 0$ | 44.47 | 39.56 | 35.67 | 32 | 34.91 | 41.07 |
| $r = 1$ | 18.55 | 19.34 | 15.69 | 17.85 | 19.96 | 24.6 |
| $r = 2$ | 5.05 | 8.44 | 6.87 | 7.52 | 9.24 | 12.97 |

*Source:* Prepared by the authors.
Note 1: The results refer to the best model with intercept in the co-integration vector.
Note 2: The results refer to the trace of statistics.
Note 3: The critical values of the trace of statistics referred to those found in S. Johansen, *Likelihood-Based Inference in Cointegrated Vector Autorregresive Models*, New York, Oxford University Press, 1995.

H0: the null hypothesis is that there are r co-integration vectors.
M0: Total imports.
M1: Imports of medium- and high-technology manufactures.
M2: Imports of low-technology or natural-resource-based manufactures.
M3: Imports of international commodities.

**ANNEX 7**

Co-integration test

| HO | Test statistics | | | Critical values | | |
|---|---|---|---|---|---|---|
| | $p = 1$ | $p = 2$ | $p = 3$ | 90% | 95% | 99% |
| *Income-elasticity of X0* | | | | | | |
| $r = 0$ | 36.44 | 40.27 | 48.21 | 32 | 34.91 | 41.07 |
| $r = 1$ | 9.7 | 11.87 | 16.46 | 17.85 | 19.96 | 24.6 |
| $r = 2$ | 2.98 | 2.17 | 4.79 | 7.52 | 9.24 | 12.97 |
| *Income-elasticity of X1* | | | | | | |
| $r = 0$ | 45.69 | 61.08 | 51.54 | 32 | 34.91 | 41.07 |
| $r = 1$ | 20.41 | 29.3 | 20.8 | 17.85 | 19.96 | 24.6 |
| $r = 2$ | 6.53 | 7.21 | 4.47 | 7.52 | 9.24 | 12.97 |
| *Income-elasticity of X2* | | | | | | |
| $r = 0$ | 40.84 | 41.87 | 40.64 | 32 | 34.91 | 41.07 |
| r = 1 | 12.19 | 13.65 | 15.28 | 17.85 | 19.96 | 24.6 |
| $r = 2$ | 5.28 | 5.33 | 5.31 | 7.52 | 9.24 | 12.97 |
| *Income-elasticity of X3* | | | | | | |
| $r = 0$ | 34.02 | 49.86 | 80.43 | 32 | 34.91 | 41.07 |
| $r = 1$ | 9.59 | 14.75 | 36.36 | 17.85 | 19.96 | 24.6 |
| $r = 2$ | 1.55 | 2.33 | 17.59 | 7.52 | 9.24 | 12.97 |

*Source:* Prepared by the authors.
Note 1: The results refer to the model with an intercept in the co-integration vector.
Note 2: The results refer to the trace of statistic.
Note 3: The critical values of the trace statistic are those found in S. Johansen, *Likelihood-Based Inference in Cointegrated Vector Autorregresive Models*, New York, Oxford University Press, 1995.

H0: Null hypothesis.
X0: Total exports.
X1: Exports of medium- and high-technology manufactures.
X2: Exports of low-technology or natural-resource-based manufactures.
X3: Exports of international commodities.

ANNEX 8

Likelihood-ratio test

| Sector | M0 | | M1 | | M2: | | M3 | |
|---|---|---|---|---|---|---|---|---|
| | Test | *p*-value | Test | *p*-value | Test | *p*-valor | Test | *p*-value |
| M0 | - | - | 7.7 | 0.02 | 7.77 | 0.02 | 7.92 | 0.02 |
| M1 | 10.98 | 0 | - | - | 3.36 | 0.19 | 11.14 | 0 |
| M2: | 8.52 | 0.01 | 6.35 | 0.04 | - | - | 8.55 | 0.01 |
| M3 | 6.63 | 0.04 | 6.63 | 0.04 | 6.63 | 0.04 | - | - |

*Source:* Prepared by the authors.
Note: The null hypothesis of the test is that the coefficients under restriction (income-elasticity of imports) are the same in the models represented in each line and column.

M0: Total imports.
M1: Imports of medium- and high-technology manufactures.
M2: Imports of low-technology or natural-resource-based manufactures.
M3: Imports of international commodities.

ANNEX 9

Likelihood-ratio test

| Sector | X0 | | X1 | | X2 | | X3 | |
|---|---|---|---|---|---|---|---|---|
| | Test | *p*-value | Test | *p*-value | Test | *p*-value | Test | *p*-value |
| X0 | - | - | 5.72 | 0.06 | 5.73 | 0.06 | 5.71 | 0.06 |
| X1 | 8.09 | 0.02 | - | - | 8.08 | 0.02 | 8.1 | 0.02 |
| X2 | 5 | 0.08 | 5.07 | 0.08 | - | - | 5.05 | 0.08 |
| X3 | 6.28 | 0.04 | 6.28 | 0.04 | 6.28 | 0.04 | - | - |

*Source:* Prepared by the authors.
Note: The null hypothesis of the test is that the coefficients under restriction (income-elasticity of exports) are the same in the models represented in each line and column.

X0: Total exports.
X1: Exports of medium- and high-technology manufactures.
X2: Exports of low-technology or natural-resource based manufactures.
X3: Exports of international commodities.

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