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Economic growth and balance-of-payments constraint in Brazil: An analysis of the 1995–2013 period

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Abstract

The purpose of this work is to analyze the balance-of-payments-constrained growth in Brazil considering Thirwall's Law (1979). To this end, we estimate export and import demand functions using two econometric models: vector error correction and structural state space model for the period of 1995–2013. Our results suggest that the balance of payments is a constraint to the Brazilian economic growth, given: (i) the ratio between exports and imports income elasticities; (ii) the low sensitivity of exports to changes in the real exchange rate; and (iii) the evidence that exports are more sensitive to alterations in commodities prices than to changes in the real exchange rate.

JEL classifications: F43; F14

Keywords: Balance-of-payments-constrained growth; Exports; Emerging economies; Demand-led growth

1. Introduction

The concern about the extent to which external constraints to the balance of payments (BOP) may limit the long-term growth of economies in general, and of peripheral ones in particular, is a central theme in various theoretical traditions critical of *mainstream* Economics. Thus, for example, Structuralist and Keynesian models do not agree with the conventional view that the long-term economic performance depend essentially on supply side factors (Pasinetti, 1981,

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1993; Thirlwall, 2013; Cimoli and Porcile, 2014). Additionally, they do not work with the same micro-fundamentals derived from the assumption that economic agents make their decisions in competitive conditions and through rational expectations.

Those alternative views have in common the emphasis they put on events on the demand-side, the importance they give to institutional factors, the significance of the inter-relationship between the monetary-credit side and the real side of economies, and the denial that macroeconomic outcomes are mere aggregate results of decisions taken at the microeconomic level. A special case in non-mainstream literature is Thirlwall (1979) and the subsequent developments it inspired (Thirlwall and Hussain, 1982; Moreno-Brid, 1998/1999, 2003; Barbosa-Filho, 2001; Araújo and Lima, 2007; Carvalho and Lima, 2009; Gouvea and Lima, 2010; Ferrari et al., 2013).

Thirlwall's Law (TL, from now on), in its original form, suggests that an economy cannot grow above the pace of global growth if the income elasticity of exports is lower than the income elasticity of imports. As himself recognizes (Thirlwall, 2011, 2013), this view originates from the seminal works of Harrod (1933), Prebisch (1949, 1982), Chenery and Bruno (1962) and Chenery and Macewan (1966). All these authors tackle an essential issue: what a country produces and exports, as well as how the rest of the world spends, are crucial issues to the long-term growth dynamics of an economy.

Taking those considerations into account, *our main goal* in this paper is to assess whether, in the case of the Brazilian economy, it can be observed a change in exports and imports elasticities that might have, precisely, led to a greater external constraint to its growth. We plan to do this by applying two complementary econometric approaches: the structural models in the format of State Space, also known as unobservable components model; and the vector error correction model (VEC), which is a variation of the vector autoregressive model (VAR). As far as we have knowledge, this combination of approaches has not been done to date, thus, it could be a contribution to this subject.

The *central hypothesis* of our study is that the ongoing process of regressive specialization[1] is potentially worsening Brazilian external constraint to growth, in the sense expressed by Thirlwall (1979). We suggest, following the previous literature in this subject, that the deindustrialization process (Palma, 2012), coupled with a greater dependence on natural resources exports, might lead to changes in elasticities for both imports and exports. Imports of manufactured goods, especially those with higher technological complexity, tend to become increasingly more sensitive to changes in national income; while exports of natural resources tend to become less sensitive to changes in world income. Consequently, the BOP under these conditions would suffer constraints as Brazil's lower exports income is coupled with a higher imports expenses.

In order to reach our *main objective* and to test our *central hypothesis*, we thought best to analyze two phases both ending in 2013: a more extensive one (1995–2013), that begins after the Real Plan, that is the stabilization policy, which we will call period 1 (P1 from now on); and a shorter one, period 2 (P2, 2001–2013), that starts with the effects of China entry into the World Trade Organization (WTO). The main results from those econometric models point out that, in fact, the external restrictions on growth for Brazil has increased, especially after 2001. This result is in conformity with Thirlwall's Law.

This paper continues as follows: Section 2 presents a short review of the literature on the matter; Section 3 describes the methodology and the results of our study; Section 4 presents our conclusions.

2. Economic growth and the balance-of-payments constraint: literature review

2.1. Thirlwall's original model, some extensions and critics

Thirlwall (1979) criticizes neoclassical growth models because they look to explain differences in growth rates across countries only by supply side factors, such as capital, labor and productivity. Alternatively, he picks on the Keynesian

[1] By regressive specialization we refer to the reversal of the modernization trends experienced during the post war period, sometimes called developmentalism, which led to a productive and foreign trade structures characterized, among other things, by: (i) diversification – at sector and product levels; (ii) an increase in manufacturing sector's share in the total value added; (iii) an increase in manufacturing products' share in total merchandise exports; and (iv) a significant increase in productivity associated with those structural changes. Therefore, a regressive specialization should be expected when productivity is stagnated, manufacturing sector value added grows below the GDP average, and exports are increasingly natural resources-oriented. Further references on this matter can be found in Palma (2012), Nassif et al. (2013), Unctad (2014), Cimoli and Porcile (2014), da Silva Bichara et al. (2016) and Unido (2016).

approach to build a dynamic version of Harrod's foreign trade multiplier model (1933). His central proposition is that a country cannot grow faster than the restriction imposed by its BP, unless it can finance itself indefinitely – which would be a very unlikely event, especially for developing economies. His central hypothesis is that if the trade account is in balance, the long-term growth rate will be determined by the ratio between the rate of growth of exports and income elasticity of demand for imports. Formally, we have:

$$P_{dt}X_t = P_{ft}M_tE_t \tag{1}$$

where *Pdt* is the price of exports in domestic currency at time *t*, *Xt* is the total quantity exported in time *t* ("exports"); *Pft* is the price of imports in foreign currency at time *t*; *Mt* is the quantity imported at time *t* ("imports"); and *Et* is the exchange rate (ratio between the domestic currency and foreign currency) at time *t*. At first, the BP will be reduced to just the trade account. To verify its equilibrium condition over time, Thirlwall (1979) presents the following equations – where lower case letters represent variation rates:

$$p_{dt} + x_t = p_{ft} + m_t + e_t \tag{2}$$

The imports demand function is:

$$M_t = \left(P_{ft}E_t\right)^{\psi} P_{dt}^{\Phi} Y_t^{\pi} \tag{3}$$

where ψ is the price elasticity of demand for imports ($\psi < 0$); Φ is the cross-price elasticity of demand for imports ($\Phi > 0$); *Y* represents income, and π is the income elasticity of demand for imports ($\pi > 0$). Thus, where lower case letters represent variation rates:

$$m_t = \psi p_{ft} + \psi e_t + \Phi p_{dt} + \pi y_t \tag{4}$$

The exports demand function is:

$$X_t = \left(\frac{P_{dt}}{E_t}\right)^{\eta} P_{ft}^{\delta} Z_t^{\varepsilon} \tag{5}$$

where η is the price elasticity of demand for exports ($\eta < 0$), δ is the cross-price elasticity of demand for exports ($\delta > 0$); and *Zt* is the world's income at time *t*, ε is the income elasticity demand for exports ($\varepsilon > 0$).

The growth rate of exports can be written as follows, where lower case letters represent variation rates:

$$x_t = \eta p_{dt} - \eta e_t + \delta p_{ft} + \varepsilon z_t \tag{6}$$

Replacing Eqs. (4) and (6) in Eq. (2), it is possible to obtain the income growth rate compatible with BP equilibrium:

$$y_{Bt} = \frac{\left[p_{dt}\left(1+\eta-\Phi\right) - p_{ft}\left(1-\delta+\psi\right) - e_t\left(1+\eta+\psi\right) + \varepsilon(\mathrm{zt})\right]}{\pi} \tag{7}$$

From Eq. (7) it is possible to infer that:

1. Higher domestic prices (P_{dt}) reduces the growth rate compatible with BP equilibrium (Y_{BT}), i.e. if $|\eta + \Phi > 1|$;
2. Higher international prices (P_{ft}) increases growth compatible with BP equilibrium (Y_{BT}), that is, if $|\delta + \psi > 1|$;
3. A domestic currency devaluation ($E_t > 0$) increases growth compatible with BP equilibrium (Y_{BT}). In this case, $|\eta + \psi > 1|$. Such a condition cannot last forever, as this would require devaluating the domestic currency continuously;
4. Higher world income (*Zt*) increases growth compatible with BP equilibrium (Y_{BT});
5. Higher income elasticity of demand for imports (π) reduces growth compatible with BP equilibrium (Y_{BT}).

For simplicity sake, Thirlwall (1979) assumes that $\psi = \Phi$ and $\eta = \delta$.[2] This would make price elasticities equal to cross-price elasticities. Additionally, Thirlwall considers that either the Marshall–Lerner condition is met or that prices are stable in the long run,[3] which would enable him to reduce Eq. (7) even further:

$$y_{Bt} = \frac{x_t}{\pi} \tag{8}$$

Thus, the growth rate compatible with BP equilibrium is one that equals the export growth ratio of a country with its income elasticity of demand for imports: $x_t = \varepsilon(z_t)$. Eq. (8) is the weak version of Thirlwall's Law (Perraton, 2003). In the strong version: (i) the export demand function is also estimated; and (ii) $\varepsilon(z_t)$ is used instead of x_t to calculate growth compatible with BP equilibrium.

Thirlwall's original model has received both further extensions as well as criticisms (Mccombie and Thirlwall, 2004; Thirlwall, 2011, 2013). Interesting cases worth mentioning are the inclusion of a country's external financial relations[4] and of how it deals with its external debt[5] (Moreno-Brid, 1998/1999, 2003; Barbosa-Filho, 2001; Carvalho and Lima, 2009). Other innovative efforts have been the multisectorial[6] model (MSTL), which takes into account the real exchange rate and endogenous elasticities (Ferrari et al., 2013); and the addition of structural problems such as the persistence of technological asymmetries and productive heterogeneity (Cimoli and Porcile, 2014).

On the other hand, criticisms have come from, among others, Mccombie (1981), who states that the relationship exposed by Thirlwall (1979) seems to be just a simple identity. In his view, this would bring it close to circular reasoning. For him, the flaw in Thirlwall's model is that it does not take into account price adjustments.[7] In the case of Mcgregor and Swales (1985, 1986) TL is put into question because: (i) the import and export functions do not include non-price competition; and (ii) Eq. (8) is only valid if it is assumed $p_{dt} - p_{ft} - et = 0$, in Eq. (7). For these authors, Thirlwall (1979) is accepting the validity of "law of one price", which would imply that the whole world produces the same product.[8]

Neoclassical authors, such as Crafts (1988) and Krugman (1989), reject that balance-of-payments is a constraint to economic growth. Crafts (1988) goes as far as totally discarding the Keynesian view when reaffirming the neoclassical model. He basis his view by estimating the income elasticity of demand for exports for Britain, and concludes that its economic growth rate was not restricted by its BP, but by supply side factors. Thus, he explained different growth rates as being determined, in the first place by the difference in total factor productivity growth rates. Krugman (1989) agreed

[2] Thirlwall assumes that $\psi = \Phi$ and $\eta = \delta$ because these data are not available. In fact, when one calculates the functions demand for exports and imports, one is interested in imported and exported values, not in their quantities (quantum).

[3] It is important to recall that literature establishes that the cross-price elasticity usually has a positive sign, while the price elasticity of demand has negative one. Regarding the proposition that prices do not change in the long run, Carvalho (2007) argues that this has been a major criticism of Thirlwall's Law, since it disregards the possibility of adjustment through prices, as assumed by neoclassical theory. In Thirlwall (1979) all adjustments occur through income, and not prices.

[4] Thirlwall and Hussain (1982) introduce into Thirlwall's (1979) original model the possibility that the growth rate compatible with equilibrium BP could be increased (decreased) due to capital inflows (outflows).

[5] While capital inflows allow a country to grow above the restriction imposed by the current account, there are limits on how much it can get into debt. Moreno-Brid (1998/1999) formally incorporates this case, which had already been suggested by Mccombie and Thirlwall (1997). Moreno-Brid (1998/1999) includes the stock of external debt to Thirlwall and Hussain (1982), which allows to consider that the relationship between foreign debt and domestic product as an additional restriction on long-term growth of a country. This same author, in a later work, extended the original model, once again, this time by exploring the effects of interest payments (Moreno-Brid, 2003). This later contribution was in reply to Barbosa-Filho (2001) who pointed out the need to include interest payments into Moreno-Brid (1998/1999).

[6] Based on Pasinetti (1981, 1993), Araujo and Lima (2007) built a model of balance-of-payments equilibrium growth rate analogous to Thirlwall (1979), where the growth rate of per capita income is directly proportional to the growth rate of exports, such a proportionality being inversely (directly) related to sectoral income elasticities of imports (exports).

[7] Empirical work based on Thirlwall (1979) usually takes into account prices when income elasticities of demand for imports and exports are estimated. Nevertheless, in many cases, they are small or insignificant. Mccombie (2011) argues that the imports and exports demand functions are in fact behavioral functions. Moreover, it seems consistent with the Keynesian theory that the price elasticities are low or insignificant for such functions as adjustment occurs via income and not through prices.

[8] Thirlwall (2011, 2013) and Mccombie (2011) respond to those criticisms by claiming that: (i) there is evidence that relative prices do not differ significantly; (ii) those elasticities are so low that they have no effect on the BP; (iii) other causes explain why prices do not show large variations, such as real wage resistance and oligopolistic structures; (iv) Thirlwall (1979) is not necessarily related to the neoclassical theory as a consequence of assuming an important role for income elasticity of demand for exports, or because empirical works find that elasticities are statistically significant; and finally (v) if the Marshall–Lerner condition is satisfied, it is not reasonable to assume that exports can grow indefinitely by means of a continuously depreciating the domestic currency.

with Craftś conclusion. He reached similar results as Thirlwall (1979) regarding elasticities' behavior, but followed a different path. He examined the reason that real exchange rates have remained relatively stable between countries. He suggested the net effect the relationship between trade elasticities and growth rates makes the trends in real exchange rates to remain stable. This that he called "rule of 45°" has argued by many authors, starting from Thirlwall (2011) himself to be no more than another arrangement of the strong version of the TL, as presented here in Eq. (8), but using (X_t) instead of $\varepsilon\,(z_t)$.

Palley (2002) and Setterfield (2006) explored problems associated with over-or-under capacity utilization.[9] According to those authors, it is important to explain how the long-run equilibrium growth rate of the economy is determined, as it overcomes supply-side constraints. Even though they acknowledged that economic growth is push by the demand side, they emphasized the need to take into account how demand expansion interacts with production capacity constraints. Palley's model solves this compatibilization problem, by making the income elasticity of demand for imports endogenous to the degree of capacity utilization. On the other hand, Setterfield's model advances alternative solutions to the adjustment mechanism between demand and supply. First, he makes productivity growth a function of the degree of capacity utilization. Thus, if income growth exceeds that of capacity, the potential growth converges towards the balance of payments equilibrium growth rate. Secondly, he analyses the interaction between the growth of exports and investment. When export growth is high and income growth exceeds the growth of capacity utilization, investments also increase, filling the supply-demand gap (and vice-versa). Cimoli and Porcile (2014) go a step further by incorporating a Latin American Structuralist view in their model. In this case, interaction between structural factors such as technological asymmetry and structural heterogeneity work together with components of demand to determine the external constraints on growth.

2.2. *Some empirical evidence*

Empirical literature on this subject is quite vast and relative diverse when one considers different functional specifications of TL and alternative econometric techniques – such as time-series models for a specific country, or cross-section and panel data models for several countries at a time. Nevertheless, there is a convergence of results that validate the hypothesis that domestic growth rate is BP constrained. In many cases,[10] functions were estimated using cointegration techniques, revealing the presence of a long-term relationship between the involved series. For some of these authors,[11] the parameter estimated for the price elasticity in the import demand function was statistically insignificant. As argued by Vieira and Holland (2008), among others, this result, which would mean the exclusion of price elasticity in the imports demand function, can compromise the outcome of the estimated parameter for the income elasticity. In other cases, the result was that the Marshall-Lerner condition was not considered valid.[12]

For the Brazilian case, a typical empirical strategy has been to separate data series into different time frames in order to compare the effects some important economic policies, such as trade liberalization, exchange rate devaluation and so on. These works found that Brazil has suffered an increase of its external restriction.[13] Specifically, trade liberalization has been a policy which resulted in an increased in the income elasticity of demand for imports. For their part, Carvalho et al. (2011) and Smith and Teixeira (2012) applied the multisectorial model (MSTL) to highlight the importance of the productive structure to explain this result.

On the other hand, there are some other works that have sought to estimate trade elasticities for Brazil that do not follow Thirlwall's model. Nevertheless, we took them into account because we think that their different approaches still helped us to design better our own empirical strategy and also to evaluate our results more broadly. One interesting example is Resende (2001), who tests the hypothesis that the Brazilian imports depend on the import capacity, meaning

[9] As Thirlwall recognizes: "The balance of payments equilibrium growth rate is by definition a demand-constrained growth rate. It would only be by chance that it equals the capacity, or supply-constrained, growth rate determined by the availability of factor supplies." (Thirlwall, 2011, p. 328–329).

[10] Moreno-Brid and Pérez (1999), López and Cruz (2000), Bértola et al. (2002), Jayme (2003), Holland et al. (2004), Vieira and Holland (2008), Carvalho et al. (2008), Carvalho et al. (2011), Soares and Teixeira (2012).

[11] For example: Thirlwall and Hussain (1982), Moreno-Brid and Perez (1999), López and Cruz (2000), Bértola et al. (2002), Carvalho and Lima Santos (2008) and Carvalho and Lima (2009).

[12] More details about this can be found in López and Cruz (2000), Bértola et al. (2002) and Carvalho (2007).

[13] Jayme (2003), Vieira and Holland (2008), Carvalho and Lima (2009) and Nassif et al. (2013).

the availability of foreign exchange coming from exports plus capital inflows.[14] The author included other variables in his model, such as the exchange rate, installed capacity in the economy, the Brazilian GDP, the *quantum* of imports, as well as some *dummy variables*. Besides that, he estimated the import function by end-use categories, with quarterly data for the period 1978–1998. The econometric method used was cointegration, through correction of errors by the Engle–Granger and Johansen procedure. His main results were: (i) installed capacity was not statistically different from zero; (ii) up to the fourth quarter of 1989, the estimated coefficient for income elasticity of demand for total imports was low (0.54); (iii) however, from the first quarter of 1990 onwards it passed to 3.85; this means that the process of trade liberalization in the 1990s made the demand for imports more sensitive to changes in income; (iv) up to the third quarter of 1994, the price elasticity of demand for imports was not statistically different from zero; after this period, it was −1.3912[15]; and (v) the import capacity showed unstable behavior, given the disruption in the third quarter of 1994; until that time, the parameter was 0.63; after the Real Plan, it fell to −0.03. From these results, the author suggests that external vulnerability increased after 1994.

For basically the same period (1978–1999), Silva et al. (2001) estimated non-linear import functions for Brazil, applying the artificial neural networks methodology. Estimates were made for total imports and for intermediate goods imports. The following variables were used: volume of total imports, GDP, real exchange rate, price index and the rate of capacity utilization. The authors divided the analysis in three periods: from the first quarter 1978 to the third quarter 1989; from the fourth quarter 1989 to the second quarter 1994; and from the third quarter of 1994 to the fourth quarter of 1999. These periods were chosen based on graphical analysis, which, according to the authors, point out where there were more significant structural changes. The average income elasticities found for the total imports demand function were −0.006097 (1978.1–1989.3); 0.179801 (1989.4–1994.2) and 1.227445 (1994.3–1999.4). For the price elasticity, the estimated coefficients were −0.225738; −0.90537; −1.175467, respectively, and for the average productive capacity the elasticities found were 0.050331; 0.04423 and 0.290725, in chronological order. Silva et al. (2001) suggested that trade liberalization policy in the 1980s and 1990s explained most of the changes in the elasticities values.

Morais and Portugal (2004) analyzed the Brazilian imports' demand through two different models – the Markov–Switching model (MS-VEC) and the VAR/VEC model – and periods – from 1947 to 2002, using annual data, and from the first quarter of 1978 to the second quarter of 2002, using quarterly data. They were mainly interested in detecting structural changes in demand due to trade liberalization, international crises and modifications in the exchange rate regime.[16] Their main results were: (i) for the long-term function, the coefficients were −0.648 and 0.675 for the price elasticity and income elasticity, respectively; (ii) for the short term function, income elasticity was 1.706 and the price elasticity was −0.426; (iii) the MS-VEC estimated in a nonlinear model resulted in a coefficient of 4.704 for income elasticity and −0.522 for the price elasticity; (iv) using quarterly data, the coefficients estimated by linear model were 0.821 for the income elasticity and −0.91 for the price elasticity.

Santos et al. (2011) calculated[17] the income and price elasticities for Brazilian exports and imports. The authors applied static and dynamic panel data models for all Brazilian states, except Tocantins. The static panel for exports resulted in the following income and price elasticities, respectively, 1.258 and 0.24. When the authors analyzed the period 1992–2004 results were: 0.657 for the income elasticity and 0.705 for price elasticity. Using a dynamic panel for exports, results for those elasticities were 0.334 and 0.371. For imports, Santos et al. (2011) also estimated static and dynamic panels. In these cases, income and price elasticities were, respectively, 1.279 and −0,437 for the static model; and 0.469 and −0.396 for the dynamic model.

[14] In fact, in its full expression, the variable "import capacity", which defines the availability of foreign exchange, is given by the ratio between the sum of exports, capital flows errors and omissions over the total import price index. For its part, capital flows consist of interest, profits and dividends, net direct investment, loans and financing of medium and long term and amortization.

[15] According to Resende (2001), this result suggests that monetary stabilization increased the sensitivity of agents to changes in relative prices of imports.

[16] The variables used were: quantum of imports, GDP, real exchange rate (for this, it was used the ratio of external price level and the domestic price index multiplied by the nominal exchange rate and a variable named import tariffs was used) and the level of economic activity. They also found that models with or without tariffs had very close results.

[17] The period analyzed was 1992–2007 (exports) and 1992–2006 (imports). Variables used were: exports and imports deflated, respectively, by the Brazilian export price index and the wholesale price index from United States; the real effective exchange rate; and the world imports deflated by the world import price index as a proxy to the world income.

From this literature review, we have not found the simultaneous use of the structural models in the format of state space and the vector error correction model (VEC), which is a variation of the vector autoregressive model (VAR). We turn to our exercise, which applies, precisely, this combination of approaches, in the hope of contributing to this subject. Additionally, we think this article could be a contribution by including in export demand function the commodity price index in VAR/VEC model, an exercise that as far as we know has not yet been applied to the Brazilian case.

3. The Brazilian experience between 1995 and 2013

The exercises that follow are aimed at: (i) identifying the income and price elasticities for exports and imports; and (ii) assessing the dynamic interactions between the variables that affect the foreign trade of goods and determine (or not) restrictions on the growth of the Brazilian economy. The demand functions for Brazilian exports and imports were estimated from the first quarter of 1995 to the fourth quarter of 2013. We chose this period because it was characterized by: (i) the aftermath of the Brazilian stabilization program (the *Real* Plan); (ii) the 1999 exchange rate crisis in Brazil, which changed the exchange rate and the monetary regimes, from one characterized by a pegged rate to free floating one combined with an inflation targeting; (iii) a rise in international *commodity* prices, particularly since 2002; and (iv) several international liquidity volatility periods, being the most outstanding the subprime crisis. Starting from low and volatile growth, associated with internal and external macroeconomic imbalances, during most of the 1980s and 1990s, the Brazilian economy experienced a growth acceleration, between 2004 to 2010, followed by anemic growth and increasing vulnerabilities.

To assess the validity of a strong version of TL, we started by checking the structural breaks in the exports and imports series and estimated their demand functions. The statistical methodology chosen was, initially, the decomposition of the series studied in their unobservable components, considering a state space format (Harvey et al., 2004; Commandeur and Koopman, 2007). In this case, structural breaks and other irregularities are endogenously determined, and not exogenously established, as it was the case in the studies reviewed in section 2. Here we think lies our contribution. Next, in a second exercise, we apply the vector error correction model (VEC) to observe how our interest variables interact dynamically (Patterson, 2000; Enders, 2010).

When we analyzed the empirical literature, conventional or Keynesian, it is clear that there is no consensus regarding which series to use to estimate the import and export functions. However, there is some agreement that functions should include domestic and foreign income and the real exchange rate, each of which represents, respectively, the income and price elasticities. Thus, following the original Thirlwall (1979), we decided to use the following series[18]:

a) Brazil's exports of goods *free on board* (X_{BR}): Value range of goods sold by Brazilian companies to other countries, excluding the costs of freight and insurance, in millions of US dollars (source: the Central Bank of Brazil—BCB).
b) Brazil's imports of goods *free on board* (M_{BR}): Value set of goods purchased by Brazilian companies from other countries, excluding the costs of freight and insurance, in millions of US dollars (source: the Central Bank of Brazil—BCB).
c) Real exchange rate (E_{BR}). This series was built using the consumer price index (IPCA) (source: Brazilian Institute of Geography and Statistics—IBGE); the CPI, the US consumer's price index (source: the International Monetary Fund—e IMF); and the spot exchange rate (R$/US$) (source: BCB). The sign expected for this elasticity is negative in the case of demand for imports, and positive in demand for exports.
d) Brazil's GDP (GDP_{BR}). Quarterly volume index of GDP at market prices (source: IBGE). The expected sign for this variable in relation to imports is positive.
e) World income (GDP_W). As its *proxy*, we added the GDP of 46 countries at 2005 constant prices, in US dollars in quarterly data—which would average more than 90% of world's GDP (source: The Economist[19]). The expected sign for this variable in relation to the exports is positive.
f) *Commodities* price index (*COMM*): Prices of all commodities (source: IMF).

[18] Importantly, although Perraton (2003) note that bias may occur in the estimation of the import function from developing countries, because in these regions tariff and non-tariff barriers are high, it was decided to keep as close as possible to the original formulation Thirlwall, in his 1979 work.
[19] No quarterly data available on the World Bank or IMF website, then a proxy was used for global income.

Table 1
Results of elasticities analysis (state space methodology).

	Exports demand function		Imports demand function	
	GDP_W	E_{BR}	GDP_{BR}	E_{BR}
1995–2013	3.2237 (0.00000)	−0.2737 (0.00004)	4.0193 (0.00000)	−0.2771 (0.00001)
2001–2013	1.4622 (0.00000)	−0.4379 (0.00000)	4.5662 (0.00000)	−0.0672 (0.34697)

Source: authors' calculations using STAMP 8.2.
p-Value (between parentheses).

We applied a logarithmic transformation and a seasonal adjustment, through the X12 multiplicative method, to all variables. The application of a state space model[20] to estimate the demand functions for exports and imports involved the following steps: (i) univariate model to exports series, to identify the occurrence of irregularities in the series for P1 (1995–2013); (ii) the demand functions for exports and imports for P1 (1995–2013) and P2 (2001–2013)[21] were initially estimated; (iii) the statistics of the estimated residuals were checked using an heteroscedasticity test, Box-Ljung statistic, normality test, histogram and correlogram (iv) after estimating these functions we were able to identify structural breaks endogenously.

Table 1 present some of our results for the elasticities of the export and import demand functions.[22]

The estimated parameters suggest a deepening of the external constraint for Brazil. A comparison of the short and the long phases reveal a considerable reduction in income elasticity, from 3.22 to 1.46, in the export demand function, while income elasticity for the imports function increases from 4.01 to 4.57. Our results imply that Brazilian exports became less sensitive to variations in world income.

The change of the estimated parameter for the imports demand income elasticity, from 4.02 to 4.56, shows that during the short phase its sensitivity with respect to domestic income variations increased. In the case of price elasticities, the sign of the estimated parameters were the expected for both phases. Nevertheless, for the short one, it could not be considered different from zero, considering a 5% level of significance.

The relationship between real exchange rate and exports was the opposite of what would be expected. Overall, during this phase the long trend of the domestic currency was one of appreciation of the *Real*. Despite this, Brazilian exports grew. This can be explained by the effect of *commodities* prices' *boom*, which affected positively Brazilian exports. Fig. 1 illustrates this phenomenon, showing increasing exports combined with an appreciated exchange rate. The hypothesis that the commodities prices' surge push exports, is tested in sequence by using the VEC methodology.

Summarizing this exercise, we can conclude that the exports and imports demand functions in Brazil showed themselves to be more elastic in respect to income, but less elastic with respect to price. Structural breaks and other irregularities in the import function were related to changes in Brazil's external trade policy and to the effects of

[20] A structural time series model (STM) is formulated in terms of unobserved components. This is called 'decomposition', and each component can have direct economic interpretation through this process. The model proposed is formulated as follows: $y_t = \mu_t + \gamma_t + \psi_t + \varepsilon_t$. The unobserved components are: trend (μ_t), seasonality (γ_t), the cyclical component (ψ_t) and irregularities (ε_t). All four components are stochastic and their distributions are mutually uncorrelated. That is, in Structural State of Space models, it is allowed that the estimated parameters are not fixed over time. Thus, by observing the movements of perturbations of these parameters, it is possible to establish the precise period of time when an exogenous shocks in each component not observed in the studied series occur. The starting point was a model called local trend, where, on the one hand, it is assumed that there are no seasonality and a cyclical component; on the other, there is a trend, with: a fixed slope; and the level defined as a random walk. Thus, $y_t = \mu_t + \varepsilon_t \; \varepsilon_t \sim NID\left(0, \sigma_\varepsilon^2\right)$ and $\mu_t = \mu_{t-1} + \eta_{t,} \; \eta_t \sim NID\left(0, \sigma_\eta^2\right)$. In this specification it is allowed that the level of the trend changes over time, according to the trajectories of η_t. Therefore, level breaks can be identified by this component. Exogenous shocks are not randomly defined, but are identified by the movements of the trend level's residuals estimated by the model. Moreover, state space time series model allows for the introduction of other exogenous explanatory variables, which follows: $y_t = \mu_t + \sum_{j=1}^{k} \beta_j . x_{jt} + \varepsilon_t$, where: x_{jt} is the value of the j-explanatory variable in time t; and βj is its estimated parameter. It is also important to notice that following this methodology it is not necessary to test stationary properties before or after the differentiation of the time series used in our models.

[21] The choice of the initial year of the short period was a result of positive break level identified in exports related to the movement of rising commodity prices on the international market. This fact can be confirmed by univariate model in state space format in the series exports.

[22] Structural breaks and their suggested interpretations can be seen in Appendix.

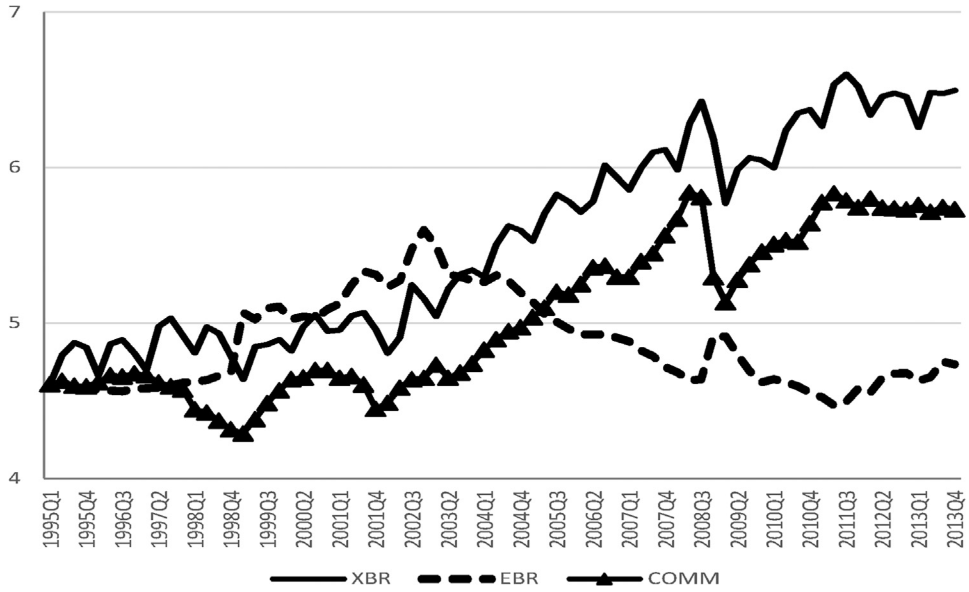

Fig. 1. Exports, *Commodities* prices and real exchange rates in Brazil, 1995–2013 (log scale).
Source: IMF, BCB and IBGE.

Table 2
Granger causality test for the exports demand function.

Null hypothesis	F-test	p-Value
ΔX_{BR} does not Granger cause ΔGDP_W	3,03,816	0.0352
ΔGDP_W does not Granger cause ΔX_{BR}	589.35	0.0013
ΔX_{BR} does not Granger cause ΔE_{BR}	1,27,941	0.2889
ΔE_{BR} does not Granger cause ΔX_{BR}	2,50,489	0.0668
ΔX_{BR} does not Granger cause $\Delta COMM$	0.4190	0.4190
Δ *COMM* does not Granger cause ΔX_{BR}	1,45,722	0.0000

Source: authors' calculations using E-views 7.0.

international crises (see Appendix A). The parameters of the export function and the structural breaks and irregularities detected in this time-series suffered the effect of rising *commodity* prices, beginning in 2002, and the entry of China into the World Trade Organization (WTO) in late 2001 (Appendix A).

Our next exercise, the application of VEC model, reinforces the above results. Following the usual procedure, we started with stationarity tests – Dickey-Fuller Augmented (DFA), Phillips-Peron (PP), Ng-Perron e Zivot-Andrews[23] (see Appendix B) – which revealed that all variables are I(1), except for GDPW, which is I(0) using Zivot-Andrews test for unit root. In fact, it is the structure of the Zivot-Andrews test itself that determines this result, as it applies a linear trend and a structural break in level.

Therefore, it is possible to state that GDPW is trend stationary. As the other results for unit root tests for this variable are I(1), it can be concluded that the result for Zivot–Adrews test does not compromise the VEC estimation for the exports demand function when using GDPW as a control variable.

Akaike and Schwarz selection criteria were used to determine the specification with three lags for both export and import equations[24] (see Appendices C and D). We also carried out the White's heterocedasticity and the Lagrange Multiplier residual autocorrelation tests. To check cointegration we used the Johansen test, considering trace criteria and maximum eigenvalue (see Appendix E). For each function, we have found a cointegration equation at 5% level

[23] Details in: Perron (1989), Zivot and Andrews (1992), Ng and Perron (2001), Saikkonen and Lütkepohl (2002).
[24] Residuals estimated confirm our option for a three lags model.

Table 3
Granger causality test for the imports demand function.

Null hypothesis	F-test	p-Value
ΔM_{BR} does not Granger cause ΔGDP_{BR}	3,03,816	0.0352
ΔGDP_{BR} does not Granger cause ΔM_{BR}	589.35	0.0013
ΔM_{BR} does not Granger cause ΔE_{BR}	1,27,941	0.2889
ΔE_{BR} does not Granger cause ΔM_{BR}	2,50,489	0.0668

Source: authors' calculations using E-views 7.0.

Table 4
Variance decomposition of X_{BR}.

Period	S.E.*	X_{BR}	GDP_W	E_{BR}	COMM
1	0.0566	100.00	0.0000	0.0000	0.0000
2	0.0899	7,90,234	86,619	18,486	1,04,661
3	0.1258	6,70,888	1,19,468	60,884	1,48,760
4	0.1521	6,39,171	1,65,483	70,044	1,25,302
5	0.1732	6,22,211	1,95,310	73,449	1,09,031
6	0.1884	6,37,364	2,00,602	67,021	95,014
7	0.2016	6,60,904	1,95,457	58,867	84,773
8	21,488	6,88,020	1,83,594	51,817	76,569
9	0.2285	7,13,420	1,71,792	45,824	68,964
10	0.2426	7,35,133	1,62,208	40,738	61,922
11	0.2571	7,53,926	1,54,267	36,504	55,303
12	0.2719	7,70,524	1,47,187	32,828	49,461

Source: authors' calculations using E-views 7.0.
Note: *S.E.: standard errors. Order of Cholesky: X_{BR}, GDP_W, E_{BR}, COMM.

of significance.[25] Unit root tests detected level structural breaks in 2008 Q2, 2009 Q1 and 2009 Q2, which led us to introduce dummies to control those irregularities.

Table 2 displays the Granger causality test for the exports demand function. Four main results came from this analysis: (i) it is not clear the casual relationship, in the Granger sense, between GDP_W and X_{BR}, since it rejects the null hypothesis in both cases; (ii) E_{BR} Granger causes X_{BR} at a 10% significance level, while in the opposite direction a relationship is rejected; (iii) *COMM* Granger causes X_{BR}; and (iv) on the whole, it is possible to accept that X_{BR} is the endogenous s variable in the system.

Table 3 shows the Granger causality test for the imports demand function. The following results should be highlighted: (i) E_{BR} Granger causes M_{BR}; and (ii) it is not possible to define a statistical causal relationship, in the Granger sense, between GDP_W and M_{BR}.

Previous tests, particularly the Granger causality test, allow us to consider that E_{BR} is the exogenous variable in our VEC models specifications. The endogenous variables for the exports demand function are X_{BR}, GDP_W and *COMM*; while for the imports demand function the endogenous variables are GDP_W, M_{BR} and E_{BR}. After those definitions, we procced with the variance decomposition (Table 4) and the impulse-response analyses (Fig. 2).

Table 4 shows that the variance of Brazilian exports is better explained by variations in GDP_W and COMM. This result converges with the impulse-response analysis. The most relevant difference in those analyses is that in the impulse-response a positive shock in GDP_W has a stronger effect in X_{BR} than a similar shock in COMM. The opposite is true in the variance composition analyses.

Fig. 2 shows the results of the generalized impulse response function (GIRF) in a VEC model for Brazil's exports. It can be seen that shocks in X_{BR}, GDP_W and *COMM* affect the growth dynamics of Brazilian exports, with GDP_W and *COMM* showing a similar cyclical pattern. For all variables, shocks are more intense up to the seventh quarter and

[25] As expected, the residues estimated in the VEC model were not normal, due to the irregularities in the series detected in the Space State models (see Appendix A). However, this outcome does not invalidate our interpretations, since the estimated parameters remain non-biased. Details in: Baltagi (2008, chapter 5) and Greene (2008, chapter 4).

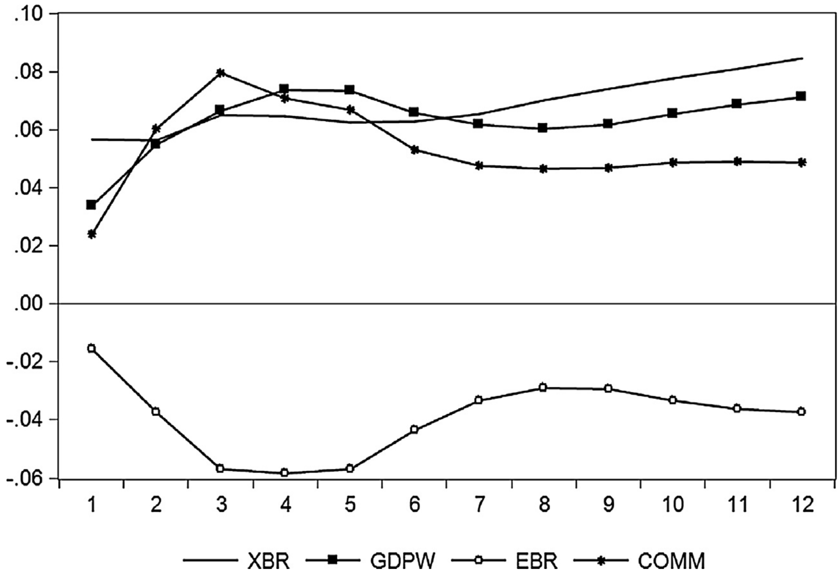

Fig. 2. Impulse-response effect on exports from the VEC model.
Source: authors' calculations using E-views 7.0.

Table 5
Equation of the VEC model for exports (1995–2013).

VEC model for exports (1995–2013)		
	β	Σ
Constant	−9.1851	1.1430
E_{BR}	−0.1825	0.0975
GDP_W	2.5936	0.4664
COMM	0.5710	0.1577

Source: authors' calculations using E-views 7.0.
Where: β is the parameter; σ is the standard error.

then they begin to stabilize. Positive shocks in GDP_W expand Brazilian exports. Its effects are only inferior to the ones that come from shocks in X_{BR}. A *COMM* shock results in a strong expansion of exports until the third quarter. From here on up to the seventh period, it falls until stabilizing at a higher level.

On the other hand, a positive shock in E_{BR}, which represents a devaluation of the domestic currency in real terms, leads to a significant decline in exports up to the third quarter. We take this particular result as spurious, as argued before. From the fourth quarter onwards, exports start increasing again. They finally stabilize around the seventh quarter, on a level slightly lower level than the one observed in the initial period.

Table 5 presents the equation for the exports demand function. The estimated parameter for the price elasticity was not statistically significant at a 5% of significance level. This result converges to the one obtained in our structural model.

As reported in Table 1 and 5 changes in the exchange rate do not appear to statistically affect Brazilian exports. Moreover, taking into account that the exercise delivered an unexpected sign, a spurious relationship between exchange rate and exports can be recognized. This result confirms that Brazilian exports were not very sensitive to real exchange rate changes during this period.

Additionally, the Granger causality test also confirmed that the real exchange rate only affects exports at more than 6.7% significance level. When the confidence interval is 95%, it cannot be rejected the hypothesis that the real exchange does not cause, in the Granger sense, exports. In other words, variations in the real exchange do not Granger cause exports at 5% level of significance. However, we must treat this conclusion with some caution as the relationship

Table 6
Variance decomposition of M_{BR}.

Period	S.E.	M_{BR}	GDP_{BR}	E_{BR}
1	0.0578	100.0000	0.0000	0.0000
2	0.1066	78.7852	17.3121	3.9026
3	0.1456	70.8068	18.0524	11.1408
4	0.1807	61.3937	21.1715	17.4349
5	0.2089	56.0942	23.5660	20.3398
6	0.2281	55.4110	23.7306	20.8584
7	0.2460	55.2892	24.4401	20.2708
8	0.2630	56.1366	24.5666	19.2968
9	0.2797	56.9454	24.5970	18.4577
10	0.2965	57.4237	24.8004	17.7759
11	0.3123	58.0363	24.8183	17.1454
12	0.3275	58.6596	24.8498	16.4906

Source: authors' calculations using E-views 7.0.
Note: *S.E.: standard errors. Order of Cholesky: M_{BR}, GDP_{BR}, E_{BR}.

Table 7
Equation of the VEC model for imports (1995–2013).

VEC model for imports (1995–2013)		
	β	σ
Constant	−5.1884	1.9667
E_{BR}	−0.7482	0.1775
GDP_{BR}	2.7881	0.3110

Source: authors' calculations using E-views 7.0.
Where: α is the parameter; ϐ is the standard error.

between exports and exchange rate is statistically equal to zero, considering 5% level of significance. Despite this, we decided to keep E_{BR} in the model in order to verify its behavior in the impulse response function.

The estimated parameter for the income elasticity in the VEC model showed the highest value. This result is in accordance with the one reached using the state space model. Both exercises show a high sensitivity of Brazilian exports to the world income. Moreover, considering a 95% confidence level, the parameter for the income elasticity in the structural model is within the limits established by the model: 1.6752 and 3.4872. In the state space model the estimated parameter was 2.59.

Table 5 shows that exports were more sensitive to changes in *commodity* prices than to changes in the real exchange rate for the 1995–2013 timeframe. The value of the estimated parameter was 0.5710, which means that a 1% increase in commodities prices causes a 0.57% rise in Brazilian exports.

Variance decomposition and the impulse-response analyses of the demand for imports function suggest that it is affected by GDP_{BR} and E_{BR}. GDP_{BR} explains 21% of imports' variance, while the exchange rate responds for 15% (Table 6).

Fig. 3 shows the results of the generalized impulse response function (GIRF) in a VEC model for Brazil's imports. We found that a shock in GDP_{BR} permanently increases the level of Brazilian imports. In addition, from the seventh quarter onwards imports stabilize at a considerably higher level than before that shock.

As expected, a shock in E_{BR}, which represents a depreciation of the domestic currency in real terms, leads to an initial fall in imports until the seventh quarter. From here on, imports stabilize at a lower level than when the shock began. The shock in GDP_{BR} produced a more intense impact on imports than the one generated from a shock in M_{BR}. These results confirm the higher sensitivity of Brazilian imports to domestic income than to the exchange rate.

Table 7 presents imports demand function equation for the 1995–2013 period. The parameter estimated for the price elasticity, proxied by the E_{BR}, is statically significant and presents the expected sign. Imports have been proved elastic in relation to income, as the parameter value to the income elasticity was 2.78, indicating that an increase of 1% in the

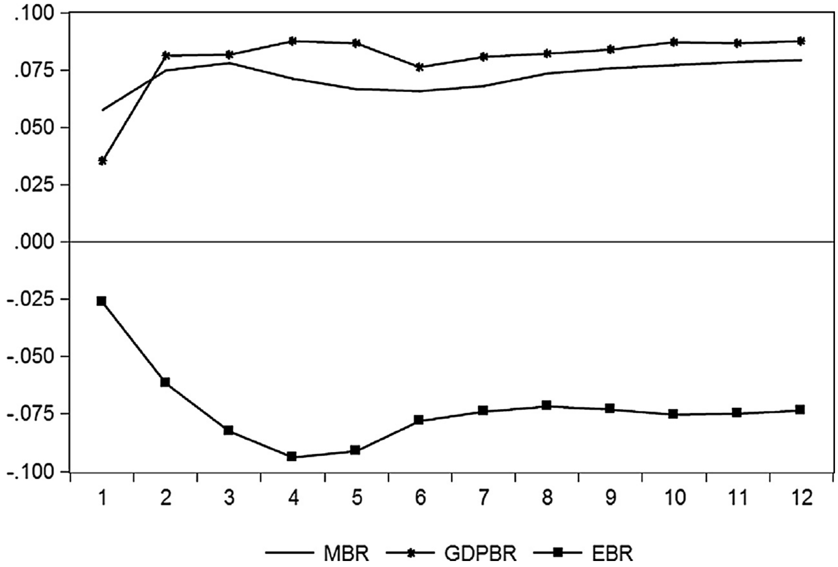

Fig. 3. Impulse-response effect on imports from the VEC model.
Source: authors' calculations using E-views 7.0.

Brazilian GDP results in an increase of 2.78% in Brazilian imports. A rise in domestic income has a positive effect on imports greater than the increase in exports resulting from a growth in world income. That is, if domestic and world income grow at the same rate, Brazil will see its imports increasing more than its exports.

Our last remark is to state that, obviously, a direct comparison between the results of two different models (State Space and VEC), should be treated carefully. This does not impede, nevertheless, that we cannot maintain our conclusion that the estimated parameters, using both techniques, are in line with the external constraint hypothesis. That is because all our estimations, using both models, showed that income elasticities of demand for exports were lower than the ones for imports.

4. Concluding remarks

In this paper, our concern was to evaluate the extent to which external constraints expressed in the balance of payments (BOP) limited the economic growth of Brazil, following a strong version of Thirlwall's Law. Despite being the object of some criticism, studies that follow the TL model or some of its variations have found support for the validity of the TL—especially in developing countries like Brazil. In general, exports and imports demand functions estimated in these studies showed that external trade is more sensitive to changes in income than in prices. Overall, those authors estimated the exports and imports demand functions using co-integration techniques.

Here we opted to combine two different techniques to offer a fresh outlook on this subject, namely structural models in the format of state space and the vector error correction model (VEC). By the first method, our imports demand function, for both the longer (1995–2013) and the shorter (2001–2013) timeframes, presented more breaks and other irregularities than the exports demand functions (see Appendix A). Thus, we conclude that the imports demand function is more unstable. A plausible explanation for this instability can be the sharp changes in Brazilian trade and macroeconomic policies, as well as the international crises that occurred along those years.

Regarding our estimations for both periods of the exports demand function, breaks and other irregularities were observed. In our view, they can be associated to commodity prices' changes. In turn, these price changes we think are related with China's growing significance in the global economy, especially after entering the WTO (2001) that generated worldwide increase in the demand for natural resources and staples. All this has been affected deeply Brazil, as they induced a fundamental structural change in its exports goods basket.;1;

All this consider, we think it can be safely concluded that Brazil's income was limited, *ceteris paribus*, to a maximum growth of 80% of world income for our P1 (1995–2013). In the case of P2 (2001–2013), as exports became less sensitive to world income and imports became more sensitive to domestic income, our conclusion it that the external constraint increased, thus limiting, *ceteris paribus*, the growth of Brazilian income even further: to a 1/3 of the world income growth rate.[26]

Our analysis applying the VEC model allows us to state that Brazilian exports were more sensitive to *commodities (COMM)* prices than to the real exchange rate. In all our calculations of the exports demand function, the estimated parameters for the real exchange rate showed an opposite sign than expected. Therefore, we assume that the relationship between those two variables should to be considered spurious.

As a general result, from both our exercises, we conclude that Brazil experienced: (i) an external constraint – given by the ratio between the exports and imports income elasticities; and (ii) a real exchange rate that did not positively affect Brazilian exports – possibly explained by the growing weight of commodities in the Brazilian export basket.

The impulse response function in the VEC model confirmed that a shock in both GDP_W and X_{BR} positively influenced Brazilian exports. On the other hand, a shock in GDP_{BR} raised imports. Another interesting result is that a shock in GDP_W led to an increase in the exports level that is, nevertheless, smaller than the increase in imports resulting from a GDP_{BR} shock.

Summing up, we consider that our results offer further evidence through a combination of different econometric methods, that we think have not been used before to analyze how Brazil suffered an external constraint to its growth, as stated in Thirlwall's model, since the early nineties, but especially in the present century. Thus, our results converge with most of the literature reviewed in Section 2, especially in regards: (i) to the perception that the Brazilian economy experienced a regressive specialization process characterized by deindustrialization and reprimarization of its exports and, consequently; (ii) to changes in exports and imports income elasticities that evidence a greater external constraint on the growth for the Brazilian economy (Nassif et al., 2013; UNIDO, 2013; UNCTAD, 2014; Cimoli and Porcile, 2014; da Silva Bichara et al., 2016).

Appendix A. State space models—exports and imports demand functions for 1995–2013.

	Exports demand function 1995–2013	Possible explanation
μ_t	−9.0144 (0.00469)	
Level break 2001 (1)	0.13289 (0.00156)	Broad recovery of exports, including raw materials and manufactured product.
Level break 2002 (3)	0.30613 (0.00000)	China's enter WTO (December 2001)
Outlier 2006 (2)	−0.11105 (0.00019)	Brazilian Customs (Receita Federal do Brasil) strike
Level break 2008 (2)	0.11535 (0.00508)	Commodities prices rise.
Level break 2009 (1)	−0.19438 (0.00001)	Suprime crisis and commodities prices drop.
E_{BR}	−0.27371 (0.00004)	
GDP_W	3.22378 (0.00000)s	
σ_ε^2	0.00000	
σ_η^2	0.00158	

Tests and residuals	
Normality	1.2585 (0.5330)
H(22)	0.80471 (0.6926)
Box–Ljung	9.9748 (0.1900)
R^2	0.99679

[26] These results are obtained by applying the elasticities reported in Table 1, as follows: (i) 1995–2013 (3.22378/4.01938 = 0.802059); (ii) 2001–2013 (1.46228/4.56628 = 0.320234). When applying those parameters to the observed growth rates, it follows that: (i) between 1995 and 2013, while world income grew on average 3.8%, Brazil grew just 3.2%; (ii) thus, balance-of-payments-constrained growth in Brazil would be 3.1% per year (3.8% × 0.802059), very close to that 3.2% observed; (iii) between 2001 and 2013, that constraint would have fallen to 1.3% (3.9% × 0.320234), against 3.5% observed in this short period. The difference between estimated and actual growth we think is probably explained by exceptionally favorable external conditions between 2002 and 2008. After the global financial crisis, especially from 2013 onwards, the deceleration in the growth rate of the Brazilian economy reconnected our results to the estimated average values.

	Imports demand function 1995–2013	Possible explanation
μ_t	−12.63293 (0.00000)	
Level break 1995(3)	−0.12038 (0.00067)	Mexico crisis and capital flights; changes in foreign trade policy and import restrictions (see Kume, 1996)
Outlier 1995(4)	−0.0854 (0.00278)	Idem (Kume, 1996)
Outlier 1996(3)	−0.07279 (0.05048)	
Level break 1996(4)	0.07841 (0.07565)	Changes in foreign trade policy and imports liberalization; conflicts with trade partners within WTO and Mercosur (Azevedo and Portugal, 1998)
Level break 1997(1)	−0.17411 (0.00001)	
Level break 1997(2)	0.12916 (0.00039)	Changes in foreign trade policy (import tariff reductions for machineries and equipment, raw material, automotive sector etc.)
Outlier 1998(1)	0.11935 (0.00006)	Sharp increase in imports of the automotive sector due to tariff reduction and increase in domestic credit; climate problems in country's northeast region stimulated a rise in foods imports.
Level break 2001(4)	−0.12127 (0.00073)	September 11th terrorist attack; reduction in the expected growth rate of the global economy.
Level break 2002(1)	−0.1038 (0.00371)	September 11th terrorist attack; reduction in the expected growth rate of the global economy.
Outlier 2002(4)	−0.09157 (0.00209)	Inauguration of the new government; deterioration in private sector expectations due to the new left-wing administration.
Level break 2003(2)	−0.08845 (0.01412)	Trade account problems and reversion
Level break 2008(2)	0.0954 (0.0064)	Subprime crisis (began in August 2007; aggravated form March 2008 onwards); imports surge anticipating prices changes, particularly a domestic currency depreciation due to the crisis.
Outlier 2008(4)	0.08826 (0.02224)	Subprime crisis; sudden drop in Brazilian GDP growth rate.
Outlier 2009(1)	−0.1444 (0.00288)	Subprime crisis; sudden drop in Brazilian GDP growth rate.
Level break 2009(2)	−0.30032 (0.00000)	Subprime crisis; sudden drop in Brazilian GDP growth rate.
Outlier 2012(3)	−0.09771 (0.0006)	Sovereign debt crises the Emirates and several European countries; recession in Brazil.
E_{BR}	−0.27712 (0.00001)	
GDP_{BR}	4.01938 (0.00000)	
σ^2_ε	0.00028	
σ^2_η	0.000652	

Tests and residuals	
Normality	1.6072 (0.4477)
H(13)	0.96659 (0.5292)
Box–Ljung	5.4594 (0.6041)
R^2	0.99813

Source: authors' calculations using STAMP 8.2.
p-Value (between parentheses).

Appendix B. Dickey–Fuller augmented (DFA), with and without structural breaks, Phillips–Peron (PP), Ng–Perron e Zivot–Andrews (ZA).

	ADF test[1]			PP test[2]		
Series	Statistic value	CV* 5%	Order of integration	Statistic value	CV* 5%	Order of integration
X_{BR}	−2.1023 Trend**.0***	−3.4785	I(1)	−2.2769 Trend**.0***	−3.4785	I(1)

M_{BR}	−2.2143 Trend**. 1***	−3.4716	I(1)	−1.9910 Trend**.0***	−3.4785	I(1)
GDP_{BR}	−2.3099 Trend**. 1***	−3.4716	I(1)	−2.6452 Trend**.0***	−3.4785	I(1)
GDP_{W}	−2.149 Trend**.2***	−3.4725	I(1)	−1.8262 Trend**.0***	−3.4785	I(1)
E_{BR}	−1.2873 No trend**.0***	−2.9006	I(1)	−1.4234 no Trend**.0***	−2.9006	I(1)
COMM	−3.3204 Trend**.1***	−3.4716	I(1)	−2.6041 Trend**.0***	−3.4785	I(1)

NG–Perron test[3]

Series	MZa statistic	CV 5%	Order of integration	MZt statistic	CV 5%	Order of integration
X_{BR}	1.2507	−8.1000	I(1)	1.458	−1.9800	I(1)
M_{BR}	0.6185	−8.1000	I(1)	0.379	−1.9800	I(1)
GDP_{BR}	1.6906	−8.1000	I(1) with trend	2.236	−1.9800	I(1) with trend
GDP_{W}	1.2701	−8.1000	I(1)	1.381	−1.9800	I(1)
E_{BR}	−3.1251	−8.1000	I(1)	−1.2499	−1.9800	I(1)
COMM	0.0111	−8.1000	I(1)	0.0064	−1.9800	I(1)

NG–Perron test[3]

Series	MSB	VC 5%	Order of integration	MPT	VC 5%	Order of integration
X_{BR}	1.1658	0.2330	I(1)	96.9908	3.1700	I(1)
M_{BR}	0.6139	0.2330	I(1)	28.5977	3.1700	I(1)
GDP_{BR}	1.3224	0.2330	I(1) with trend	133.455	3.1700	I(1) with trend
GDP_{W}	1.0874	0.2330	I(1)	85.5989	3.1700	I(1)
E_{BR}	0.3999	0.2330	I(1)	7.8396	3.1700	I(1)
COMM	0.5781	0.2330	I(1)	23.3349	3.1700	I(1)

ADF test with break[4]				ZA test with break[5]		
Series	ADF statistic	VC 5%	Order of integration—break	ZA statistic	VC 5%	Order of integration—break
X_{BR}	−3.1405	−4.4436	I(1)—2002/Q2	−3.332	−4.8	I(1)—2003/Q4
M_{BR}	−2.4994	−4.4436	I(1)—2005/Q4	−3.287	−4.8	I(1)—1998/Q4
GDP_{BR}	−1.6978	−4.4436	I(1)—2003/Q3	−3.72	−4.8	I(1)—1998/Q1
GDP_{W}	−2.3974	−4.4436	I(1)—2009/Q2	−5.693	−4.8	I(0)—2008/Q4
E_{BR}	−2.0604	−4.4436	I(1)—2004/Q2	−3.772	−4.8	I(1)—1999/Q1
COMM	−3.1636	−4.4436	I(1)—2003/Q3	−4.273	−4.8	I(1)—1998/Q1

Source: authors' elaboration using Eviews 9.0 Explanatory note: (i) *p-Value* is between blankets; *t* indicates a tendency parameter added to the model; *d* indicates the time series is in first difference.

Notas: [1] Augmented Dickey–Fuller test statistic. Lag lenght selection using Akaike criterion. [2] Phillips–Perron test. [3] NG–Perron test. Lag lenght selection using Akaike criterion. Spectral estimation method using default (AR GLS-detrended). [4] Augmented Dickey–Fuller test statistic with break. Lag lenght selection using Akaike criterion. [5] Zandrews test with break. * Critical value. ** With or without (no) trend. *** Number of lags.

Appendix C. Exports demand function: Akaike and Schwarz selection criteria, White's Heteroscedasticity and Lagrange Multiplier residual autocorrelation tests.

Lags	2		3		4	
	AIC	SBC	AIC	SBC	AIC	SBC
	−16.3865	−14.9746	−16.52540	−14.59650	−16.13960	−13.68570

White's test for Heterocedasticity					
Chi-sq	p-Value	Chi-sq	p-Value	Chi-sq	p-Value
202.1025	0.2604	276.3430	0.3823	368.1558	0.2420

Lagrange multiplier residual autocorrelation test						
Lags	LM	p-Value	LM	p-Value	LM	p-Value
1	35.0283	0.0039	15.8076	0.4665	24.8641	0.0723
2	13.1062	0.6650	15.0246	0.5228	13.3359	0.6481
3	12.4793	71.04	7.8953	0.9519	8.4540	0.9342
4	19.3048	0.2532	10.9322	0.8136	11.0607	0.8057
5	66.9363	0.9787	5.9524	0.9886	6.7096	0.9785

Source: authors' elaboration using Eviews 9.0

Appendix D. Imports demand function: Akaike and Schwarz selection criteria. White's test for heterocedasticity and lagrange multiplier residual autocorrelation tests.

Lags	2		3		4	
	AIC	SBC	AIC	SBC	AIC	SBC
	−11.4422	−10.5637	−11.5442	−10.3742	−11.3476	−9.8816

White's test for heterocedasticity					
Chi-sq	p-Value	Chi-sq	p-Value	Chi-sq	p-Value
109.6239	0.0782	141.7407	0.1600	175.5634	0.2206

Lagrange multiplier residual autocorrelation test						
Lags	LM	p-Value	LM	p-Value	LM	p-Value
1	16.6271	0.0549	9.2725	0.4125	13.6973	0.1335
2	12.3363	0.1950	4.7109	0.8587	20.5515	0.0148
3	7.7057	0.5640	8.4661	0.4879	9.2945	0.4105
4	16.2071	0.0627	4.6897	0.8605	6.6169	0.6769
5	6.1117	0.7287	9.7192	0.3737	12.0491	0.2106

Source: authors' elaboration using Eviews 9.0

Appendix E. Johansen cointegration tests.

Export demand function						
Cointegrating equation	Trace test	Critical value*	p-Value	Maximum eigenvalue	Critical value*	p-Value
None	61.6684	54.079	0.0091	30.8849	28.5880	0.0250
≤1	30.7834	35.1927	0.1384	14.2774	22.2996	0.4369
≤2	16.5060	20.2618	0.1520	9.7229	15.8921	0.3602
≤3	6.7830	9.1645	0.1383	6.7830	9.1645	0.1383

Import demand function						
Cointegrating equation	Trace test	Critical value*	p-Value	Maximum eigenvalue	Critical value*	p-Value
None	48.281	35.1927	0.0012	26.8586	22.2996	0.0108
≤1	21.4223	20.2618	0.0345	15.7249	15.8921	0.0531
≤2	5.6973	9.1645	0.2154	5.6973	9.1645	0.2154

Source: authors' elaboration using Eviews 9.0.
*Critical value at 5% significance level.

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