

Endogeneity of the elasticities and the real exchange rate in a balance of payments constrained growth model: cross-country empirical evidence^a

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ABSTRACT

Balance of payments constrained growth models are notable for their longevity. This is especially true for the case of Thirlwall's Law, which defines that a country's sustainable growth rate is given by the ratio between the income elasticity of exports and that of imports. In light of this, the current paper explores the hypothesis that the income elasticities of this type of models are endogenous. The debate on the latter is resurgent in the literature. The results provide evidence that the ratio is, indeed, exogenous, and that the level of the real exchange rate influences economic growth as it determines such ratio. In other words, the real exchange rate is important for improving non-price competitiveness without, however, making the ratio between elasticities endogenous.

Keywords: Thirlwall's Law. Income Elasticity. Real Exchange Rate.

Classificação JEL: O11, O14 e O19

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1 INTRODUCTION

Thirlwall's (1979) seminal paper suggests that a country's maximum sustainable growth rate is given by the equation that defines the growth rate compatible with balance of payments equilibrium. Its equation is $y_{BP} = x/\pi = \varepsilon z/\pi$, where x is the growth rate of exports, π is the income elasticity of the demand for imports, ε is the income elasticity of the demand for exports and z is the growth rate of world income. This relationship came to be known as Thirlwall's Law.

As McCombie (2011) puts it, the rationality behind this "law" is that no country can grow faster than the rate compatible with balance of payments equilibrium for long periods of time. Indeed, in this case, its foreign debt, as a proportion of GDP, would rise to such a level that would cause loss of international confidence, a decrease in the capacity of acquiring foreign credit, and a currency crisis. On the other hand, if the balance of payments equilibrium growth rate is lower than factor endowments would otherwise allow, the country is constrained to grow at a lower speed.

Through time, objections to Thirlwall's hypotheses have arisen. It is true that the existing studies, both for developed and for emerging countries, suggest that "Thirlwall's Law" cannot be rejected or, yet, that there might be longstanding differences between income elasticities of countries. This notwithstanding, few works suggest an endogenous relationship between the ratio of income elasticities and relative growth rates. The importance of the real exchange rate for the balance of payments constraint and for economic growth is another neglected issue.

This work intends to empirically assess the hypothesis that the elasticities of the balance of payments constrained growth model are endogenous. It furthermore proposes to identify the level of the real exchange rate as one of the elements that explain growth, particularly for developing countries. In all effect, the works based on Thirlwall's (1979) model assume the hypothesis that, in the long-term, relative prices either remain unchanged or

have a negligible impact in the long run. There is, on the other hand, an emerging literature that highlights the influence of the exchange rate on growth, both directly (see, for example, Rodrik, 2008; Gala, 2008; Sampaio and Gala, 2008; Rapetti, et al, 2012) and indirectly - in this case, as it determines the income elasticities (as in Missio and Jayme Jr., 2012).

Besides this introduction and the conclusions, this article is divided into three more sections. The following one discusses demand-led growth models and the relevant theoretical issues. Section 3 in turn presents the model and the data we used, while the fourth one empirically analyses the relationship between the endogeneity of the elasticities and the role of the real exchange rate.

2. DEMAND-LED GROWTH MODELS AND THE ROLE OF ENDOGENOUS ELASTICITIES

Thirlwall (2002, p. 52) notes that “[i]n neoclassical theory, output growth is a function of factor inputs and factor productivity with no recognition that factor inputs are endogenous, and that factor productivity growth may also be a function of the pressure of demand in an economy. In practice, labour is a derived demand from the demand for output itself. Capital is a produced means of production, and is therefore as much a consequence of the growth of output as its cause. Factor productivity growth will be endogenous if there are static and dynamic returns to scale.”

Thirlwall’s first model shows basically that the export demand function is the most important component of autonomous demand in an open economy. The growth of exports thus governs the long-term growth of output, with the other components of demand adapting to it. It is thus assumed that:

$$g_t = y(x_t) \tag{1}$$

where g_t is the growth of output over time and x_t is the growth of exports. The export demand function is straightforward:

$$X_t = A(P_{dt}/P_{ft})^\eta Z_t^\varepsilon \quad (2)$$

which, expressed as rates of change, becomes:

$$x_t = \eta(P_{dt}/P_{ft}) + \varepsilon(z_t) \quad (3)$$

where P_d are domestic prices, P_f are the prices of competitors measured in a common currency, Z is income outside the country, $\eta(< 0)$ is the income elasticity of the demand for exports and $\varepsilon(> 0)$ is the income elasticity of the demand for exports.

The growth of the income of the rest of the world and foreign prices can be considered exogenous, but the rise of domestic prices can be considered endogenous. It is derived from a mark-up pricing equation in which prices are based on unit labour costs and a mark-up rate:

$$P_{dt} = (W_t/R_t)(T_t) \quad (4)$$

where W is the national wage rate, R is the average output of labour and T is $1 +$ the mark-up on unit labour costs. In rates of change,

$$p_{dt} = \omega_t - r_t + \tau_t \quad (5)$$

Productivity gains, in turn, partly depend on the growth of output itself. This is due to static and dynamic returns to scale, as given by Verdoorn's Law:

$$r_t = r_{at} + \lambda(g_t) \quad (6)$$

where r_{at} is the autonomous growth of productivity and λ is Verdoorn's coefficient. Verdoorn's relation establishes the possibility of a virtuous growth cycle, led by demand.

The model's equilibrium solution is reached through the following procedure: (6) is substituted into (5), the latter's results into (3) and, finally, this is substituted into (1). The result is:

$$g_t = \gamma \frac{[\eta(\omega - r_{at} + \tau_t - p_{ft}) + \varepsilon(z_t)]}{1 + \gamma\eta\lambda} \quad (7)$$

The Verdoorn coefficient (λ) enlarges growth rate differences between economies arising from differences in other parameters and variables (which means that the higher is λ , the smaller will be the denominator, since $\eta < 0$). If $\lambda = 0$, the differences are not increased.

If equation (7) is seen merely as an export-led model, without any Verdoorn effect feedback and with constant prices, equation (7) reduces to:

$$g_t = \gamma \varepsilon(z_t) \quad (8)$$

By imposing a balance of payments constraint one obtains $\gamma = 1/\pi$, where π is the income elasticity of the demand for imports. Thus,

$$g_t = \varepsilon(z_t)/\pi \quad \text{or} \quad g_t/z_t = \varepsilon/\pi. \quad (9)$$

This result shows that the growth rate of a country relative to all the others (z) is equiproportional to the ratio of the income elasticities of the demand for exports and imports - as Thirlwall (1979) has shown. This is the Hicks supermultiplier.

Based on a similar formulation, Krugman (1989) proposed inverting the causality of the equations above. In his paper, the growth of the labour force determines the growth of output, and the rapid increase of the latter leads to fast-growing exports - hence the apparently higher income elasticity of the demand for exports. Causality runs, contrary to Kaldorian-inspired models, from growth to the export elasticities. It is thus the case that the income elasticities, according to this approach, are not structural parameters, but rather variables that adjust to reach equilibrium with the ratio between the growth rates of national and world income. In other words, Krugman makes the elasticities endogenous.

As McCombie and Thirlwall (1994) also do, Krugman (1989) rejected the hypothesis that variations of the real exchange rate are an important factor for maintaining balance of payments equilibrium. Since prices do not adjust - for output varies in response to variations of the real exchange rate - and assuming income gaps are differences in factor endowments and productivity, based on this analysis the author concludes that the elasticities that must

adjust to income variations¹. According to him, the explanation is that different growth rates impact trade flows in a manner that creates differences in the apparent elasticity. Elasticity is apparent, in turn, because countries do not in effect face the demand curve, but rather the demand curve supply variations bring about (Carvalho, 2007).

McCombie (2011) considers Krugman's paper important because it discusses precisely the direction of causality. Taking into account the New Trade Theory, the monopolistic competition arising therefrom and increasing returns to scale, Krugman argued that faster growth leads to higher specialisation and the production of new goods to be sold in the world market. Therefore, high-income elasticities of the demand for exports depend on supply-side dynamics and on fast growth, not the other way round.

McCombie (2011) also argued that there are three fatal problems with Krugman's explanation. First, the degree of specialisation and the capacity of profiting from it are, at least partially, a function of the size of the economy. Second, there are many ways slow output growth can lead to a slow growth of total factor productivity. Indeed, there is a rich literature on growth models, such the export led growth using the Hicks supermultiplier, the cumulative causation (Myrdal, 1957), Schumpeterian models induced investment by technical progress, learning by doing, economies of scale among others. Verdoorn's Law supplies substantial evidence on the importance of these elements (McCombie and Thirlwall, 1994; McCombie *et al.*, 2002). Finally, the third problem is that, for a developing country, it is rather unlikely that specialising in a commodity will increase its income elasticity of the demand for exports.

Thirlwall (2005) considers that Krugman's reversed causality hypothesis is a tautology. In Thirlwall's (1979) model, wherein causality runs from the elasticities to growth, the former reflect the structure of production. This is the basic assumption of all classic centre-periphery models. Even amongst industrialised countries (Krugman's main focus), feedback mechanisms described above tend to perpetuate initial differences in income

¹ Thirlwall called this the 45-degrees rule. Cf. McCombie and Thirlwall (1994).

elasticities associated, on the one hand, to “inferior” industrial structures, and, on the other, to “superior” ones (Thirlwall, 2005).

In models inspired by Thirlwall (1979), the “lack of structure” of the elasticities many times involves, as in Krugman’s (1989) approach, the question of the extent to which income elasticities can be taken as exogenous (as the original models in line with Thirlwall’s suggest) or endogenous (as Krugman suggests).

Based on Thirlwall’s original approach, authors such as McCombie and Roberts (2002) and Missio and Jayme Jr. (2012) propose solutions for making the income elasticities endogenous without, however, inverting the direction of causality. These authors maintain the premise that a country’s sustainable growth rate is given by the product of the ratio of its income elasticities and the growth rate of world income, without the need of assuming that these elasticities are exogenous.

It should not be forgotten that, in many instances, the income elasticities of demand of the countries are largely determined by natural resource endowments and the characteristics of the goods they produce. These are the result of history, which are independent of the growth of output. An obvious example is the contrast between the production of primary and industrial goods: primary goods tend to have an income elasticity of demand less than unity (Engel’s Law), while most industrial products have an income elasticity greater than unity (Thirlwall, 2005).

In this vein, a slightly different way of making the elasticities endogenous, which furthermore allows for a structural analysis of their changes, is expanding Thirlwall’s model to a multi-sector approach. By doing so, the sectoral composition of the country’s structure of production and its specialisation pattern makes aggregate elasticities endogenous. This is what Araújo and Lima (2007) intend with their model.

McCombie and Roberts (2002), in turn, propose a balance of payments constraint model with hysteresis in the elasticities. Specifically, the income elasticities of the demand

are a non-linear function of past growth rates (a sufficient condition to break with the equilibrium conditions of the standard model).

Missio and Jayme Jr. (2012) explore the relationship between the exchange rate, structural heterogeneity and the income elasticities of the demand for exports and imports in developing economies. Their goal is to test whether a competitive real exchange rate leads to a diversification of investment and output of sectors that work in global markets. The authors show that real exchange rate undervaluation affects an economy's sectoral composition. The elasticities are endogenous in the authors' model through the level of the real exchange rate. If the latter is depreciated, this might foster research and development, given its positive impact on self-financing conditions and access to credit, thus making it possible to modernise and diversify the structure of production. In the long-term, this leads to higher export capacity and reduced dependence on imports.

3 TESTING THE HYPOTHESIS OF ENDOGENOUS ELASTICITIES AND THE ROLE OF THE REAL EXCHANGE RATE

3.1 DATA SOURCES

In order to analyse the hypothesis that the ratio of the income elasticities is endogenous, as well as the importance of the exchange rate, we estimate income elasticities for a series of countries, using the annual volume of exports and imports and world and domestic income. The data come from the World Development Indicators (World Bank), and they are listed in Table A in appendix.²

To find the real exchange rate we take the World Development Indicators (World Bank). We use the Consumer Price Index (CPI) for the countries listed in table A, with the United States as the basis for all foreign price levels and 2005 as the base-year. Besides the CPI, we also collected time series of the nominal exchange rate, in local currency units per

² The countries selected and the reasons for their choice are in appendix.

U.S. dollars. To examine the endogeneity of elasticities (instrumental variables) we employ the average real exchange rate of the last 10 years for which there is data.

To look into the endogeneity of the ratio of the income elasticities we employ the share of technology-intensive sectors in a country's total exports as an instrument to perform the Durbin-Wu-Hausman (DWH) endogeneity test. We estimate the "share of technology-intensive sectors in total exports" using the Lall's (2001) methodology. The author classifies output into primary products (PP), resource based manufactures (RB), low technology manufactures (LT), medium technology manufactures (MT) and high technology manufactures (HT). Based on this category, we can group MT and HT manufactures into a high technology sector (HT) and RB and LT manufactures into a low technology one (LT), leaving primary products in a category of their own.

We thus took the share of the high technology sector (MT+HT) in total exports as the instrument for the ratio of elasticities, in order to estimate the instrumental variables models. We define this variable as the average value of seven years of variations (2004 to 2010).

The series of domestic product, world product, exports and imports, all taken from the World Development Indicators (World Bank), are measured in constant 2000 US dollars.

The share of the different sectors in a country's total exports, according to Lall's classification (2011), can be found at the website of the Economic Commission for Latin America and the Caribbean, in the Interactive Graphic System of International Economics Trends section (IGSIET).

3.2 AGGREGATE ESTIMATION OF THE ELASTICITIES OF FOREIGN TRADE

In order to test the hypothesis that the ratio of the elasticities is endogenous, we employ the Durbin-Wu-Hausman (DWH) endogeneity test. It tests for endogeneity in a model estimated by instrumental variables, based on Cameron and Trivedi (2009). The instrumental variables estimator (IV) is consistent under the assumption of valid instruments (z). The latter are variables correlated to the regressor x , which satisfy $E(u|Z) = 0$. The IV approach is the

original and most widely used method to estimate the parameters of models with endogenous regressors.

Our research strategy is as follows. We first estimate the ratio of income elasticities of the demand for exports and imports for 38 countries. Then, we run a cross-country regression of the average relative growth rate of output against the previously estimated ratio.

From equation 9 we find the testable equation (balance of payments constrained growth):

$$\left(\frac{y}{z}\right)_i = \beta \left(\frac{\varepsilon_i}{\pi_i}\right) + u_i \quad (10)$$

Where y_i/z is the ratio between national income and world income and ε_i/π_i is the ratio of the income elasticities of the demand for exports and imports. For the simplest version of Thirlwall's Law in equation (10) to be valid, β must be equal to unity. For the endogeneity hypothesis to be valid, ε_i/π_i must be endogenous in this equation.

To obtain these estimates we perform the error correction term (ECT), since it contributes to the parameterization of a Vector Error Correction (VEC) equation. However, the VEC parameterization is not possible for all countries, given that some residuals are auto-correlated, heteroskedastic and non-normally distributed. For these cases, we estimate the parameter using an autoregressive distributed lag model (ADL). This model, besides breaking with the hypothesis of endogenous variables, allows other parameterizations that can adjust for the problems of the residuals (in some cases).

Table 1 displays the estimates of the income elasticities for several countries. The numbers in bold were estimated by the vector error correction model, while those not in bold were estimated by the ADL model.

Table 1
Estimation of the elasticities

Country	Time Period	Elasticities		Ratio	RWGDP	BPCG	GDP	GDP/RWGDP
		Exports	Imports					
Argentina	1962-2011	2,2379	2,503	0,8941	3,4548	3,0889	2,842	0,8226
		[16,8]	[11,1]					
Australia	1960-2011	1,5701	2,0274	0,7744	3,471	2,6881	3,4938	1,0066
		[16,4]	[10,4]					
Belgium	1960-2010	1,4433	1,7918	0,8055	3,4869	2,8087	2,7296	0,7828
		[10,4]	[9,6]					
Brazil	1980-2011	2,2326	2,2853	0,9769	2,7929	2,7285	2,7291	0,9771
		[43,2]	[9,3]					
Cameroon	1968-2011	4,1951	3,8381	1,093	3,1754	3,4707	3,6356	1,1449
		[2,6]	[3,3]					
Canada	1960-2010	1,5221	1,8878	0,8063	3,4869	2,8114	3,2967	0,9454
		[13,3]	[9,97]					
Chile	1970-2011	2,4445	1,5368	1,5906	3,0402	4,8359	4,1227	1,356
		[9,8]	[11,4]					
China	1986-2011	6,0254	1,862	3,236	2,8325	9,1658	9,4374	3,3319
		[27,4]	[9,2]					
Colombia	1960-2010	1,5517	1,4992	1,035	3,4869	3,609	4,1264	1,1834
		[8,2]	[4,2]					
Ivory Coast	1960-2011	1,2367	1,3441	0,9201	3,471	3,1937	3,3494	0,965
		[8,9]	[5,7]					
Dominican Republic	1960-2011	1,5594	0,9055	1,7221	3,471	5,9776	5,162	1,4872
		[8,4]	[20,0]					
Ecuador	1960-2010	2,0555	1,4656	1,4025	3,4869	4,8904	3,8526	1,1049
		[17,98]	[10,8]					
France	1960-2010	2,07522	2,00728	1,0338	3,4869	3,6049	2,8863	0,8278
		[6,3]	[34,9]					
Germany	1970-2010	1,5809	1,9788	0,7989	3,0491	2,436	2	0,6559
		[26,9]	[23,3]					
Hong Kong	1981-2010	2,7504	1,98	1,3891	2,8288	3,9294	4,7643	1,6842
		[7,65]	[34,0]					
India	1960-2011	4,8035	3,1494	1,5252	3,471	5,294	5,004	1,4417
		[6,3]	[3,4]					
Indonesia	1967-2011	2,7768	1,439	1,9297	3,2039	6,1825	5,859	1,8287
		[7,4]	[16,3]					
Italy	1960-2010	1,7213	2,2386	0,7689	3,4869	2,6812	2,7236	0,7811
		[14,3]	[3,7]					
Japan	1960-2010	1,1852	1,1319	1,0471	3,4869	3,6511	3,9156	1,1229
		[3,4]	[3,97]					
South Korea	1966-2010	3,3855	1,3492	2,5093	3,2755	8,2191	6,7434	2,0587
		[17,6]	[19,2]					
Malasia	1960-2010	3,4398	1,4453	2,38	3,4869	8,2988	6,2008	1,7783
		[3,2]	[10,9]					
Mauritius	1976-2011	1,353**	0,8602	1,5729	2,9655	4,6644	4,4118	1,4877
		[2,45]	[10,3]					
Mexico	1960-2011	2,9336	2,3239	1,2624	3,471	4,3817	3,984	1,1478
		[13,4]	[3,48]					
Netherlands	1960-2010	1,5549	1,9507	0,7971	3,4869	2,7794	3,0017	0,8608
		[12,2]	[15,8]					
Paquistan	1960-2011	4,5401	3,3655 **	1,349	3,471	4,6824	5,1463	1,4827
		[4,6]	[2,5]					
Paraguay	1960-2011	2,0107	1,6408	1,2254	3,471	4,2535	4,2231	1,2167
		[6,7]	[13,5]					
Peru	1960-2011	0,8545	0,7602	1,124	3,471	3,9016	3,5285	1,0166
		[5,7]	[5,55]					
Philippines	1960-2011	2,18133	2,06845	1,0546	3,471	3,6604	3,9345	1,1335
		[7,9]	[3,03]					
Singapore	1975-2011	3,4963	1,5583	2,2437	2,9128	6,5352	6,7224	2,3079
		[47,7]	[46,4]					
South Africa	1960-2010	1,21532	1,69164	0,7184	3,4869	2,5051	3,1743	0,9103
		[2,8]	[6,5]					
Sri Lanka	1984-2011	2,01865	1,40247	1,4394	2,9356	4,2253	4,854	1,6535
		[9,96]	[18,8]					
Switzerland	1980-2010	1,76278	3,2693	0,5392	2,7967	1,508	1,6357	0,5849
		[6,4]	[2,2]					
Syria	1975-2010	2,34852	1,36497	1,7206	2,9193	5,0229	4,703	1,611
		[3,7]	[2,6]					
Thailand	1960-2011	2,969	1,319	2,2509	3,471	7,813	6,0069	1,7306
		[6,7]	[13,4]					
Tunisia	1983-2011	1,55875	0,8341	1,8688	2,9295	5,4745	4,0638	1,3872
		[3,9]	[7,4]					
Uruguay	1960-2011	1,57996	2,28502	0,6914	3,471	2,4	2,1805	0,6282
		[8,6]	[22,8]					
Turkey	1987-2011	2,91603	2,08383	1,3994	2,8144	3,9384	4,0906	1,4534
		[6,1]	[2,44]					
United Kingdom	1988-2011	0,875711	0,934777	0,9368	2,7859	2,6098	2,2482	0,807
		[32,2]	[13,2]					

Notes: *Significant at 1%; **Significant at 5%; In bold: VEC; Standard deviation between brackets.
Source: the authors.

The coefficients shown in table 1 have the expected signs. They are, furthermore, significant for all countries, both for exports and imports, at 1% and 5%. Finally, they show that the balance of payments equilibrium growth rate (BPEGR) is close to the actual growth rate of the countries. This is the first evidence in favour of Thirlwall's Law.

3.3 IDENTIFYING THE INSTRUMENTAL VARIABLES

The aim of this section is to present the econometric method to test the hypothesis that the ratio of elasticities is endogenous, as well as justifying the use of the level of exchange rate and the share of high technology manufactures in foreign trade as valid instruments to perform our econometric exercise. When we assume that variables are endogenous, in panel or in cross-section data, we need to use instrumental variables to avoid endogeneity. The statistical test used for this hypothesis is the Durbin-Wu-Hausman (DWH), as well as the traditional Hausman tests, which allows for testing whether the regressor is endogenous.³ The Durbin-Wu-Hausman⁴ (DWH) test is a more robust version of the Hausman test, for it uses the device of augmented regressors (Davidson, 2000).

3.3.1 THE SHARE OF HIGH TECHNOLOGY MANUFACTURES IN FOREIGN TRADE

We chose this variable based on the work of Araújo and Lima (2007). The authors developed a model including various sectors, leading to what they call the Multi-Sectoral Thirlwall's Law (MSTL). It is derived from a Pasinettian framework. The results show that the *per capita* growth rate of a country is directly related to that of its exports (or the sectoral income elasticities multiplied by the growth rate of the world economy) and inversely related to the sectoral income elasticities of the demand for imports. It should further be noted that the sectoral income elasticities of the demand for exports and imports are weighed by coefficients that measure the participation of each sector in, respectively, total exports and imports.

³ For further information on the instrumental variables model, see Cameron and Trivedi (2009).

⁴ The Durbin-Wu-Hausman test is implemented in Stata 11 by the command *estat endogenous*.

The major consequence of this model is that changes in the sectoral composition of the economy's output (i.e., in the structure of production) impact its growth rate. Romero, Silveira and Jayme Jr. (2011) estimated sectoral elasticities for Brazil, obtaining results that support the multi-sector version of Thirlwall's Law. Thus, changes in the sectoral composition of output are reflected in aggregate income elasticities. Similarly, Araújo and Lima (2007) estimated MSTL elasticities for a number of Latin American and Asian countries. They verified that more technology-intensive sectors have higher income elasticities, and that these differences are greater for exports than for imports.

These evidences show that, as industrialization deepens - and, most importantly, as the share of technology-intensive sectors in the economy increases -, the elasticities of exports and imports also vary. This impacts the growth rate of output. Indeed, by making the productive structure of a country dynamic, one allows for the cumulativeness of short-term effects on the economy, which can lead to changes in the long-term patterns of the same country.

Here we therefore assume that the share of high-technology manufactures has a direct impact on the income elasticities. The reason for this is that, according to MSTL and the empirical literature (see Romero, Silveira, Jayme Jr., 2011; Gouvêa and Lima, 2009; Araújo and Lima, 2007), the greater the share of high technology manufactures in the economy, the greater will be the income elasticity of the demand for exports (which relaxes the balance of payments constraint, increasing the ratio of the elasticities). Hence, the faster will also be economic growth.

According to the same hypothesis, the impact of the share of high technology manufactures on economic growth is indirect, i.e, *via* the income elasticities. This can work as a powerful instrument for testing the endogeneity of the elasticities. We used the Lall (2001) criterion for differentiating the technological content of economic sectors, grouping the

medium and high technology manufactures into a single sector based on the average 2004 - 2010 value.

3.3.2 THE LEVEL OF THE REAL EXCHANGE RATE

The use of the level of the real exchange rate as an instrument for the ratio of the elasticities stems from the theory on the Balassa-Samuelson effect, as well as the theoretical and empirical evidences Rodrik (2008), Sampaio and Gala (2008), Ferrari *et al.* (2010), Rapetti, Skott, Razmi (2012) and Missio and Jayme Jr. (2012) find. According to Rodrik (2008) and Sampaio and Gala (2008), exchange rates deviations, calculated by the Balassa-Samuelson effect, are significant in explaining economic growth.

Assuming the validity of Balassa-Samuelson effect, and, even more, taking the level of the real exchange rate as an instrument for the ratio of the income elasticities, it can be said that the real exchange rate somehow controls for the productivity of the economy. Therefore, it has an indirect influence on economic growth through the ratio of the elasticities. In other words, the real exchange rate (and productivity) alters the ratio of the elasticities, consequently affecting economic growth.⁵

Missio and Jayme Jr. (2012) and Ferrari *et al.* (2010) also show that the real exchange rate and the ratio of elasticities have influence on growth. That is to say, the exchange rate might affecting the income elasticities of the demand for exports and imports, either relaxing or tightening the balance of payments constraint on growth, according to Thirlwall's equilibrium equation.

Ferrari *et al.* (2010) investigate the basic hypothesis that managing the real exchange rate can lead to effects that transcend short-term aggregate demand adjustments. It can

⁵ For the theoretical discussion on the Balassa-Samuelson effect, see Balassa (1964^a, 1964b) and Samuelson (1964).

actually shift the elasticities, and hence change the long-term relation between the growth rates of domestic and world output.⁶

We can conclude that McCombie and Roberts (2002) suppose that the real exchange rate has an indirect, long-term effect on the economy's total output. The reason for this is that the exchange rate affects the short-term growth of output (even assuming PPP), thus also transforming the economy's structure of production and, hence, the income elasticities.

Inasmuch as the exchange rate is an essential determinant of the relative prices of the economy, its variations change the incentives for producing numerous goods. This fosters or disarticulates various sectors and productive chains. This discussion is not exclusively related to the distribution of incentives between tradable and non-tradable sectors (Rodrik, 2008), but also, and most importantly, to incentives within tradable sectors themselves. According to the theoretical argument advanced here, the proper management of the exchange rate can redirect income to less traditional (and more transversal) sectors, thereby allowing them to develop. As an undervalued exchange rate makes the prices of non-traditional sectors competitive in the international and domestic markets, these sectors get a (unique) chance of developing themselves (as an outcome of dynamic economies of scale, learning-by-doing etc.) and boosting their price, even their non-price-competitiveness (considering that qualitative gains can be achieved via the same incentives).

Finally, Missio and Jayme Jr. (2012) explores the possibility of a relationship between the level of the exchange rate, structural heterogeneity, and the income elasticities of the demand for exports and imports in developing economies. The authors provide evidence that a competitive exchange rate can induce a diversification of investments and goods in sectors that operate in the world market.

⁶ It is worth mentioning that, in Krugman's model (1989), the expansion of the labour force determines output growth. A rapid rise in the latter would, in turn, lead to fast-growing exports. In other words, the income elasticities become endogenous due to supply-side variables.

3.4. USING INSTRUMENTS TO TEST THE ENDOGENEITY OF ELASTICITIES

According to Cameron and Trivedi (2009), the validity of an instrument cannot be tested in a just-identified model. But it is possible to test overidentifying instruments in an overidentified model by a General Method of Moments (GMM).⁷ The starting point is the fitted value of the criterion function after optimal GMM⁸, i.e., $Q(\hat{\beta}) = \{(1/N)(y - X\hat{\beta})'Z\}\hat{S}^{-1}\{(1/N)Z'(y - X\hat{\beta})\}$. If the population moment conditions $E\{Z'(y - X\beta)\} = 0$ are correct, then $Z'(y - X\hat{\beta}) \simeq 0$, so $Q(\hat{\beta})$ should be close to zero. Under the null hypothesis that all instruments are valid, it can be shown that $Q(\hat{\beta})$ has an asymptotic chi-squared distribution with degrees of freedom equal to the number of overidentifying restrictions.

Large values of $Q(\hat{\beta})$ lead to rejection of $H_0: E\{Z'(y - X\beta)\} = 0$. Rejection is interpreted as indicating that at least one of the instruments is not valid. Tests can have power in other directions, however. It is possible that rejection of H_0 indicates that the model $X\beta$ for the conditional mean is misspecified. Since this is the unique test to validate the overidentifying instruments, failure to reject H_0 does not warranty that all the instruments are valid. This once again highlights the importance of the theoretical argumentation underpinning instruments employed.

3.4.1 IV ESTIMATION AND THE ENDOGENEITY TEST: AN OVERIDENTIFIED MODEL

The fundamental hypothesis for the consistency of the OLS estimator is that the error term is not correlated to the regressor, i.e., $E(u|X) = 0$. If this hypothesis does not hold, then the OLS estimator cannot be interpreted as a causal effect.

For the matter at hand, the exogeneity hypothesis, a usual assumption for testing Thirlwall's Law, is an essential element to find the balance of payments equilibrium growth

⁷ The tests were run in *Stata 11*, using the *estat overid* command after IV regression.

⁸ The GMM estimator is $\hat{\beta}_{GMM} = (X'ZWZ'X)^{-1}X'ZWZ'y$, where W is any full-rank symmetric-weighting matrix.

rate. If the hypothesis is violated, as amongst others McCombie and Roberts (2002) and Missio and Jayme Jr. (2012) suggest, then Thirlwall's equilibrium might not be valid or it might still be valid, but express a bi-directional relationship between the equilibrium growth rate (which reflects the ratio of the elasticities) and actual growth. In other words, if the ratio of the elasticities is exogenous (structural), Thirlwall's (1979) simplest model holds. Sophisticated versions of the model are more appropriate, such as MSTL or a model that includes the level of the real exchange rate as a subsidiary element in balance of payments constrained growth. This is why we test whether the ratio of the elasticities is endogenous, employing the Durbin-Wu-Hausman (DWH) test, as explained above.

The DWH test initially considers that the ratio of the elasticities (ε/π) "variable" is endogenous. It then tests its endogeneity by means of an instrumental variables model. It is worth mentioning that the endogeneity hypothesis imposed on the ratio of the elasticities will "only" be made to perform the DWH test.

The first stage presents the test of the instruments against the "potentially" endogenous variable. It is thus defined:

$$\left(\frac{\varepsilon}{\pi}\right)_i = \beta_{man}.M_i + \beta_{CR}CR_i + u_i \quad (11)$$

where ε/π is the ratio of the trade income elasticities has already defined, M is the share of high-technology manufactured goods in total exports and CR is the level of the real exchange rate.

Equation (11) defines an overidentified model with two instruments, namely, the share of high-technology manufactured goods and the level of the real exchange rate. The advantage of an overidentified model is that it allows for testing overidentifying restrictions, whereby one can test the validity of overidentified instruments via a GMM estimation of the parameters.

The endogeneity test for the ratio of the elasticities is made on the structural equation (10), which has already been defined. We opted for a model without the constant term, for if

we include the latter it would no longer be a test for Thirlwall’s Law. According to Cameron and Trivedi (2009), when there are more instruments than regressors (an overidentified scenario) the most efficient estimators are the two stage least squares (2SLS) and GMM.

However, in an overidentified model, 2SLS and GMM estimators can lead to different results. The 2SLS estimator is more efficient if the errors u_i are independent and homoskedastic. We first present, nevertheless, the results for the first stage of the estimation, which only make sense for a model estimated by 2SLS. The GMM estimator has the same result for the first stage. The estimation is presented in table 2.

Table 2 – First stage regression (equation 11)

Estimator	Standard-errors adjustment	(β_{man}) estimator: share of manufactured goods	(β_{cr}) estimator:
		[t-statistic]	real exchange rate
		{p-value}	[t-statistic]
			{p-value}
2SLS	VCE (Robust)	2,0082*	0,1749*
		[6,49]	[8,84]
		{0,00}	{0,00}
	No adjustments	2,0082*	0,1749*
		[7,14]	[5,68]
		{0,00}	{0,00}

*Significant at 1% ** Significant at 5%
Source: the authors.

The first stage indicates that the instruments are significant in determining the endogeneity of the tested variable. Specifically, both the “share of high-technology manufactured goods” and the “real exchange rate” are significant at 1% in determining the ratio of the income elasticities of the demand for exports and imports.

The validity of the instruments always demands a more careful analysis. Due to this, in addition to the theoretical discussion presented in the former sections, we choose to perform an overidentifying restrictions test, based on equation (10). The results are presented at table 3 and show that the ratio of the elasticities is significant in determining the growth rate. Besides, the Wald test on restrictions rejects the null hypothesis that the estimator of the ratio of the elasticities is equal to unity. It does so at a 10% significance level for the models with adjusted residuals and at 5% for the model with unadjusted residuals, against Thirlwall’s

(1979) simplest model. This findings reveals that there might be other determinants in the canonical model, such as the possibility of capital flows, as Thirlwall and Hussein (1982) have already suggested, or the other factors herein discussed.

Table 3 – Overidentified models: test of equation (10)

Standard-errors adjustment	$\beta(\varepsilon/\pi)$ estimator: ratio of the elastic.		Overidentifying restrictions test: Hansen-Sargan test		$(H_0: \beta_{\varepsilon/\pi} = 1)$ Wald test (restriction):
	[Z-statistic]		Score Chi2	Hansen's J Chi2	Chi2 statistic
	{p-value}		{p-value}	{p-value}	{p-value}
VCE (Robust)	0,9516*		0,03558		3,25
	[35,47]		{0,8504}		{0,0712}
	{0,00}				
No adjustments	0,9516*		0,0238	0,02257	4,01**
	[39,37]		{0,8774}	{0,8806}	{0,0452}
	{0,00}				
WMATRIX (Robust)	0,9528*			0,03558	3,27
	[36,52]			{0,8504}	{0,0707}
	{0,00}				

*Significant at 1% ** Significant at 5%

Source: the authors.

The results of the overidentifying restrictions test do not reject the null hypothesis that all instruments are valid, given that $p > 0,10$ for all identified models: 2SLS (with and without adjusted residuals) and GMM.

In all effect, it was not possible to reject the hypothesis that the share of high-technology manufactured goods and the real exchange rate are valid instruments for the ratio of the income elasticities. Nevertheless, and once more, it is important to test for endogeneity, so that the results presented in table 4 (Wald test on restrictions and overidentification) can be more judiciously analysed.

The test indicates that, for an overidentified model with two instruments (the share of high-technology manufactured goods and the real exchange rate), the hypothesis that the ratio of the elasticities is an exogenous determinant of relative growth cannot be rejected. This is another empirical evidence in favour of Thirlwall's Law. Likewise, the level of the real exchange rate is a subsidiary element of growth, particularly as it affects non-price competitiveness.

Table 4 – Endogeneity: robust Durbin-Wu-Hausman test

H ₀ = the variables are exogenous	Standard-errors adjustment	Robust Score Chi2	Robust Regression F	GMM C Statistic Chi2
		{p-value}	{p-value}	{p-value}
2SLS	VCE (Robust)	132.096 {0,2504}	14.072 {0,2433}	
	No adjustments	14.425 {0,2297}	14.205 {0,2411}	
GMM	WMATRIX (Robust)			13.054 {0,2532}

* Significant at 1% ** Significant at 5%;
Source: the authors.

5 CONCLUSIONS

This paper finds evidence that the level of the real exchange rate is a significant and important determinant of the trade income elasticities. This holds in spite of the fact that the endogeneity tests indicated that the hypothesis of endogenous elasticities is not valid.

Indeed, the level of the real exchange rate affects the ratio of the elasticities by increasing the gains from the sale of tradable goods, profit margins and investment, thus leading to the diversification of the investments and products of sectors that operate in the world market⁹. A managed exchange rate relaxes the constraint and maintains the balance of payments in equilibrium, as it increases the economy's competitiveness (assuming that the income elasticity of the demand for exports of primary goods is low and that the income elasticity of the demand for imports of manufactures is high). Not only so, it also spurs technological development, in light of its benefits to funding and credit, thus stimulating research and innovation. Consequently, the level of exchange rate can affect the supply-side of the economy in the long-term. This theoretical framework leads to the understanding that the income elasticities of the demand for exports and imports are influenced by the real exchange rate, inasmuch as they depend on technological development and the diversification of production.

⁹ This condition depends, however, on the economy's growth regime: it cannot apply to wage-led growth. On this topic, see Missio and Jayme Jr. (2012).

Indeed, technological progress in developing countries depends on companies having available funds. In this regard, exchange rate devaluations, as they redistribute income from wages to profits, provide companies with access to larger sums of resources to engage in innovative activities. Therefore, the empirical evidence and the theoretical discussion we present endorse the fact that the level of the real exchange rate plays a subsidiary role in the long-term growth of the economies, particularly developing ones. It should be noted, however, that this is a result of higher ratio of income elasticities, which in turn relax the balance of payments constraint and spur economic growth, and not of a price competitiveness-induced improvement in trade.

Regarding the endogeneity of the elasticities, the results do not reject the hypothesis that the ratio of the elasticities is exogenous. They therefore support Thirlwall's model, and not Krugman's 45-degree rule (Krugman, 1989). The restrictions test for the validity of Thirlwall's Law implies, however, that the author's canonical model is not sufficient to explain the growth of the analysed countries. As previously mentioned, this suggests that other variables, such as capital flows and foreign debt, should also be taken into consideration when studying growth. The literature has already identified and tested models for these variables: namely, Thirlwall and Hussain (1982) proposed the theoretical model that acknowledges the importance of capital flows in balance of payments constrained growth, and Moreno-Brid (1998) proposed the model that includes a sustainable debt constraint. Future research can include capital flows in the equation, so it can be possible to analyse the relationship among this variable, trade income elasticities, the level of exchange rate, and multi-sectoral Thirlwall's law.

Finally, the role of the level of the real exchange rate cannot be neglected when analysing demand-led growth in balance of payments constrained growth models, particularly in light of its stimulus to more productive and technology-intensive sectors. In other words, the real exchange rate is one of the determinants of income elasticity.

6 REFERENCES

- ARAUJO, R. A.; LIMA, G. T. A Structural economics-dynamics approach to balance-of payments constrained growth. *Cambridge Journal of Economics*, 31, 755-774, 2007.
- BALASSA, B. An empirical demonstration of classical comparative cost theory. *Review of Economics and Statistics*, Cambridge, v. 45, n. 3, p. 231-238, ago. 1964.
- . The purchasing-power parity doctrine: a reappraisal. *Journal of Political Economy*, Chicago, v. 72, n. 6, p. 584-596, dez. 1964.
- BLECKER, R.; RAZMI, A. The fallacy of composition and contractionary devaluations: output effects of real exchange rate shocks in semi-industrialised countries. *Cambridge Journal of Economics*, 32 (1), 83–109. 2008.
- CAMERON, A. C; TRIVEDI, P. K. *Microeconometrics Using Stata*. Texas: Stata Press, 2009.
- CARVALHO, V. R. S. *A restrição externa e a perda de dinamismo da economia brasileira: investigando as relações entre estrutura produtiva e crescimento econômico*. Dissertação de mestrado, FEA/USP. 29º prêmio BNDES de economia, 2007.
- DAVIDSON, J. *Econometric Theory*. Oxford: Blackwell, 2000.
- FERRARI, M. A. R.; FREITAS, F. N. P.; BARBOSA FILHO, N. H. O Papel da Taxa de Câmbio Real nos Modelos de Restrição Externa: Uma proposta de releitura com elasticidades endógenas. In: *III International Meeting of the Brazilian Keynesian Association*, São Paulo, 2010.
- GALA, P. Real Exchange rate levels and economic development: theoretical analysis and econometric evidence. *Cambridge Journal of Economics*, vol. 32, p. 273-288, mar., 2008.
- GOUVEA, R. R.; LIMA, G. T. Structural change, balance-of-payments constrained and economic growth: evidence from the multi-sectoral Thirlwall's Law. *Anais do XXXVII Encontro Nacional de Economia da ANPEC*, Dezembro, 2009.
- KALDOR, N. *Causes of the slow rate of economic growth of the United Kingdom*, Cambridge: Cambridge University Press, 1966.
- KRUGMAN, P. Differences in Income Elasticities and Trends in Real Exchange Rates. *European Economic Review*. V. 33, 1989.
- LALL, S. *Competitiveness, technology and skills*. Cheltenham: Edward Elgar, 2001.
- MCCOMBIE, J. S. L. Criticisms and defences of the balance-of-payments constrained growth model: some old, some new. *PSL Quarterly Review*. vol. 64, no. 259, 353–92. 2011.
- MCCOMBIE J.S.L, PUGNO M. and SORO B. (eds.) *Productivity growth and economic performance: essays on Verdoorn's Law*, Basingstoke: Palgrave Macmillan. 2002.
- MCCOMBIE, J. S. L, ROBERTS, M. The role of the balance of payments in economic growth. In: Setterfield, M. (org.). *The Economics of Demand Led-Growth*. Edward Elgar: Aldershot, 2002.
- MCCOMBIE, J. S. L.; THIRLWALL, A. P. *Economic Growth and the Balance-of-Payments Constraint*. London: St. Martin's Press. 1994.
- MISSIO, F.; JAYME JR, F. G. Structural Heterogeneity and Endogeneity of Elasticities on the Balance of Payments Constrained Growth Model. In: Souziakis, Elias; Cerqueira,

- Pedro. (Org.) *Models of Balance of Payments Constrained Growth*. 1ed. London: Palgrave, v. 1, p. 239-267. 2012.
- MORENO-BRID, J. C. Mexico's Economic Growth and the Balance of Payments Constraints. *International Review of Applied Economics*, 1998.
- MYRDAL G. *Economic theory and underdeveloped regions*, London: Duckworth. 1957.
- RAPETTI, M., P. SKOTT, A. RAZMI. The Real Exchange Rate and Economic Growth: Are Developing Countries Special? *International Review of Applied Economics*, 26(6), pp. 735-56.
- RODRIK, D. The Real Exchange Rate and Economic Growth. *Brookings Papers on Economic Activity*, vol.2 pp 365-412. 2008.
- ROMERO, J. P.; SILVEIRA, F.; JAYME JR, F. G. Structural Change and Balance of Payments Constrained Growth: Theory and Brazilian Case. *Cepal Review*, 2011. No prelo.
- SAMUELSON, P. Theoretical notes on trade problems. *Review of Economics and Statistics*, Cambridge, v. 46, n. 2, p. 145-154, maio 1964.
- SAMPAIO, D. M. S.; GALA, P. Desequilíbrio Cambial e Crescimento Econômico – Uma análise empírica baseada no modelo Balassa-Samuelson. *Encontro Nacional de Economia da ANPEC*, 2008.
- SETTERFIELD, M. The remarkable durability of Thirlwall's Law. *Trinity College Department of Economics Working Paper*, n. 11-05, jun, 2011.
- THIRLWALL, A. Balance of Payments Constraint as an Explanation of International Growth Rate Differences. *Banca Nazionale del Lavoro Quarterly Review*. March, pp. 45-53, 1979.
- THIRLWALL, A. P. *The Nature of Economic Growth: An Alternative Framework for Understanding the Performance of Nations*. Edgar Elgar, Cheltenham, 2002.
- THIRLWALL, A. P. Balance of Payments Constrained Growth Models: History and Overview. *Workshop on 'Thirlwall's Law and Balance of Payments Constrained Growth*, University of Coimbra, 24-25 Junho, 2011.
- THIRLWALL, A. P.; HUSSAIN, M. N. The balance of payments constraint, capital flows and growth rates differences between developing countries. *Oxford Economic Papers*, v. 34, p. 498-509, 1982.

Appendix: Countries of the sample

We follow Blecker and Razmi (2008) to select the countries used in this study. The authors restricted their sample to developing countries, in which the export of manufactured goods could have a large influence on their aggregate growth.

The first group of countries to be considered are the largest developing countries whose exports consists of at least 70% of manufactured products. This is because the manufactured goods, by hypothesis, have a higher possibility of differentiation than commodities and primary products. This share corresponds to the average of 68% of manufactured exports during the period 1999-2003 reported by UNCTAD (2005). Using this methodology as a reference (share of 70%), countries that meet this criterion were updated considering its export in the last year available. The 18 developing countries that meet the Blecker and Razmi (2008)'s paper were: Bangladesh, China, South Korea, Philippines, Hong Kong, India, Jamaica, Malaysia, Mauritius, Mexico, Pakistan, Dominican Republic, Singapore, Sri Lanka, Taiwan, Thailand, Tunisia and Turkey.

These countries were submitted to the discretion of technological classification of Lall (2001). For the purposes of this work, it is expected that if the sum of the ratings RN, LV, MV and HV is above 70 percent, they are manufactured. Only Jamaica does not meet the criteria and is therefore excluded from the test. Besides Jamaica, Taiwan and Bangladesh do not have enough data, which also justified the exclusion of these countries.

Besides, according to Blecker and Razmi (2008), we considered in this study a sample of industrialized countries consisting of nine of the ten largest importers of manufactured goods from developing nations. United States are excluded from the sample because they are used as a reference for all other countries. Furthermore, Australia is included in this sample. Thus, the countries are Australia, Belgium, Canada, France, Holland, England, Italy, Japan and Switzerland.

Finally, although a sample of countries whose exports manufactured goods is less than 70% are included. These countries were selected according to data availability (for Russia, for example, there is not sufficient data) and because of the importance of the country in international trade. The group of developing countries with export basket is less than 70 percent manufactured chosen for the study are: South Africa, Argentina, Brazil, Cameroon, Chile, Colombia, Côte d'Ivoire, Ecuador, Indonesia, Paraguay, Peru Syria and Uruguay.

Tabela A – Manufatures Exports (% total)

PAÍSES	ANO	PP	MRN	MBT	MMT	MAT	Others
<i>Developing Countries</i>							
<i>Manufacturies</i>							
≥ 70%							
China	2011	2,29	9,67	30,32	24,45	32,80	0,47
South Korea	2011	0,75	18,26	9,12	44,54	26,51	0,82
Filipines	2011	7,85	18,26	6,12	14,50	30,89	22,38
Hong Kong	2011	1,25	7,85	18,74	17,51	48,01	6,65
India	2010	12,84	38,16	20,67	18,77	7,33	2,23
Malaysia	2011	17,17	24,28	9,51	16,03	32,23	0,79
Mauricio Islands	2011	4,80	33,26	51,93	5,58	2,51	1,91
Mexico	2011	18,91	9,28	8,59	37,74	22,31	3,16
Paquistan	2011	18,98	11,78	59,07	9,03	1,07	0,08
Dominican Republic	2011	10,15	25,40	34,51	24,02	5,52	0,41
Singapore	2011	0,94	27,91	5,07	19,90	37,26	8,91
Sri Lanka	2011	24,95	18,70	47,07	5,69	1,12	2,46
Tayland	2011	12,88	23,41	11,21	29,86	18,16	4,48
Tunisia	2010	17,02	13,13	32,88	25,65	11,21	0,11
Turkey	2011	7,76	17,80	33,69	33,61	4,23	2,91
<i>Developing Countries:</i>							
<i>Manufacturies</i>							
≤ 70%							
Sout Africa	2011	29,61	29,07	4,69	25,74	2,60	8,29
Argentina	2011	45,55	20,44	3,72	22,56	2,62	5,10
Brazil	2011	48,98	19,53	5,05	18,99	4,28	3,16
Cameroon	2010	64,21	19,07	2,18	3,26	0,50	0,77
Chile	2011	35,27	54,24	2,62	5,35	0,63	1,89
Colombia	2011	64,57	14,78	5,02	8,10	2,06	5,47
Ivory Coast	2011	65,88	20,46	2,80	4,09	1,53	5,24
Equador	2011	78,58	14,54	2,24	3,60	0,40	0,63
Indonesia	2011	45,62	25,78	11,08	11,49	4,90	1,12
Paraguay	2011	77,58	13,31	6,23	1,67	1,07	0,14
Peru	2011	47,39	22,21	5,87	2,23	0,33	21,97
Siria	2010	55,04	21,25	13,57	8,86	1,09	0,20
Uruguay	2009	57,82	19,30	11,34	7,03	2,48	2,03

Fonte: Elaborado pelo autor com base nos dados da *Economic Comission for Latin America and The Caribbean – SIGCI*, agregado segundo Lall (2001).