Thirlwall's Law and the Specification of Export and Import Demand Functions: An Investigation of the Impact of Relative Productivity Growth on Trade Performance[1]

João P. Romero
Centro de Desenvolvimento e Planejamento Regional (CEDEPLAR), Universidade Federal de Minas Gerais (UFMG).
Email: jpromero@cedeplar.ufmg.br

John S. L. McCombie
Department of Land Economy, University of Cambridge.
Email: jslm2@cam.ac.uk

Abstract: The contribution of this paper is threefold. Firstly, it proposes a general specification for export and import functions that encompass the contributions of both Kaldorian and Schumpeterian literatures on the determinants of trade performance. Secondly, the paper provides evidence of the impact of non-price competitiveness, measured by relative total factor productivity growth, on export and import growth in different technological sectors. Thirdly, it shows that using the expanded export and import functions leads to an expanded Thirlwall's Law, which solves the inconsistency between the Kaldor-Dixon-Thirlwall and the balance-of-payments constrained growth models.

CAMBRIDGE CENTRE FOR ECONOMIC AND PUBLIC POLICY

CCEPP WP02-16

DEPARTMENT OF LAND ECONOMY

UNIVERSITY OF CAMBRIDGE

JUNE 2016

[1] Corresponding author: João P. Romero. Address: Rua Coronel Murta 668, Mangabeiras – Belo Horizonte, MG. CEP 30315-140.

1. Introduction

The Kaldor-Dixon-Thirlwall model developed by Dixon and Thirlwall (1975) is the canonical model of economic growth in the Kaldorian tradition. This model sought to integrate Kaldor's (1966; 1970) main contributions to understanding the process of economic growth, while providing a formal structure to describe this process. In this model, the growth of external demand leads to output and productivity growth, which results in gains in price competitiveness, leading to increases in export demand, and so on.

In spite of its importance, the original Kaldor-Dixon-Thirlwall model is inconsistent with another influential Kaldorian model: the balance-of-payments constrained growth model. The latter, developed by Thirlwall (1979), emphasises that balance-of-payments disequilibria constrain the growth of internal demand, curtailing the process of cumulative growth described by Dixon and Thirlwall (1975). In principle, this constraint can be incorporated into Dixon and Thirlwall's (1975) model (e.g. Thirlwall and Dixon, 1979; Blecker, 2013). However, in Thirlwall's (1979) approach, changes in relative prices do not affect export and import growth in the long-term, either due to the elasticity pessimism or due to the long-term constancy of relative prices (see Blecker, 2013). Without price effects on export growth, the mechanism of cumulative causation described in the Kaldor-Dixon-Thirlwall model ceases to operate and the model loses much of its relevance. This is a serious limitation, given that there is a considerable amount of evidence suggesting that price competition does not significantly affect export performance in the long-term (see McCombie and Thirlwall, 1994).

A possible solution to this limitation of the Kaldor-Dixon-Thirlwall model is to change the channel through which cumulative causation operates. As Roberts (2002) and Setterfield (2011) have stressed, if productivity growth impacts on both price and non-price competitiveness, then cumulative growth occurs in spite of the neutrality of price competitiveness in the long-term. In this alternative approach, external demand leads to output and productivity growth, which generates increases in the quality of production (instead of, or in spite of, reducing prices), which then leads to increases in export demand, and so on. Nonetheless, the quality of the products of competing countries must be taken into account as well, given that it influences the non-price competitiveness of local production. Thus, as normally considered regarding price competitiveness, for the non-price competitiveness of domestic production to improve, it is actually necessary to obtain higher productivity growth than that of foreign competitors.

Following this alternative approach, it is possible to derive an expanded Thirlwall's Law that explicitly incorporates the importance of non-price factors for long-term growth and solves the main critique directed at the Kaldor-Dixon-Thirlwall model. This expanded Thirlwall's Law is found using a balance-of-payments constrained growth framework, while adopting expanded export and import functions that explicitly account for non-price competitiveness via relative productivity growth. Empirical studies on the determinants of trade inspired in Schumpeter's (1943) ideas use measures of relative technological competitiveness and productive capacity amongst the determinants of trade performance (e.g. Fagerberg, 1988; Greenhalgh, 1990; Amable and Verspagen, 1995). These variables, however, are only part of the factors that encompass non-price competitiveness. Relative productivity growth, in turn, encompasses not only technological competitiveness, but also other non-price competitiveness factors. Evidently, productivity growth incorporates changes in costs and efficiency as well. However, in econometric investigations, the effect of productivity growth on export and import growth captures only non-price competitiveness when changes in relative prices are controlled for.

Furthermore, recent works have shown that the sectoral composition of trade influences the equilibrium growth rate due to differences in income elasticities of demand for goods from different sectors (e.g. Araújo and Lima, 2007; Gouvea and Lima, 2010; Romero and McCombie, 2016a). Consequently, it is also important to investigate whether non-price competitiveness has different effects on trade performance across sectors.

The contribution of this paper is threefold. Firstly, it proposes a general specification for export and import functions that encompass the contributions of both Kaldorian and Schumpeterian literatures on the determinants of trade performance. Secondly, it shows that using these expanded export and import functions leads to an expanded Thirlwall's Law, which solves the inconsistency between the Kaldor-Dixon-Thirlwall and the balance-of-payments constrained growth models by introducing the direct effect of productivity growth on export and import growth via improvements in non-price competitiveness. Thirdly, the paper investigates the impact of non-price competitiveness, measured by relative total factor productivity growth, on export and import growth by technological sector. To the best of our knowledge, this relationship has never before been investigated empirically. In order to do so, this paper's tests combine trade data with productivity data at industry-level, in a sample of 11 manufacturing industries in 7 developed countries over the period 1984-2006.[2] Furthermore, the industries were divided in two groups, low-tech and high-tech, in order to assess whether the parameters differ between technological sectors. This empirical analysis provides evidence of the validity of the expanded export and import functions and of the expanded Thirlwall's Law.

The paper is divided in 5 sections including this introduction. Section 2 discusses the specification of export and import demand functions, taking into account both the Kaldorian and the Schumpeterian literatures that investigate the determinants of trade performance. Section 3 then presents the expanded Thirlwall's Law both in its

[2] 2006 is taken as the terminal date to avoid the distortions to the relationships caused by the Great Recession.

aggregate and its multi-sectoral forms. Section 4 presents an empirical investigation, comparing the different specifications of export and import demand functions and assessing the fit of the equilibrium growth rates calculated following the different versions of Thirlwall's Law in relation to the actual growth rates of the countries analysed during the period under investigation. Section 5 presents the paper's conclusions.

2. Demand functions

Notwithstanding the importance of the income elasticities in balance-of-payments constrained growth models, these elasticities are still a black box. Income elasticities are normally associated with non-price factors, so that the higher a country's non-price competitiveness is, the higher is its income elasticity of demand for exports, the opposite holding for imports. However, only a few empirical works have attempted to test what are the specific non-price factors behind the income elasticities of demand (e.g. Greenhalgh, 1990).

As a first approximation to the determinants of the income elasticities of demand for exports and imports, Setterfield (2011) has proposed that the magnitude of income elasticities depends on the levels of productivity in the domestic economy and in the world economy, respectively. According to Setterfield (2011, p. 415), "the basic hypothesis here is that the higher is the level of productivity, the higher is the quality of goods produced in a particular region, and so the larger will be the increase in demand for the region's output associated with any given increase in income (*ceteris paribus*)".[3]

However, the quality of the products of competing countries affects the magnitude of income elasticities as well, given that it influences the non-price competitiveness of local production. Thus, this effect must also be considered. In effect, studies that estimate demand functions for specific products normally take into account the price and quality of competitors (e.g. Hausman, 1997; Nevo, 2001). Furtheremore, the demand functions used in the Kaldorian literature take into account both domestic and foreign prices when measuring price competitiveness. Hence, measures of non-price competitiveness should enter in a similar way.

Ideally, the demand function of a given good should take into account the features of the product and of the competitors' products, as well as their prices and the income of the consumers (e.g. Hausman, 1997; Nevo, 2001). However, taking into account the different characteristics of each good is an extremely difficult task, especially in macroeconomic investigations. Traditionally, the Kaldorian literature considers that non-price factors are captured in the income elasticity of demand, assuming that goods

[3] It is important to note that the model has the same mechanism of the original Kaldor-Dixon-Thirlwall model, in which productivity growth impacts on export growth. The only difference is the channel through which this impact operates, changing from price to non-price competitiveness. Hence, the model does not subvert the Kaldorian demand oriented approach (see Setterfield, 2011).

with higher demand have higher quality, given relative prices. This specification, therefore, is a second-best option, adopted in face of unobservable differences in quality (amongst other non-price competitiveness factors). By contrast, introducing differences in productivity to capture differences in the non-price competitiveness of the products of competing countries provides more information on the determinants of export and import demand.

However, comparisons of productivity between countries are only meaningful at a disaggregated level. When using aggregate data, introducing relative productivity into demand functions involves a more stringent assumption, given that comparing the aggregate productivity of different countries disregards differences in the sectoral composition of production between countries. In this case, if two countries have different productive structures and different sectoral compositions of trade, then comparing their aggregate productivity is like comparing oranges and computers even if their productivity is exactly the same in each sector. Thus, although this critique could be directed to any investigation that does not adopt a perfectly disaggregated level of analysis, which is an impossible task, it is possible to argue that comparing the productivities of each industry in different countries involves a considerably less stringent assumption than comparing aggregate productivities.

To sum up, adopting a disaggregated approach to the determinants of export and import growth reveals that different goods present: (i) different income elasticities of demand, due to differences in their intrinsic characteristics, i.e. inter-product desirability; and (ii) different non-price elasticities of demand, due to differences in their quality and other non-price competitiveness factors, i.e. intra-product desirability. In other words, the demand for the production of a country can increase faster than the demand for the production of another country either: (i) because individuals prefer to consume the computers produced by the former in relation to the bananas produced by the latter when their income increases; or/and (ii) because the computers produced by the former present higher quality than the computers produced by the latter.

2.1. Kaldorian demand functions

Thirlwall's (1979) model employs standard export and import demand functions, as used by Houthakker and Maggee (1969):

$$X = a\left(\frac{EP_f}{P}\right)^{\eta} Z^{\varepsilon} \tag{1}$$

$$M = b\left(\frac{P}{EP_f}\right)^{\psi} Y^{\pi} \tag{2}$$

where E is the exchange rate, M is imports, X is exports, and P and P_f are the domestic and the foreign price levels, respectively. Moreover, Z and Y are the foreign and domestic income levels, $\eta < 0$ and $\psi < 0$ are the price elasticities of demand for exports and imports, $\varepsilon > 0$ and $\pi > 0$ are the income-elasticities of demand for exports and imports, respectively. Finally, a and b are constants.

Consequently, as emphasised in the Kaldorian tradition, in the demand functions (1) and (2), the non-price competitiveness of local production is captured by the income elasticities of demand (see McCombie and Thirlwall, 1994).

The vast majority of works that have investigated the empirical validity of Thirlwall's Law employed demand functions as specified in equations (1) and (2) (e.g. Perraton, 2003; Bagnai, 2010). In general, these works confirm the predictions of the model, with price elasticities being negative, although often not significant, while income elasticities are positive and significant. Furthermore, differences in income elasticities between countries are interpreted as evidence that these elasticities capture the non-price competitiveness of each country's production.

2.2. Schumpeterian demand functions

Following Schumpeter's (1934; 1943) emphasis on the importance of technological competitiveness for trade performance, Schumpeterian works have sought to investigate the determinants of trade specifically accounting for technological competitiveness (e.g. Greenhalgh, 1990; Greenhalgh *et al.*, 1994; Amable and Verspagen, 1995; Wakelin, 1998).

Although there is no consensus in the Schumpeterian literature about the specification of the relationship between technological competitiveness and trade, Fagerberg's (1988) export and import functions represent the core ideas of the Schumpeterian approach to the determinants of trade:

$$\frac{X}{Z} = a\left(\frac{EP_f}{P}\right)^{\eta}\left(\frac{T}{T_f}\right)^{\mu} C^{\sigma} \tag{3}$$

$$\frac{M}{Y} = b\left(\frac{P}{EP_f}\right)^{\psi}\left(\frac{T_f}{T}\right)^{\nu} C^{\varsigma} \tag{4}$$

where T denotes the level of technological competitiveness, C denotes productive capacity (or the capacity to attend to growing demand), μ and ν are the technology elasticities of demand for exports and imports, respectively, and σ and ς are the productive capacity elasticity of demand for exports and imports, respectively. Fagerberg (1988) introduces capacity in the functions assuming that the capacity of local production to attend to growing demand influences the total amount of exports and imports.

Most works in the Schumpeterian literature focus only on export performance. These works have found that both technological competitiveness and productive capacity influence trade performance when employing the specification described in equation (3) (e.g. Soete, 1981; Hughes, 1986; Fagerberg, 1988; Magnier and Toujas-Bernate, 1994; Amable and Verspagen, 1995; Wakelin, 1998). In these studies, patents and R&D are normally used as proxies for technological competitiveness, while investment is normally adopted as a proxy for productive capacity. A number of Schumpeterian works use the share of exports in world trade as the dependent variable in equation (3). A demonstration of how using this alternative specification is equivalent to using the share of exports in world income in the export function (3) is presented in Appendix 1.

2.3. General demand functions

Combining the empirical evidence found in the Kaldorian and the Schumpeterian literatures, it is possible to arrive at a general form for export and import demand functions, given by:

$$X = a\left(\frac{EP_f}{P}\right)^{\eta}\left(\frac{N}{N_f}\right)^{\mu} C^{\sigma} Z^{\varepsilon} \tag{5}$$

$$M = b\left(\frac{P}{EP_f}\right)^{\psi}\left(\frac{N_f}{N}\right)^{\nu} C^{\varsigma} Y^{\pi} \tag{6}$$

where $N = O^{\omega}T$ denotes non-price competitiveness, with *O* denoting other non-price competitiveness factors apart from technological competitiveness (*T*). Hence, N is more general than the technological competitiveness (*T*) emphasised in the Schumpeterian literature. Hence, assuming that productivity growth is not only associated with cost reductions but also with quality improvements, productivity can be used as a proxy for *N* when prices are already accounted for.

Equations (5) and (6) encompass both the Kaldorian and the Schumpeterian approaches to trade performance. The difference between the two is represented in the assumptions made about the parameters of the general functions. On the one hand, the Kaldorian literature assumes that $\mu = \sigma = 0$ for exports and $\nu = \varsigma = 0$ for imports, so that non-price competitiveness factors and productive capacity are captured by the income elasticities of demand $\pi, \varepsilon \neq 0$. On the other hand, the Schumpeterian literature assumes that $\mu, \sigma \neq 0$ for exports and $\nu, \varsigma \neq 0$ for imports, so that technological competitiveness and productive capacity are explicitly accounted for, while income elasticities of demand are assumed fixed $\varepsilon = \pi = 1$ and other non-price competitiveness factors (*O*) are not taken into account, i.e. $\omega = 0$.[4] These assumptions are summarized in Table 1.

As mentioned before, however, it is crucial to understand the implications of estimating these general demand functions for different sectors. In this case, although part of the non-price competitiveness factors associated with the production of each sector is removed from the income elasticities with the introduction of relative productivity in the demand functions, this variable captures only *intra-sector* non-price competitiveness, not taking into account *inter-sector* non-price competitiveness. This stems from the specification adopted for the demand functions, which does not take into account the cross non-price elasticities of demand. This specification, therefore, allows income elasticities of demand to differ between sectors, keeping the central role of these elasticities as stressed in the Kaldorian literature. Hence, as income grows, demand for different products grows at different rates following consumers' preferences *between different products*, in spite of the quality of each product in relation to the quality of its competitors *within the same product category*.

Table 1: Kaldorian and Schumpeterian specifications of export and import demand functions

Parameter	Kaldorian	Schumpeterian
ω	-	$= 0$
Export function		
μ	$= 0$	> 0
σ	$= 0$	> 0
ε	> 0	$= 1$
Import function		
ν	$= 0$	> 0
ς	$= 0$	< 0
π	> 0	$= 1$

Source: Authors' elaboration.

3. Expanded Thirlwall's Law

Using the general export and import functions it is possible to derive an expanded version of the balance-of-payments constrained growth model developed by Thirlwall (1979). Taking logarithms and differentiating equations (5) and (6) with respect to time yields:

$$\hat{X} = \eta(\hat{P} - \hat{P}_f - \hat{E}) + \varepsilon\hat{Z} + \mu(\hat{N} - \hat{N}_f) + \sigma\hat{C} \qquad (7)$$

[4] More generally, the Schumpeterian literature assumes that there are no differences between countries in the values of the income elasticities of demand.

$$\hat{M} = \psi(\hat{P}_f - \hat{P} + \hat{E}) + \pi\hat{Y} + \nu(\hat{N}_f - \hat{N}) - \varsigma\hat{C} \tag{8}$$

where the circumflex over the variables indicate growth rates.

Thus, considering the following balance-of-payments equilibrium condition:

$$\hat{X} + \hat{P} = \hat{M} + \hat{P}_f + \hat{E} \tag{9}$$

Substituting equations (7) and (8) into equation (9) yields the long-term rate of growth of domestic income compatible with balance-of-payments equilibrium:

$$\hat{Y}_{BOP} = \frac{(1+\eta+\psi)(\hat{P} - \hat{P}_f - \hat{E}) + (\mu+\nu)(\hat{N} - \hat{N}_f) + (\sigma+\varsigma)\hat{C} + \varepsilon\hat{Z}}{\pi} \tag{10}$$

Finally, if relative prices are assumed to be constant in the long run, or if the price elasticities sum to unity (i.e. the Marshall-Lerner condition does not hold), then equation (10) can be reduced to express the Extended Thirlwall's Law (E-TL):

$$\hat{Y}_{BOP} = \frac{(\mu+\nu)(\hat{N} - \hat{N}_f) + (\sigma+\varsigma)\hat{C} + \varepsilon\hat{Z}}{\pi} \tag{11}$$

Thus, equation (11) shows that higher growth rates of productive capacity and of non-price competitiveness lead to higher equilibrium growth rates, *ceteris paribus*.

Analogously to the MSTL, it is also possible to derive the Extended Multi-Sectoral Thirlwall's Law (E-MSTL) by representing equations (7) and (8) for each sector i, substituting these equations in a multi-sectoral balance-of-payments equilibrium condition and assuming once again that relative prices are constant:

$$\hat{Y}_{BOP} = \frac{\left(\sum_{i=1}^{k} (\phi_i\mu_i + \theta_i\nu_i)(\hat{N}_i - \hat{N}_{fi}) + (\phi_i\sigma_i + \theta_i\varsigma_i)\hat{C}_i + \phi_i\varepsilon_i\hat{Z}\right)}{\left(\sum_{i=1}^{k} \theta_i\pi_i\right)} \tag{12}$$

where ϕ_i and θ_i are the shares of each sector in total exports and imports, respectively.

4. Empirical investigation

4.1. Estimation method

Using the general export and import demand functions given by equations (5) and (6) is possible to test the hypotheses adopted in the Kaldorian and the Schumpeterian literatures. Thus, taking logarithms of these equations gives the equations to be estimated:

$$\ln X_{ijt} = \beta_0 - \beta_1 \ln P_{ijt} + \beta_1 \ln P_{fijt} + \beta_2 \ln N_{ijt} - \beta_2 \ln N_{fijt} + \beta_3 \ln C_{ijt} + \beta_4 \ln Z_{jt} + u_{ijt} \qquad (13)$$

$$\ln M_{ijt} = \beta_5 - \beta_6 \ln P_{fijt} + \beta_6 \ln P_{ijt} + \beta_7 \ln N_{fijt} - \beta_7 \ln N_{ijt} - \beta_8 \ln C_{ijt} + \beta_9 \ln Y_{jt} + u_{ijt} \qquad (14)$$

where i are industries in j countries at time t.

There are two econometric problems involved in estimating equations (13) and (14). Firstly, it is important to control for unobserved country and industry fixed effects associated with the explanatory variables. Secondly, it also important to control for simultaneity related to several of the explanatory variables: the growth rates of domestic prices, productivity, and capital stock (C) in equation (13); and the growth rates of domestic income, prices, productivity and capital stock in equation (14). Exports might affect domestic prices and productivity through increasing returns, and capital stock through the impact of demand on investment. Foreign income, productivity and prices are assumed exogenous. Imports might affect domestic prices through higher competition, productivity through technological absorption, capital stock through disincentives for investment, and aggregate domestic income through demand. Foreign prices and productivity are considered exogenous, assuming that the effect of imports on the world economy is negligible.

System Generalized Method of Moments (GMM) estimator was employed to address these problems (Blundell and Bond, 2000). This method employs a system of equations in levels and differences to estimate the parameters using as instruments the lags of the variables in differences and levels, respectively, while controlling for FE (see Roodman, 2009, p. 86). To guarantee the consistency of the System-GMM estimator, three assumptions must be fulfilled: (i) the error term must not be serially correlated; (ii) the instruments introduced must be valid; and (iii) the correlation between the instruments and the fixed effects must be null. The Arellano and Bond (1991) AR test was used to assess the first assumption, while Hansen's J test of over-identification was employed to assess the second one.[5] In all the System-GMM regressions the number of

[5] As Roodman (2009, p. 119) argues, "negative first-order serial correlation is expected in differences and evidence of it is uninformative". Hence, the relevant test is the AR(2) or up, depending on the first lag used as instrument (Roodman, 2009, p. 108; 124).

instruments was kept small to avoid spurious significance due to instrument proliferation (Roodman, 2009). The number of lags adopted in each model was guided by the analysis of the validity of the instruments, following Arellano-Bond's AR Test and Hansen's J Test. Attention was also paid to the stability of the results found with different lags.

4.2. Data description

Data from three different databases were combined in order to regress equations (13) and (14): (i) disaggregated trade data from the UN Comtrade Database; (ii) disaggregated quality-adjusted price indexes from Feenstra and Romalis (2014); and (iii) productivity and investment data from the EU KLEMS Database (version March 2011).

Trade data were gathered from the UN Comtrade Database, classified according to the Standard International Trade Classification (SITC) (Revision 2) 4-digit product categories. Quality-adjusted price indexes calculated by Feenstra and Romalis (2014) for each SITC category were used to deflate the respective export and import values. Then, trade data was transformed from SITC (Rev. 2) 4-digits to ISIC (Rev. 2) 3-digits using the correspondence table developed by Muendler (2009), which is based on the OECD correspondence between SITC and ISIC. This data was transformed into EU KLEMS industries using the correspondence presented in Appendix 2. As usual, import prices were used as proxies for foreign prices for each country and industry. Export and import prices in the EU KLEMS industries were calculated as weighted averages of the quality-adjusted price indexes of each product within each EU KLEMS industry.

The data used to calculate total factor productivity (TFP), in turn, was gathered from the EU KLEMS Database. International data were made compatible using industry-specific value added and capital Purchasing Power Parities (PPPs) from Inklaar and Timmer (2008), following the methodology of Timmer *et al.* (2007, p. 50-1). Through this method all the data were transformed to constant 1995 US dollars. Capital stock was divided in two types of assets: information and communication technology (ICT) assets and Non-ICT assets.

Thus, data on real value added (*Y*) and capital stocks (*K*) in 1995 US dollars, labour shares ($1-\alpha$), and number of hours worked by persons engaged in production (*L*) were used to calculate ln TFP as:

$$\ln TFP_{ijt} = \ln Y_{ijt} - (1-\alpha_{ICTijt} - \alpha_{NICTijt})\ln L_{ijt} - \alpha_{ICTijt}\ln K_{ICTijt} - \alpha_{NITijt}\ln K_{NICTijt} \qquad (15)$$

where α are the shares of capital stocks in value added.

GDP data in constant 2000 US dollars were gathered from the World Development Indicators. Foreign GDP, used to estimate equation (13), was calculated subtracting the country's GDP from the world's GDP.

The sample of countries adopted in this paper's investigation was guided by data availability. Firstly, the coverage of the quality-adjusted price indexes from Feenstra and Romalis (2014) used to deflate export and import values led to an initial sample of 14 European countries over the period 1984-2011 (see Romero and McCombie, 2016a). Secondly, the availability of the data used to calculate TFP by industry (see Romero and McCombie, 2016b) led to the final sample of 7 European countries (Austria, Denmark, Finland, Germany, Netherlands, Spain, and United Kingdom) over the period 1984-2006.

The analysis focuses on 11 manufacturing industries, following the classification used in the EU KLEMS Database (see Appendix 2). Two industries were considered influential outliers and excluded from the analysis. The Fuel industry was excluded due to the strangely high variation of its TFP (see Romero and McCombie, 2016b). The Chemical industry, in turn, was considered an influential outlier due to its effects on the price elasticity of demand. The inclusion of this industry when estimating the simple export function generates positive and significant price elasticity. However, the price elasticity becomes negative and not significant, as expected, when this industry is excluded.

The 11 manufacturing industries were split into two samples following the OECD technological classification. The first sample, henceforth called low-tech industries, comprises 5 low-tech industries (Food, Textiles, Wood, Paper and Other Manufactures) plus 3 medium-low-tech industries (Plastics, Minerals and Metals). The second sample, henceforth called high-tech industries, comprises 3 medium-high industries (Machinery and Transport) plus the high-tech industry (Electrical).

In addition, the data were transformed into four-year averages. This reduces serial correlation and smooths short-term business cycle fluctuations. Although most works use five-year averages, four-year averages were used in this paper in order to increase the number of time periods available.

Table 2 presents the descriptive statistics of the variables used to estimate equations (13) and (14). All the variables are within the expected ranges.

Table 2: Descriptive statistics

	Observations	Mean	Standard Deviation	Minimum	Maximum
Ln of Exports	546	22.02	1.46	18.08	26.06
Ln of Imports	546	22.34	1.32	18.64	25.41
Ln of Domestic Prices	546	-0.27	0.96	-3.10	1.60
Ln of Foreign Prices	546	-0.33	0.91	-3.29	1.40
Ln of Foreign Income	546	30.94	0.20	30.59	31.24
Ln of Domestic Income	546	26.63	1.02	25.17	28.31
Ln of Domestic TFP	546	1.90	0.93	-1.53	3.80
Ln of Foreign TFP	546	2.66	0.57	1.23	3.80
Ln of Capital Stock	546	7.30	1.46	2.04	11.01

Note: The Fuels and Chemicals industries were excluded.
Source: Authors' elaboration.

4.3. Estimation results: all industries

Table 3 reports estimates of export demand functions taking into account the whole sample of industries. Except for the estimates reported in column (i), Arellano and Bond's (1991) AR Test and Hansen's (1982) J Test indicate that the instruments are valid at a 5% significance level. Column (i) presents the estimates of the simple Kaldorian export demand function. The income elasticity of demand is highly significant and the foreign and domestic prices have similar coefficients and the expected signs, although only the domestic price is marginally significant.

In column (ii) domestic TFP is introduced. Similar results are found, but now price elasticities are higher and significant, still presenting the expected signs. TFP is positive and significant, as expected. If TFP growth is indeed a good proxy for domestic non-price competitiveness, and if the latter is captured in the income elasticity of demand, then the introduction of TFP growth should affect the magnitude of the income elasticity. The effect of the introduction of this variable can be analysed as an omitted variable bias. Following Wooldridge (2009, p. 89), with the exclusion $\hat{N}$ and $\hat{N}_f$ from equation (7), the income elasticity of demand becomes:

$$\varepsilon' = \varepsilon + \mu\beta_{NX} - \mu\beta_{NXf} \qquad (16)$$

where ε is the intra-sector productivity-neutral income elasticity of demand for exports, and β_{NX} and β_{NXf} denote the coefficients of the regressions of $\hat{Z}$ on $\hat{N}$ and on $\hat{N}_f$, respectively. Hence, from equation (16), the introduction of TFP growth as a proxy for domestic productivity growth ($\hat{N}$) should reduce the income elasticity of demand for exports to:

$$\varepsilon'' = \varepsilon' - \mu\beta_{NX} = \varepsilon - \mu\beta_{NXf} \qquad (17)$$

Table 3: Export demand functions: all industries

Dependent Variable	Ln of Exports	Ln of Exports	Ln of Exports	Ln of Exports	Ln of Exports
Method	SYS-GMM	SYS-GMM	SYS-GMM	SYS-GMM	SYS-GMM
Sample	All Industries	All Industries	All Industries	All Industries	All Industries
	(i)	(ii)	(iii)	(iv)	(v)
Ln of Foreign Income	1.863***	1.768***	2.365***	2.315***	2.139***
	(0.139)	(0.143)	(0.291)	(0.269)	(0.195)
Ln of Domestic Prices	-0.864+	-1.652*		-0.965	-0.334
	(0.542)	(0.643)		(1.412)	(0.886)
Ln of Foreign Prices	0.535	1.677*		0.641	-0.128
	(0.687)	(0.749)		(1.489)	(0.980)
Ln of Domestic TFP		0.587**	0.701+	0.574	0.644+
		(0.210)	(0.438)	(0.540)	(0.409)
Ln of Foreign TFP			-0.885+	-0.897+	-0.863*
			(0.592)	(0.563)	(0.379)
Ln of Capital Stock					0.483**
					(0.166)
Constant	-35.66***	-33.65***	-50.11***	-48.31***	-46.72***
	(4.308)	(4.258)	(8.222)	(7.705)	(5.853)
N. Observations	546	546	546	546	546
No. Groups	91	91	91	91	91
No. Instruments/Lags	7/2-4	11/2-4	6/2-3	10/2-3	13/2-3
Arellano-Bond AR Test	0.526	0.935	0.240	0.321	0.172
Hansen's J Test	0.041	0.523	0.132	0.069	0.235

Note: Figures in parenthesis are standard errors. Regressions were estimated for the period 1976-2006. The values reported for the tests are p-values. The p-value reported for the Arellano-Bond AR Test refers to the first lag used as instrument in the regression. The Sample "All Industries" comprises 11 manufacturing industries, excluding the Fuel and Chemical industries. Significance: ***=0.1%; **=1%; *=5%; ++=10%; +=15%.
Source: Authors' elaboration.

This change is confirmed in the results reported in column (ii). The introduction of domestic TFP growth generates a small reduction in the income elasticity of demand, which indicates that its effect was being incorporated in the elasticity.

In column (iii), foreign and domestic TFPs are introduced along with foreign income. Both variables are marginally significant (at the 15% level), presenting similar coefficients and the expected signs. The effect of foreign TFP, however, is slightly higher.

Following equation (16), when domestic and foreign productivity are accounted for, the income elasticity should reduce to the intra-sector productivity-neutral:

$$\varepsilon = \varepsilon' - \mu\beta_{NX} + \mu\beta_{NXf} \tag{18}$$

As expected, the income elasticity of demand increases in this specification in relation to the results of column (ii), given that by definition $\varepsilon'' = \varepsilon' - \mu\beta_{NX} < \varepsilon' - \mu\beta_{NX} + \mu\beta_{NXf} = \varepsilon$.

Interestingly, however, the results of column (iii) show also that the intra-sector productivity-neutral elasticity is higher than the original elasticity (from column (i)), i.e.

$\varepsilon' = \varepsilon + \mu\beta_{NX} - \mu\beta_{NXf} < \varepsilon$, which means that $\mu\beta_{NX} < \mu\beta_{NXf}$. This can either stem: (i) from the fact that the correlation of domestic productivity growth with foreign output growth ($\hat{Z}$) is lower than that of foreign productivity growth ($\beta_{NX} < \beta_{NXf}$), which is plausible; or (ii) from the fact that the impact of foreign productivity on export performance is actually higher than that of domestic productivity (ie. $\mu < \mu_f$); or (iii) from both factors simultaneously. Although the latter option is likely to be the explanation, the parameters reported in column (iii) indicate that at least one of the hypothesis holds: $\mu < \mu_f$. Hence, it follows that $\varepsilon > \varepsilon' > \varepsilon''$.

In column (iv), prices are introduced along with TFPs and income. The positive and significant income elasticity has a similar magnitude as in the regression presented in column (iii), while prices are not significant, although with the right signs. Domestic TFP is no longer significant, although with a positive sign, while foreign TFP is still significant and with similar magnitude.

Finally, column (v) reports the full specification given by equation (13), which includes capital stock as well. Foreign TFP is now significant at the 5% level, while domestic TFP is significant only at the 15% level. Capital stock is positive and significant, indicating that higher productive capacity increases exports. Again this leads to a reduction in the income elasticity of demand, showing that this effect was being incorporated in the elasticity (i.e. from equation (7), $\varepsilon''' = \varepsilon' - \mu\beta_{NX} + \mu\beta_{NXf} - \sigma\beta_{CX}$, where β_{CX} is the coefficient of the regression of $\hat{Z}$ on $\hat{C}$). Prices are not significant.

Table 4, in turn, reports estimates of import demand functions taking into account the whole sample of industries. Except for the regressions reported in columns (i) and (iii), Arellano and Bond's (1991) AR Test and Hansen's (1982) J Test indicate that the instruments are valid at a 5% significance level.

Column (i) presents the estimates of the simple Kaldorian import demand function. The income elasticity of demand is highly significant, while foreign and domestic prices are not significant and present the wrong signs, although with similar coefficients.

The discussion of the import demand function and the biases caused by omitting domestic and foreign productivity growth is analogous to the analysis presented for the export demand function.

Table 4: Import demand functions: all industries

Dependent Variable	Ln of Imports	Ln of Imports	Ln of Imports	Ln of Imports	Ln of Imports
Method	SYS-GMM	SYS-GMM	SYS-GMM	SYS-GMM	SYS-GMM
Sample	All Industries	All Industries	All Industries	All Industries	All Industries
	(i)	(ii)	(iii)	(iv)	(v)
Ln of Domestic Income	2.392***	2.282***	2.217***	2.074***	2.476***
	(0.114)	(0.169)	(0.247)	(0.295)	(0.310)
Ln of Domestic Prices	-0.934	0.365		1.537	-2.644
	(1.159)	(1.081)		(1.826)	(3.887)
Ln of Foreign Prices	0.788	-0.493		-2.550	2.045
	(1.333)	(1.130)		(2.123)	(3.998)
Ln of Domestic TFP		0.177	-0.908+	-2.361*	-1.700++
		(0.351)	(0.562)	(1.085)	(0.874)
Ln of Foreign TFP			0.715+	1.463++	0.682
			(0.470)	(0.813)	(0.574)
Ln of Capital Stock					-0.163
					(0.274)
Constant	-41.41***	-38.76***	-36.80***	-32.70***	-40.94***
	(3.056)	(4.162)	(6.316)	(7.581)	(6.713)
N. Observations	546	546	546	546	546
No. Groups	91	91	91	91	91
No. Instruments/Lags	11/2-3	11/2-3	8/2-3	12/3-4	11/3
Arellano-Bond AR Test	0.010	0.119	0.031	0.156	0.898
Hansen's J Test	0.565	0.396	0.260	0.789	0.476

Note: Figures in parenthesis are standard errors. Regressions were estimated for the period 1976-2006. The values reported for the tests are p-values. The p-value reported for the Arellano-Bond AR Test refers to the first lag used as instrument in the regression. The Sample "All Industries" comprises 11 manufacturing industries, excluding the Fuel and Chemical industries. Significance: ***=0.1%; **=1%; *=5%; ++=10%; +=15%.
Source: Authors' elaboration.

Following equation (8), if domestic and foreign productivities are not considered, the income elasticity of demand for imports becomes:

$$\pi' = \pi + \nu\beta_{NMf} - \nu\beta_{NM} \tag{19}$$

where π is the intra-sector productivity-neutral income elasticity of demand for imports, and β_{NM} and β_{NMf} denote the coefficients of the regressions of $\hat{Y}$ on $\hat{N}$ and on $\hat{N}_f$, respectively.

In column (ii) domestic TFP is introduced. In this regression, however, prices and TFP are not significant and have the wrong signs. Moreover, the income elasticity suffers a small reduction that goes against the predicted effect, i.e. $\pi' < \pi'' = \pi' + \nu\beta_{NM} = \pi + \nu\beta_{NMf}$.

In column (iii) foreign and domestic TFPs are introduced along with domestic income. Both variables are marginally significant (at the 15% level), presenting similar coefficients and the expected signs. The effect of domestic TFP, however, is slightly larger. As expected, the income elasticity of demand decreases in this specification.

Analogously to the export function, when TFP in the frontier is accounted for, the income elasticity of demand for imports decreases vis-à-vis the estimates of column (ii): $\pi'' = \pi' + \nu\beta_{NMf} < \pi' + \nu\beta_{NM} - \nu\beta_{NMf} = \pi$. Again, the intra-sector productivity-neutral elasticity is smaller than the original (column (i)), which indicates that: (i) $\nu > \nu_f$ (as suggested by the results of column (iii)); or (ii) $\beta_{NM} > \beta_{NMf}$; or (iii) both. Hence, it follows that $\pi < \pi' < \pi''$.

In column (iv) prices are introduced along with TFPs and income. The positive and significant income elasticity has a slightly lower magnitude in relation to the regression presented in column (iii), while prices are not significant, although with the expected signs. Domestic and foreign TFP are now significant at 5 and 10% levels, respectively, and present larger coefficients.

Finally, column (v) reports the full specification given by equation (14), which includes the capital stock as well. Domestic TFP is significant at the 10% level, while foreign TFP looses its significance. Capital stock is negative, as expected, indicating that higher productive capacity reduces imports. Yet, the variable is not significant. The introduction of the capital stock, however, leads to an increase in the income elasticity of demand, which suggests that this effect was being incorporated in the elasticity (i.e. from equation (8), $\pi''' = \pi' + \nu\beta_{NM} - \nu\beta_{NMf} + \sigma\beta_{CM}$, where β_{CM} is the coefficient of the regression of $\hat{Y}$ on $\hat{C}$). Prices are once again not significant.

The results discussed in this section suggest that a more complete understanding of the determinants of trade performance can be obtained when combining the Kaldorian and the Schumpeterian approaches to the determinants of trade. The regressions provide support to the idea that domestic and foreign productivity capture non-price competitiveness of domestic and foreign production (which encompasses technological competitiveness) when controlling for changes in relative prices. Furthermore, the same applies to productive capacity. The results show also that income elasticities of demand capture the effects of relative productivity when these variables are not controlled for. Thus, the estimated parameters provide partial support to the Schumpeterian approach. Nevertheless, income elasticities of demand are the key determinants of exports and imports, and the fact they are different from unity provides support to the Kaldorian approach.

To sum up, the results provide initial support to the claim that the general export and import demand functions are preferable in relation to the functions traditionally used in the Kaldorian and the Schumpeterian literatures.

4.4. Estimation results: by technological sectors

Tables 5 and 6 report regressions following the same pattern presented in Tables 3 and 4, but dividing the sample of industries into low-tech and high-tech.

The first five columns of Tables 5 and 6 report results for the sample of low-tech industries, while the last five columns report results for the sample of high-tech industries. In all regressions but one (column (iii) of Table 6) the Arellano and Bond (1991) AR test and the Hansen (1982) LM test suggest the validity of the instruments, and the results for both groups of industries follow the same pattern observed in Tables 3 and 4. Income elasticities are significant in all regressions, domestic and foreign TFP are significant in most regressions, as well as productive capacity, while prices are not significant. Regarding exports, as in Table 3, the income elasticity of demand increases with the introduction of domestic and foreign TFP, and reduces somewhat with the introduction of productive capacity. Analogously, regarding imports, as in Table 4, the income elasticity of demand decreases with the introduction of domestic and foreign TFP, and increases slightly with the introduction of productive capacity.

Table 5: Export demand functions: by technological sectors

Dependent Variable	Ln of Exports	Ln of Exports	Ln of Exports	Ln of Exports	Ln of Exports	Ln of Exports	Ln of Exports	Ln of Exports	Ln of Exports	Ln of Exports
Method	SYS-GMM	SYS-GMM	SYS-GMM	SYS-GMM	SYS-GMM	SYS-GMM	SYS-GMM	SYS-GMM	SYS-GMM	SYS-GMM
Sample	Low-Tech Industries	Low-Tech Industries	Low-Tech Industries	Low-Tech Industries	Low-Tech Industries	High-Tech Industries	High-Tech Industries	High-Tech Industries	High-Tech Industries	High-Tech Industries
	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)	(ix)	(x)
Ln of Foreign Income	1.776***	1.755***	2.154***	2.107***	1.963***	2.609***	2.456++	3.065***	3.291*	2.646***
	(0.147)	(0.234)	(0.236)	(0.187)	(0.188)	(0.398)	(1.208)	(0.667)	(1.369)	(0.512)
Ln of Domestic Prices	-0.842	-0.118		-0.561	-0.00256	2.174	0.190		0.103	0.259
	(2.389)	(2.880)		(1.301)	(1.726)	(1.394)	(3.339)		(3.080)	(1.099)
Ln of Foreign Prices	0.882	0.439		0.432	-0.0529	-0.0449	1.564		1.635	0.541
	(2.340)	(2.736)		(1.213)	(1.768)	(1.613)	(4.779)		(4.919)	(2.060)
Ln of Domestic TFP		0.322	0.455++	0.230	0.430++		0.945	1.996**	1.380++	0.889++
		(0.418)	(0.265)	(0.293)	(0.257)		(1.332)	(0.678)	(0.697)	(0.438)
Ln of Foreign TFP			-0.737++	-0.540++	-0.529*			-1.728++	-1.078	-1.082+
			(0.419)	(0.289)	(0.242)			(0.992)	(1.061)	(0.648)
Ln of Capital Stock					0.273++					0.578**
					(0.139)					(0.151)
Constant	-33.18***	-33.21***	-43.85***	-42.47***	-40.45***	-54.75***	-52.49	-71.07**	-76.26++	-60.62**
	(4.461)	(6.564)	(6.614)	(5.313)	(5.557)	(13.11)	(36.86)	(19.45)	(42.43)	(16.38)
N. Observations	420	420	420	420	420	126	126	126	126	126
No. Groups	70	70	70	70	70	21	21	21	21	21
No. Instruments/Lags	6/2-3	9/2-3	6/2-3	9/2-3	13/2-3	6/2-3	11/3-5	5/2	12/3-5	19/2-5
Arellano-Bond AR Test	0.802	0.762	0.159	0.136	0.119	0.700	0.696	0.113	0.745	0.179
Hansen's J Test	0.654	0.459	0.125	0.309	0.386	0.455	0.218	0.833	0.182	0.354

Note: Figures in parenthesis are standard errors. Regressions were estimated for the period 1976-2006. The values reported for the tests are p-values. The p-value reported for the Arellano-Bond AR Test refers to the first lag used as instrument in the regression. Significance: ***=0.1%; **=1%; *=5%; ++=10%; +=15%.
Source: Authors' elaboration.

Table 6: Import demand functions: by technological sectors

Dependent Variable	Ln of Imports	Ln of Imports	Ln of Imports	Ln of Imports	Ln of Imports	Ln of Imports	Ln of Imports	Ln of Imports	Ln of Imports	Ln of Imports
Method	SYS-GMM	SYS-GMM	SYS-GMM	SYS-GMM	SYS-GMM	SYS-GMM	SYS-GMM	SYS-GMM	SYS-GMM	SYS-GMM
Sample	Low-Tech Industries	Low-Tech Industries	Low-Tech Industries	Low-Tech Industries	Low-Tech Industries	High-Tech Industries	High-Tech Industries	High-Tech Industries	High-Tech Industries	High-Tech Industries
	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)	(ix)	(x)
Ln of Domestic Income	2.307***	2.345***	1.998***	2.365***	2.486***	2.599***	2.529***	1.799***	1.795*	1.957*
	(0.385)	(0.236)	(0.211)	(0.359)	(0.386)	(0.629)	(0.497)	(0.350)	(0.647)	(0.875)
Ln of Domestic Prices	-0.778	-0.647		0.695	-1.143	-0.551	0.0194		0.168	0.698
	(3.442)	(1.762)		(2.586)	(2.644)	(2.147)	(1.941)		(1.523)	(1.854)
Ln of Foreign Prices	1.097	1.010		-1.234	0.719	-0.275	-0.842		0.430	-0.240
	(3.618)	(1.721)		(2.648)	(2.708)	(2.844)	(2.694)		(2.867)	(2.589)
Ln of Domestic TFP		0.0662	-1.430*	-1.285++	-0.650		-0.182	-1.317+	-1.762+	-1.393++
		(0.385)	(0.562)	(0.645)	(0.596)		(0.936)	(0.786)	(1.047)	(0.769)
Ln of Foreign TFP			0.863+	0.568	0.0599			1.708*	1.960*	1.592*
			(0.520)	(0.560)	(0.520)			(0.747)	(0.761)	(0.638)
Ln of Capital Stock					0.133					-0.237
					(0.403)					(0.654)
Constant	-39.35***	-40.44***	-30.75***	-40.11***	-44.04***	-46.94*	-44.56**	-26.34**	-25.22	-27.73
	(10.14)	(6.080)	(5.250)	(8.830)	(8.809)	(18.09)	(12.81)	(8.830)	(17.90)	(20.68)
N. Observations	420	420	420	420	420	126	126	126	126	126
No. Groups	70	70	70	70	70	21	21	21	21	21
No. Instruments/Lags	8/2-3	11/2-3	6/3	9/2	11/2	8/2-3	11/3-4	8/2-3	9/2	11/2
Arellano-Bond AR Test	0.139	0.010	0.114	0.110	0.070	0.384	0.363	0.904	0.488	0.763
Hansen's J Test	0.356	0.459	0.209	0.551	0.426	0.940	0.521	0.674	0.624	0.339

Note: Figures in parenthesis are standard errors. Regressions were estimated for the period 1976-2006. The values reported for the tests are p-values. The p-value reported for the Arellano-Bond AR Test refers to the first lag used as instrument in the regression. Significance: ***=0.1%; **=1%; *=5%; ++=10%; +=15%.
Source: Authors' elaboration.

The results reported in Tables 5 and 6 convey two important pieces of information. First, the results indicate that the effect of non-price competitiveness (i.e. domestic and foreign TFP growth) on export and import growth is considerably different between technological sectors, estimated to be around 0.5 and 0.9 for low-tech industries and around 1 and 1.5 for high-tech industries, respectively. As expected, therefore, non-price competitiveness exerts a larger impact on high-tech industries than on low-tech industries, possibly due to the fact that in the latter group of industries there is less room for product differentiation and/or because world demand grows faster for high-tech goods. Second, in spite of this difference, income elasticities of demand are also considerably higher for high-tech than for low-tech industries. As argued before, this is not unexpected, given that different types of goods still face different demand even when controlling for non-price competitiveness. Regarding exports, in the simple export functions, the income elasticities of low-tech and high-tech industries are 1.8 and 2.6, respectively, while in the expanded export functions the income elasticities are 1.9 and 2.6. The results are slightly poorer for imports. Yet, in the simple import functions, the income elasticities of low-tech and high-tech industries are also 1.9 and 2.6, respectively. However, in the expanded export functions the income elasticities of low-tech and high-tech goods become 2.5 and 2, respectively.

4.5. Fit of the models

In order to assess the fit of the models, Table 7 compares actual growth rates with the equilibrium growth rates predicted by each of the models: the Expanded Thirlwall's Law (E-TL), the Multi-Sectoral Thirlwall's Law (MSTL) and the Expanded Multi-Sectoral Thirlwall's Law (E-MSTL). A more formal assessment of the fit of the models (as the regression of the equilibrium growth rates on the actual growth rates) is precluded by the small number of countries analyses. Yet, comparing the fit of the equilibrium growth rates found in this paper with the fit of the equilibrium growth rates found in other studies provides an initial indication about the validity of the models.

Table 7 shows that both the MSTL and the E-TL generate considerably good predictions of the actual growth rates observed in each of the countries analysed during the period studied. For the former, the average difference between the actual and the equilibrium rates was only 0.34. For the latter, the average difference was only 0.73. Taking into account a sample of 7 works that have tested Thirlwall's Law for different countries (Thirlwall, 1979, Bairam, 1988; Bairam and Dempster, 1991; Perraton, 2003; Bagnai, 2010; Gouvea and Lima, 2010; 2013), the average difference between the two growth rates is 1.29 considering all counties, and 0.76 considering only high-income countries. Thus, the average differences found for the E-TL and the MSTL are within acceptable ranges, indeed less than the average difference found in previous works.

Table 7: Comparison between actual growth rates and models' equilibrium growth rates

Country	Actual Growth Rate	E-TL	Diff. 1	MSTL	Diff. 2	E-MSTL	Diff. 4
Austria	2.54	1.66	0.88	2.73	**0.19**	3.04	**0.50**
Denmark	2.10	1.20	0.90	2.63	**0.52**	2.54	**0.43**
Finland	2.61	3.87	**1.25**	2.66	**0.04**	4.48	**1.86**
Germany	2.02	2.62	**0.60**	2.99	**0.97**	3.90	**1.89**
Netherlands	2.73	2.17	0.56	2.68	0.05	2.75	**0.02**
Spain	3.27	2.80	0.47	2.73	0.54	2.85	0.42
United Kingdom	2.82	3.24	**0.42**	2.84	**0.02**	5.82	**3.00**
Average	2.58	2.51	0.73	2.75	0.34	3.63	1.16

Note: E-TL = Expanded Thirlwall's Law; MSTL = Multi-Sectoral Thirlwall's Law; E-MSTL = Expanded Multi-Sectoral Thirlwall's Law. Bold numbers indicate a negative difference.
Source: Authors' elaboration.

However, Table 7 shows also that the average difference between the actual and the equilibrium growth rates increases to 1.16 using the E-MSTL. Although this difference is not too large in comparison with other works, it is considerably worse than the ones found using the MSTL and the E-TL. A possible explanation for the poorer result found using the E-MSTL is the size of the sample in the regressions for the high-tech sector. Given that there are only 7 countries and 3 high-tech industries, this leads to 21 units in the panels. The small size of this sample reduces the efficiency and consistency of the results, especially in face of the possibility of measurement errors in TFP measures. This could explain why the E-MSTL tends to overestimate the actual growth rates, while the MSTL is not affected by the size of the sample. Furthermore, measurement errors in TFP could explain also the slightly higher error found for the E-TL in comparison with the MSTL. Hence, further work is necessary to arrive at more conclusive assessments of the expanded specifications tested in this paper.

5. Concluding remarks

This paper showed that it is possible to derive export and import functions that encompass the contributions of both Kaldorian and Schumpeterian literatures to understanding the determinants of trade performance. These functions explicitly account for the effect of relative productivity on export and import demand via non-price competitiveness, given that changes in relative prices are controlled for, while considering the effect of income growth and productive capacity on export and import growth. This generates a more comprehensive explanation for the determinants of trade than the explanations provided by each of the traditions separately. The expanded export and import functions were then used to obtain an expanded Thirlwall's Law, showing that these functions can be used to understand economic growth in a context of balance-of-payments constraint. Finally, an empirical investigation was carried out to assess the impact of non-price competitiveness, measured by relative productivity growth, on export and import growth, taking into account differences between technological sectors.

The econometric investigation reported in this paper indicated that the growth rates of exports and imports are partially determined by relative productivity growth and productive capacity, which suggests the validity of the expanded export and import functions. Most importantly, although domestic and foreign productivity growth are only marginally significant in some of the regressions, in all the regressions the introduction of these variables leads to changes in the magnitude of the income elasticities of demand. This observation suggests that including these variables increases the explanatory power of the estimates, while their exclusion leads to omitted variable bias.

Furthermore, the investigation provided evidence of the validity of the expanded Thirlwall's Law. In addition, the tests indicated that low-tech industries present lower income and non-price elasticities of demand than high-tech industries. This suggests that moving the economy towards the production and export of high-tech goods contributes to increase long-term growth not only because the income elasticity of these goods are intrinsically higher than that of low-tech goods, but also because higher productivity growth in high-tech industries has a larger effect on trade performance and growth than in low-tech industries.

The investigation suggested also that introducing relative productivity in export and import functions only captures intra-industry non-price competitiveness, while inter-sector non-price competitiveness is still captured in the income elasticities of demand, given that cross-sector non-price competition was not considered in the specification of the demand functions adopted in this paper. In other words, adopting a disaggregated approach to the determinants of export and import growth reveals that different goods present: (i) different income elasticities of demand, due to differences in their intrinsic characteristics, i.e. inter-product desirability; and (ii) different non-price elasticities of demand, due to differences in their quality and other non-price competitiveness factors, i.e. intra-product desirability.

This paper, therefore, provides an initial connection between the results found in by Romero and McCombie (2016a; 2016b). The econometric analyses presented in these papers suggest that high-tech industries present not only higher income elasticities of demand, but also higher degrees of returns to scale. The present paper, in turn, indicates that productivity growth feeds back into trade performance through non-price competitiveness, which creates a circuit of cumulative causation that does not depend on price competitiveness, as in Dixon and Thirlwall's (1975) model.

Appendix 1

A number of works in the Schumpeterian tradition adopted export demand functions slightly different from Fagerberg's (1988), using export shares in total trade as the dependent variable:

$$\frac{X}{X_W} = a\left(\frac{EP_f}{P}\right)^{\eta}\left(\frac{T}{T_f}\right)^{\mu} C^{\sigma} \tag{A1}$$

where the subscript W denotes world total.

Interestingly, empirical works that have estimated demand functions based on equations (A1) found results that are very similar to the estimates found using equations (13) (e.g. Magnier and Toujas-Bernate, 1994; Amable and Verspagen, 1995; Wakelin, 1998).

The similarity of the results found when estimating these two types of demand functions can be explained using Hicks' (1950) super-multiplier, which is one of the pillars of Kaldorian theory and of the Kaldor-Dixon-Thirlwall model. The super-multiplier represents the relationship between exports growth and output growth, i.e. $y = \gamma x$. Consequently, in levels, the multiplier becomes:

$$Y = cX^{\gamma} \tag{A2}$$

where c is a proportionality parameter.

Finally, if this multiplier holds for each country and $\gamma = 1$, as assumed by Thirlwall (1979) and found by Atesoglu (1994), summing equation (A2) across all $i = 1, \ldots, k$ countries in the world yields:

$$Z = cX_W \tag{A3}$$

where $Z = \sum_{i=1}^{k} Y_i$, and $X_W^{\gamma} = \sum_{i=1}^{k} X_i^{\gamma}$. Hence, substituting equation (A3) into equation (13) and rearranging leads to:

$$\frac{X}{X_W} = d\left(\frac{EP_f}{P}\right)^{\eta}\left(\frac{T}{T_f}\right)^{\mu} C^{\sigma} \tag{A4}$$

Equation (A4) only differs from equation (A1) in terms of the constant $a \neq d = ca$. Thus, taking logarithms and differentiating equations (A1) and (A4) with respect to time yields the same equation, which is the one used in empirical works.

Appendix 2

Table A1: Correspondence table between ISIC (Rev.2) 3-digits and EU KLEMS Industries

ISIC (Rev.2)	ISIC (Rev. 2) Industries	EU KLEMS (ISIC Rev.3)
3	TOTAL MANUFACTURING INDUSTRY	D
31	Food, drink and tobacco	15 to 16
32	Textiles, apparel and leather	17 to 19
33	Wood products and furniture	20
34	Paper, paper products and printing	21 to 22
351+352	Chemicals, drugs and medicines	24
353+354	Petroleum refineries and products	23
355+356	Rubber and plastic products	25
36	Non-metallic mineral products	26
37	Basic metal industries	27 to 28
381	Metal products	27 to 28
382*	Non-electrical machinery, office and computing machinery	29
383	Electrical machinery and communication equipment	30 to 33
384	Shipbuilding and repairing, motor vehicles, aircraft, and other transport equipment	34 to 35
385	Professional goods	30 to 33
39	Other manufacturing, n.e.c.	36 to 37
1	Agriculture, hunting, forestry and logging	A to B
2	Mining and quarrying	C
4	Electricity, Gas and Water	E

Note: The ISIC (Rev.2) industries are the ones covered by the ANBERD Database, following the description provided in OECD Stats. *=Mismatch between the ISIC (Rev.2) 3-digits and the EU KLEMS (ISIC Rev.3). In EU KLEMS this industry excludes office and computing machinery, which is introduced into the industry Electrical machinery & communication equipment. However, this separation is not possible at the 3-digit classification.
Source: Authors' elaboration.

Acknowledgements: We would like to thank Professor Tony Thirlwall and Dr. Nigel Alington, for their helpful comments. The usual disclaimer applies. This work was supported by the Coordination for the Improvement of Higher Education Personnel (CAPES-Brazil) in a partnership with the Cambridge Trusts, under Grant number 0257-11-7.

References

Amable, B.; Verspagen, B. (1995): 'The Role of Technology in Market Share Dynamics', *Applied Economics*, 27(2), pp. 127-204.

Araújo, R.; Lima, G. T. (2007): 'A structural economic dynamics approach to balance-of-payments-constrained growth', *Cambridge Journal of Economics*, 31(5), pp. 755-74.

Arellano, M.; Bond, S. (1991): 'Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations', *Review of Economic Studies*, 58, 277-297.

Bairam, E. (1988): 'Balance of payments, the Harrod foreign trade multiplier and economic growth: the European and North American experience, 1970-85', *Applied Economics*, 20, pp. 1635-42.

Bairam, E.; Dempster, G. J. (1991): 'The Harrod foreign trade multiplier and economic growth in Asian countries', *Applied Economics*, 23, pp. 1719-24.

Bagnai, A. (2010): 'Structural changes, cointegration and the empirics of Thirlwall's Law', *Applied Economics*, 42, pp. 1315-1329.

Blecker, R. A. (2013): 'Long-Run Growth in Open Economies: Export-Led Cumulative Causation of a Balance-of-Payments Constraint?', in Harcourt, G.; Kriesler, P. (ed.): *The Oxford Handbook of Post-Keynesian Economics*, Oxford University Press, Oxford.

Blundell, R.; Bond, S. (2000): 'GMM estimation with persistent panel data: an application to production functions', *Econometric Review*, 19(3), pp. 321-340.

Dixon, R.; Thirwall, A. P. (1975): 'A Model of Regional Growth-rate Differences on Kaldorian Lines', *Oxford Economic Papers*, 27(2), pp. 201-214.

Feenstra, R. C.; Romalis (2014): 'International Prices and Endogenous Quality', *Quarterly Journal of Economics*, 129 (2), pp. 477-527..

Fagerberg, J. (1988): 'International Competitiveness', *Economic Journal*, 98(2), pp. 255-74.

Gouvea, R. R.; Lima, G. T. (2010): 'Structural change, balance-of-payments constraint and economic growth: evidence from the multi-sectoral Thirlwall's law', *Journal of Post Keynesian Economics*, 33, pp. 171-206.

Gouvea, R. R.; Lima, G. T. (2013): 'Balance-of-payments-constrained growth in a multisectoral framework: a panel data investigation', *Journal of Economic Studies*, 40(2), pp. 240-254.

Greenhalgh, C. (1990): ‘Innovation and Trade Performance in the United Kingdom’, *Economic Journal*, 100, pp. 105-18.

Greenhalgh, C.; Taylor, P.; Wilson, R. (1994): ‘Innovation and Export Volumes and Prices: A Disaggregated Study’, *Oxford Economic Papers*, 46(1), pp. 102-135.

Hansen, L. (1982): ‘Large sample properties of generalized method of moments estimators’, *Econometrica*, 50, pp. 1029-54.

Hausman, J. (1997): ‘Valuation of new goods under perfect and imperfect competition’, in Bresnahan, T.; Gordon, R. (ed.): *The Economics of New Goods*, Studies in Income and Wealth, 58, NBER, Chicago.

Houthakker, H. S.; Magee, S. P. (1969): ‘Income and price elasticities in world trade’, *Review of Economic and Statistics*, 51(2), pp. 111-125.

Hughes, K. (1986): ‘Exports and Innovation: A Simultaneous Model’, *European Economic Review*, 30, pp. 383-399.

Inklaar, R.; Timmer, M. (2008): ‘GGDC Productivity Level Database: International Comparisons of Output, Inputs and Productivity at the Industry Level’, *GGDC Research Memorandum GD-104*, Groningen Growth and Development Centre.

Kaldor, N. (1966): *Causes of the Slow Rate of Economic Growth of the United Kingdom: an Inaugural Lecture*, Cambridge University Press, Cambridge.

Kaldor, N. (1970): ‘The Case for Regional Policies’, *Scottish Journal of Political Economy*, 17, pp. 337-48.

Magnier, A.; Toujas-Bernate, J. (1994): ‘Technology and Trade: Empirical Evidences for the Major Five Industrialized Countries’, *Weltwirtschaftliches Archiv*, 130, pp. 494-520.

McCombie, J. S. L.; Thirlwall, A. (1994): *Economic Growth and the Balance-of-Payments Constraint*, Macmillan Press Ltd, London.

Nevo, A. (2001): ‘Measuring Market Power in the Ready-to-Eat Cereal Industry’, *Econometrica*, 69(2), pp. 307-342.

Perraton, J. (2003): ‘Balance of Payments Constrained Growth and Developing Countries: an examination of Thirlwall’s hypothesis’, *International Review of Applied Economics*, 17(1), pp. 1-22.

Roberts, M. (2002): ‘Cumulative Causation and Unemployment’, in McCombie, J. S.; Pugno, M.; Soro, B. (eds.): *Productivity Growth and Economic Performance: Essays on Verdoorn’s Law*, Palgrave MacMillan, New York.

Romero, J. P.; McCombie, J. S. L. (2016a): ‘The Multi-Sectoral Thirlwall’s Law: Evidence from 14 Developed European Countries using Product-Level Data’, *International Review of Applied Economics*, 30(3), pp. 301-25.

Romero, J. P.; McCombie, J. S. L. (2016b): ‘Differences in Increasing Returns to Scale Between Technological Sectors: A Panel Data Investigation using the EU KLEMS Database’, *Journal of Economic Studies*, forthcoming.

Roodman, D. (2009): ‘How to do xtabond2: An introduction to difference and system GMM in Stata’, *Stata Journal*, 9(1), pp. 86-136.

Schumpeter, J. (1934): *The Theory of Economic Development*, Harvard University Press, Cambridge MA.

Schumpeter, J. (1943): *Capitalism, Socialism and Democracy*, Harper, New York.

Setterfield, M. (2011): 'The remarkable durability of Thirlwall's Law', *PSL Quarterly Review*, 64(259), pp. 393-427.

Soete, L. G. (1981): 'A General Test of Technological Gap Trade Theory', *Weltwirtschaftliches Archiv*, 117(4), pp. 638-60.

Thirlwall, A. (1979): 'The Balance of Payments Constraint as an Explanation of International Growth Rate Differences', *BNL Quarterly Review*, 128(791), pp. 45-53.

Thirlwall, A.; Dixon, M. (1979): 'A Model of Export-Led Growth with Balance of Payments Constraint', in Bowers, J.K. (ed.): *Inflation, Development and Integration: Essays in Honor of A. J. Brown*, Leeds University Press, Leeds.

Timmer, M.; van Moergastel, T.; Stuivenwold, E.; Ypma, G.; O'Mahont, M.; Kangasniemi, M. (2007): 'EU KLEMS Growth and Productivity Accounts: Version 1.0 Part I Methodology', EU KLEMS.

Wakelin, K. (1998): 'The role of innovation in bilateral OECD trade performance', *Applied Economics*, 30(10), pp. 1335-1346.