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Sophistication, Productivity and Trade: A Sectoral Investigation

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1 Introduction[1]

In the Kaldorian approach to economic growth, income elasticities of exports and imports are the crucial parameters determining the long-term growth rate. In this tradition, the requirement of balance-of-payments equilibrium represents the main constraint on the growth of domestic aggregate demand. If relative prices have little impact on trade flows, as the evidence suggests is the case, and balance-of-payments deficits cannot be financed indefinitely, income elasticities of exports and imports become the crucial parameters determining the long-term growth rate (Thirlwall 1979).

Consequently, it is crucial to understand what determines the magnitude of the income elasticities of trade. As McCombie and Thirlwall (1994) argued, income elasticities capture the non-price competitiveness of each country's production. Yet, very few contributions have sought to

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test what variables impact these elasticities. Empirical evidence provided by Ang et al. (2015) for Asian countries suggests that introducing technological competitiveness into a standard export demand function leads to a reduction in the income elasticity. Similar results were found by Romero and McCombie (2017). Focusing on a sample of developed economies and employing relative productivity to measure non-price competitiveness instead of technological competitiveness, they found that introducing changes in relative productivity reduces the magnitude of the income elasticities of demand for exports and imports. They argue that such changes are consistent with omitted variable bias, so that it is possible to argue that these results confirm that income elasticities are explained by non-price competitiveness.

If differences in non-price competitiveness provide the basic explanation for differences in income elasticities, sectoral differences represent a fundamental complement to this approach. It is well known that income elasticities change between sectors, so that different trade baskets are associated with different aggregate income elasticities (e.g. Araújo and Lima 2007; Gouvêa and Lima 2010; Romero and McCombie 2016). More specifically, evidence suggests that high-tech goods present higher income elasticities than low-tech goods. Hence, taking into account sectoral trade differences is paramount to understand the variability of aggregate income elasticities.

According to the structuralist approach to economic growth, economic development is a process necessarily associated with changes in the sectoral composition of production (Lewis 1955; Kuznets 1966; Kaldor 1966; Hirschman 1958; Prebisch 1962; Furtado 1964). Development and growth depend on moving the economy's structure towards high-tech, high value-added, sectors that produce goods that are complex. More recently, Hausmann et al. (2007) explored the richness of disaggregate trade data to provide compelling evidence that initial economic sophistication exerts a positive and significant impact on future GDP per capita growth rate, even when controlling for human capital, institutions and initial GDP per capita. Subsequently, more elaborate measures of product and economic sophistication were developed by Hidalgo and Hausmann (2009). These authors used Balassa's (1965) index of revealed comparative advantage (RCA) to derive measures of diversification and ubiquity of each country's exports, which were then combined to arrive at more accurate indexes of product and economic sophistication. Evidence suggests that these indexes are powerful predictors of subsequent GDP per capita growth (e.g. Felipe et al. 2010, 2013).

Taking into account the scarcity of evidence regarding the determinants of income elasticities of trade, especially when trade is disaggregated into different sectors, this chapter aims to investigate whether modern measures of productive sophistication can explain the magnitudes of income elasticities and export and import growth. More specifically, this chapter's contribution is twofold. First, using a measure of industry sophistication, the impact of initial industry sophistication on subsequent total factor productivity growth is tested using industry-level data. This analysis is carried out dividing the sample of industries into low- and high-tech, in order to assess if these sectors present different dynamics. In other words, the chapter examines whether Hausmann et al.'s (2007) hypothesis is valid for different technological sectors. Second, the chapter investigates if changes in industry sophistication impact exports and imports in low- and high-tech sectors. In this case, the index of industry sophistication is used as a proxy for the quality of the exports of a given industry. Special attention is paid to the impact exerted by the introduction of sophistication on the magnitudes of the income elasticities of demand.

The empirical exercises use product-level trade data from UN Comtrade which is combined with price data from Feenstra and Romalis (2014) and productivity data from EU KLEMS. The final dataset used comprises data for 13 industries, classified into low- or high-tech, in seven countries, over the period 1984–2006. Combining these databases restricts the time span but allows estimating the impact of industry sophistication on the total factor productivity growth of each industry in each sector. Moreover, this also allows for the estimation of export and import functions introducing changes in relative industry sophistication as an additional explanatory variable to assess its impact on the income elasticities of trade in low- and high-tech sectors.

The remainder of this chapter is organized as follows. Section 2 discusses the balance-of-payments-constrained growth theory, and the measures of product, economic and industry sophistication. Section 3 presents the empirical investigation of the impact of industry sophistication on total factor productivity in low- and high-tech sectors as well as on export and import growth. Section 4 reports the concluding remarks of the chapter.

2 Theoretical Framework

2.1 The Balance-of-Payments Constraint to Growth and Non-price Competitiveness

The Kaldorian tradition has a long track of theoretical and empirical studies investigating why economic growth is so uneven amongst countries. It emphasizes the role of demand growth as the ultimate determinant of a country's economic growth rate. In this framework, the balance of payments becomes the fundamental limit to the growth of an open economy. Exports, in turn, play the dual role of stimulating demand and of providing the foreign currency that allows the other elements of autonomous demand to grow, particularly investment. From a dynamic viewpoint, the stimulus to demand can trigger a virtuous growth cycle that tends to increase the global productivity of the economy, due to the migration of factors to more productive sectors (manufacturing) and to the greater learning-by-doing these sectors will display (Kaldor 1966).

This is the underlying argument of the balance-of-payments-constrained growth models. Thirlwall (1979) demonstrates that long-term growth is directly related to the income elasticities of demand for exports and for imports. The model is composed of three equations:

$$x_t = \eta\left(p_{dt} - p_{ft} - e_t\right) + \varepsilon z_t \tag{10.1}$$

$$m_t = \psi\left(p_{ft} + e_t - p_{dt}\right) + \pi y_t \tag{10.2}$$

$$m_t + p_{ft} + e_t = p_{dt} + x_t \tag{10.3}$$

Equations (10.1) and (10.2) represent the functions of demand for exports and for imports, respectively, both expressed in growth rates. The variable x stands for the growth rate of exports, m for the growth rate of imports, p_d and p_f are the rate of change of domestic and foreign prices, e is the rate of change of the nominal exchange rate, z is the growth of the income of the rest of the world, y is the growth of real output, η (<0) is the price elasticity of demand for exports, ψ (<0) is the price elasticity of demand for imports, ε is the income elasticity of demand for exports, and π is the income elasticity of demand for imports. Equation (10.3) is the balance-of-payments equilibrium condition.

Solving the system of Eqs. (10.1), (10.2) and (10.3), we arrive at the balance-of-payments equilibrium growth rate (the time subscripts have been dropped for expositional convenience):

$$y_{B1} = \frac{(1+\eta+\psi)\left(p_d - p_f - e\right) + \varepsilon z}{\pi} \tag{10.4}$$

This equation leads to many results: (i) a domestic inflation higher than the inflation of the rest of the world reduces the balance-of-payments equilibrium growth rate, if $|\psi + \eta| > 1$ (Marshall-Lerner condition); (ii) a currency devaluation ($e > 0$) tends to increase the balance-of-payments equilibrium growth rate, if $|\psi + \eta| > 1$; (iii) a faster growth of world income increases the balance-of-payments equilibrium growth rate; (iv) the higher is the income elasticity of demand for imports (π), the lower will be the balance-of-payments equilibrium growth rate. However, by assuming the stylized fact that terms of trade are constant in the long run ($p_{dt} - p_{ft} - e_t = 0$), the equation can be reduced to the ratio represented by Eq. (10.5), known as Thirlwall's Law:

$$y_{B2} = \frac{\varepsilon}{\pi} z \tag{10.5}$$

or

$$y_{B3} = \frac{x}{\pi} \tag{10.6}$$

This last equation represents the highest growth rate compatible with balance-of-payments equilibrium. A faster growth rate would be achieved via policies that stimulate increases in the income elasticity of demand for exports and reductions in the income elasticity of demand for exports. It is worth mentioning that Eq. (10.5) is also valid if the Marshall-Lerner conditions are just met (i.e. $\eta + \psi = -1$), even if there are substantial variations in relative prices.[2]

Although the output growth rate is determined by the growth of demand, balance-of-payments-constrained growth models also consider supply side factors. Nevertheless, these factors do not refer only to the increase of the stock of factor inputs, but also, to qualitative aspects, related to what has come to be called non-price competitiveness. In fact, a major part of the industrial output has been characterized by an oligopolistic competitive environment, in which aggressive price competition is not to be found. The predominant form of competition is, rather, non-price competition (McCombie and Thirlwall 1994).

Authors from different theoretical backgrounds have carried out empirical tests to assess the impacts of non-price competitiveness on foreign trade. Several types of proxies were used, including, amongst others, the number of patents and R&D expenditures. Some of these studies are based on the theory of the technological gap (Posner 1961; Hufbauer 1970; Greenhalgh 1990; Schott and Pick 1984; Fagerberg 1988; Wakelin 1998), while others are based on the product life cycle theory (Vernon 1966, 1970; Wells 1972) or even on the hypothesis of product differentiation and the preference for variety (Linder 1961; Davies 1976; Barker 1977). As a rule, the studies verify the importance of non-price competitiveness for the expansion of exports and, hence, for the growth of income.

The focus on non-price competitiveness, however, goes against the neoclassical assumption that similar goods are homogeneous and would, therefore, follow the 'law of one price'. Price differences, according to the neoclassical approach, would reflect a differentiation of the compared products. This procedure entirely voids the law of any empirical basis (McCombie and Thirlwall 1994). The growth of non-price competitiveness, therefore, indicates the degree of product differentiation and increases of the quality of national output. In this context, therefore, manufacturing would be more liable to be subject to such competitive gains, for primary goods tend to be more homogeneous. This is exactly what Kravis and Lipsey (1971) found, demonstrating that basic goods are more prone to price competition than manufactured goods.

The conclusion of this debate is that non-price competitiveness is an important factor explaining exports, given the preference for a variety that grows with income—even if, for the same reason, it does not lead to a reduction of imports. Theoretically, however, gains from non-price competitiveness can be obtained in any kind of products. Freeman (1979) tests the impact of different non-price competitive strategies on a set of sectors. The results show that, for the production of capital goods, competition focuses on the development of new, more technological, products. In the production of consumption goods, on the other hand, design and marketing play a more important role, while for basic materials most innovations focus on reducing inputs. Hence, sectors with higher technological intensity are more susceptible to non-price competitiveness and their elasticity of demand is, therefore, higher.

Exploring the idea that income elasticities capture non-price competitiveness and are different between sectors, Araújo and Lima (2007) introduced the Multi-Sector Thirlwall's Law (MSTL). By considering that each sector of the economy is subject to a different income elasticity of demand for its production, the model implies that shifts in sectoral shares affect the growth rate of the economy as a whole. Hence, a country's growth rate can increase even if the rest of the world continues to grow at the same pace, as long as the composition of exports and imports is favourably altered (Gouvêa and Lima 2010; Romero and McCombie 2016). In sum, the long-term growth rate depends on the sectoral structure of the economy.

A number of works have estimated income elasticities for different sectors within countries (e.g. Gouvea and Lima 2010, 2013; Romero et al. 2011; Romero and McCombie 2016). They have found that technology-intensive sectors present greater income elasticities. These studies also conclude that both the original Thirlwall's Law and its multi-sector version adequately represent the economy's real growth rate. Hence, the tests confirm the importance of increasing the share of high-tech sectors in order to accelerate growth.

Despite the recent evidence indicating that income elasticities vary considering between sectors, there have been very few attempts to investigate the determinants of the magnitudes of sectoral income elasticities. This important gap in the existing literature is partially explained by the fact that in most works that employ innovation-based measures of non-price competitiveness, income growth is not introduced as an explanatory variable of export performance.

Recent studies, however, have sought to analyse the significance of measures of non-price competitiveness when introduced in traditional export and import demand functions. Ang et al. (2015) introduced a measure of innovation stocks relative to the competitors into export demand functions. The authors have tested the effect of this measure of technological (or non-price) competitiveness on export growth for a sample of six Asian countries over the period 1953–2010, and have found robust evidence that non-price competitiveness exerts a positive and significant impact of export growth.

Romero and McCombie (2017) used total factor productivity (a measure of economic efficiency) as a proxy for product quality in different export and import industries. This proxy for non-price competitiveness is based on McCombie and Roberts (2002) and Setterfield (2011), who argue that productivity growth might determine the magnitude of the income elasticities, given that the former might result from quality improvements. Romero and McCombie (2017) tested the impact of total factor productivity relative to the frontier country for a sample of seven European countries over the period 1984–2006, dividing the sample into low- and high-tech industries. The authors found that changes in relative non-price competitiveness have a positive and significant impact on the growth rates of exports and imports of both low- and high-tech sectors. Nonetheless, the effect is greater in the high-tech sector. Most importantly, Romero and McCombie (2017) call attention to the fact that income elasticities vary considerably when relative productivity is introduced, which is consistent with omitted (quality) variable bias. Moreover, they also highlight that similar movements are observed in Ang et al.'s (2015) tests.

2.2 Product and Economic Sophistication

Seeking to investigate the importance of the composition of a country's production for economic growth, Hausmann et al. (2007) proposed two measures of product and economic sophistication.

The product sophistication index, called PRODY, is represented by the income level associated with each product, and is calculated as the weighted average of the income per capita of the countries that export the given product. Formally:

$$\mathrm{PRODY}_k = \sum_j \left[\frac{\left(x_{jk} / \sum_k x_{jk} \right)}{\sum_j \left(x_{jk} / \sum_k x_{jk} \right)} \right] \left(Y / L \right)_j \tag{10.7}$$

where x denotes the exports of good k by country j and Y/L is income per capita.

The PRODY index, therefore, ranks commodities based on the exports and each country's income levels. Hence, this index does not capture differences in product sophistication between countries. In other words, the index is an outcome-based measure of sophistication that is based on the assumption that, if a given product is largely produced by rich countries, then the product is regarded as 'sophisticated'.

The economic (or country) sophistication index, called EXPY, in turn, represents the productivity level associated with a county's export basket, and is calculated as the weighted average of the sophistication of the products exported by the country. Formally:

$$\text{EXPY}_{jt} = \sum_k \left(\frac{x_{jkt}}{\sum_k x_{jkt}} \right) \text{PRODY}_k \tag{10.8}$$

This index, therefore, is a weighted average of the PRODY indexes of each product *k* for a particular country *j* at time *t*, where the weights are the value shares of each product in the country's total exports.

Using this approach, Hausmann et al. (2007) provide evidence that current export sophistication is a good predictor of the future growth rate of income per capita. In other words, this approach suggests that fast-growing countries have EXPY indexes higher than their actual per capita incomes (such as China and India), which indicates they are producing goods associated with higher income.

Nonetheless, the authors show that producing sophisticated goods leads to high growth rates; the authors' investigation provided only an initial approximation to the determinants of EXPY. Their empirical investigation only indicates that EXPY is positively correlated with population size and land area, and not correlated with human capital and institution quality.

Hidalgo et al. (2007) addressed this limitation by investigating whether the productive structure of a country influences the path, the costs and the speed of change towards the production of sophisticated goods. As the authors stress, the production of different types of goods requires different capabilities. Consequently, the capabilities possessed by a country determine the goods the country can produce and how difficult it is for the country to start producing goods that require different (or additional) capabilities.

However, directly measuring capabilities is a complex task. As an alternative, therefore, the authors proposed using conditional probabilities to establish how close products are in terms of the capabilities required for their production. This method is based on the assumption that the probability of producing two products that require similar capabilities is higher than the probability of producing two goods that require different capabilities. Thus, the exercise used disaggregated trade to calculate the probability of a country exporting product *i* given that it exports product *k*. The authors called *proximity* this conditional probability. Finally, adopting a threshold value for proximity, the authors established linkages between products, creating a network that they called *product space*.

Using product space, Hidalgo et al. (2007) reached three interesting conclusions: (i) different countries face different opportunities for increasing their economic growth; (ii) structural change and economic growth are highly path dependent, given that each country's initial productive structure reflects a different set of capabilities; and (iii) moving towards sophisticated goods takes time, since this process requires learning new capabilities.

Another limitation of the measures proposed by Hausmann et al. (2007) is that the proposed measures do not explain what makes the products exported by rich countries important for economic growth. Indeed, the PRODY index is simply based on the assumption that sophisticated (high-productivity) goods are the goods exported by high-income countries. As Felipe et al. (2012) stresses, this makes the approach circular. Moreover, this creates some counter-intuitively high measures of product sophistication. To illustrate this problem, Reis and Farole (2012) point out that the PRODY of bacon and ham is higher than the PRODY of internal combustion engines.

Hidalgo and Hausmann (2009) address this shortcoming by developing alternative measures of product and economic complexity. The authors defined the degree of product diversification of a country as the number of products that a country exports with RCA, and the degree of ubiquity of a product as the number of countries that export a product with RCA. Formally:

$$RCA_{jkt} = \left(\frac{x_{jkt} / \sum_{k} x_{jkt}}{\sum_{j} x_{jkt} / \sum_{j} \sum_{k} x_{jkt}} \right) \tag{10.9}$$

$$D_{jt} = \sum_{k} N_{jkt} \tag{10.10}$$

$$U_{kt} = \sum_{j} N_{jkt} \tag{10.11}$$

where D denotes diversification, U denotes ubiquity and $N = 1$ if country j exports product k with RCA at time t, and $N = 0$ otherwise. The index of RCA developed by Balassa (1965) has a straightforward interpretation. If the index is higher than 1, then the country has high competitiveness in the production of the given good. The opposite holds if the index is lower than 1. Thus, the higher the diversification of a country's exports is, the higher this country's sophistication is. In contrast, the lower the ubiquity of a good is, the higher its sophistication is.

Using these indexes, Hidalgo and Hausmann (2009) and Felipe et al. (2012) show that economic growth is strongly correlated with the production of a diversified basket of goods that are not exported by many other countries. Indeed, the latter finds that the measures of economic and product sophistication proposed by Hidalgo and Hausmann (2009) are highly correlated with measures of technological capabilities used in Schumpeterian works (e.g. Archibugi and Coco 2005). Consequently, this approach shows that not only diversification and ubiquity are negatively correlated, which means diversified countries tend to produce more complex (less ubiquitous) goods, but diversification is positively correlated with income level.

However, as Hidalgo and Hausmann (2009) and Hausmann et al. (2011) stress, diversification and ubiquity are crude approximations of economic (or country) and product sophistication. They argue that ubiquity and diversity can be combined to obtain better measures of economic and product sophistication. A country with low diversification but that produces goods with high ubiquity can be considered more sophisticated than a country that has similarly low diversification but produces goods will low ubiquity. Analogously, a good with high ubiquity but produced by countries that have low diversification can be considered less sophisticated than goods with similarly high ubiquity but produced by countries that have high diversification. As Hausmann et al. (2011)

argues, this process can be repeated to progressively increase the information captured by the measures, which will converge after a few iterations. These are the product sophistication (PS) and economic sophistication (ES) indexes used in this chapter. Formally:

$$\mathrm{PS}_{kt,n} = \left(\frac{1}{U_{kt}}\right)\sum_{j} N_{jkt}\mathrm{ES}_{jt,n-1} \tag{10.12}$$

$$\mathrm{ES}_{jt,n} = \left(\frac{1}{\sum_{k} N_{jkt}\mathrm{PS}_{kt,n-1}}\right) D_{jt} \tag{10.13}$$

where *n* denotes the number of iterations.

The measures developed by Hausmann et al. (2007) and Hidalgo and Hausmann (2009) have been employed by a number of works to analyse the development trajectories of different countries, taking into account the transformations in their productive structures. Felipe et al. (2010), for instance, has shown that Pakistan was not able to move towards the production of more sophisticated goods, which resulted in recurrent balance-of-payments problems, curtailing the country's growth. Felipe et al. (2013), in turn, showed that the successful development trajectory of China was associated with progressive increases in the RCA of products with high sophistication (especially machinery and electronics).

In addition, recent works have been extrapolating these measures and using them in econometric investigations. Boschma et al. (2013), for example, applied the approach to the analysis of technological proximity and technological change in US cities. Using patent data from the United States Patent and Trademark Office (USPTO) disaggregated by International Product Categories (IPC), the authors calculated an index of Revealed Technological Advantages (RTA) analogous to Balassa's (1965) RCA and used it to construct a *technology space* analogous to Hidalgo et al.'s (2007) product space. Using the technological proximity between different patent classes, the authors showed that different technological capabilities influenced different trajectories of technological specialization between cities. Bahar et al. (2014), in turn, used RCAs and an export similarity index to show that geographic proximity influenced the productive specialization of neighbouring countries. In other words, countries that are geographically close tend to present RCAs in similar products. The authors attribute this result to technological diffusion.

2.3 Industry Sophistication

In this chapter, EXPY is transposed to the industry level to measure the sophistication of the production of a given industry in each country. Calculating this index for each of the industries in the EU KLEMS database allows analysing the relationship between sophistication and productivity at the industry level. Moreover, using the same level of aggregation allows to assess the results found by Romero and McCombie (2017), investigating the impact of industry sophistication on trade performance.

The industry sophistication index, IEXPY, is calculated as the weighted average of the *PRODY* of the *n* products that integrate each industry *i*, for each country *j*, at time *t*:

$$\mathrm{IEXPY}_{ijt} = \sum_{n} \left(\frac{x_{jkt}}{\sum_{k} x_{jkt}} \right) \mathrm{PRODY}_{k} \qquad 10.14$$

Furthermore, an additional measure of industry sophistication is proposed in this chapter. Following the methodology proposed by Hausmann et al. (2007), the IEXPY index measures industry sophistication as the weighted average of PRODY for each product *n* in industry *i* and country *j*. The alternative measure proposed here, IEXPS, replaces PRODY with the product sophistication index *PS* based on Hidalgo and Hausmann's (2009) approach:

$$\mathrm{IEXPS}_{ijt} = \sum_{n} \left(\frac{x_{jkt}}{\sum_{n} x_{jkt}} \right) \mathrm{PS}_{k} \qquad (10.15)$$

3 Empirical Investigation

3.1 Data Description

The trade data used to calculate the industry sophistication indexes discussed in the previous section are from the UN Comtrade database, classified according to the Standard International Trade Classification (SITC) (Revision 2, 4 digits), and the data on GDP per capita (2011 PPP$) are from the World Development Indicators. The indexes were calculated for the period 1984–2006, given that price data from Feenstra and Romalis (2014) are available between 1984 and 2011, and the EU KLEMS data required to calculate productivity for each industry are available from 1976 to 2006. The final sample, therefore, comprises 13 goods-producing industries in seven countries, Austria, Denmark, Finland, Germany, the Netherlands, Spain and the United Kingdom.

Table 10.1 reports the products with highest and lowest values of the PRODY and PS indexes. PS and ES indexes were calculated using the first iteration betwen diversity and ubiquity. This table illustrates the problem with the PRODY index stressed by Reis and Farole (2012), given that some primary- and resource-based products figure amongst the most sophisticated products. This table shows also that the PS index partially solves this problem, given that only one of the five most sophisticated products is a resource-based product. The other products are all medium- or high-tech products. On the other end, both indexes indicate that the products with lowest sophistication are all primary, resource-based or low-tech products.

In spite of the differences between the indexes, however, the Spearman rank correlation between the two is still considerably high (0.75). Using the average PRODY index as reference for product sophistication and adopting Leamer's (1984) classification, the most sophisticated products are machinery (PRODY of $17,696) and chemicals (PRODY of $16,770). Capital-intensive products (PRODY of $12,657) appear after forest products (PRODY of $13,954) and petroleum (PRODY of $12,669). The goods with the lowest sophistication are labour-intensive products, raw materials, animal products, cereals and tropical agriculture products, respectively. A similar picture emerges if the average PS index is used as reference for product sophistication. Chemicals (PS of 190.8) are the most sophisticated products, followed by machinery (PS of 189.4),

Table 10.1 Products with higher and lower values of the PRODY and PS indexes

SITC	Product description	PRODY	PRODY rank	PS	PS rank	Lall's (2000) technological class
Top 5 PRODY						
3413	Petroleum gases and other gaseous hydrocarbons, nes, liquefied	32462.06	1	93.60573	752	Primary products
5147	Amide-function compounds; excluding urea	29774.54	2	199.2528	167	Resource-based
7412	Furnace burners; mechanical stokers, etc., and parts thereof, nes	29135.82	3	230.5944	10	Medium-tech
5415	Hormones, natural or reproduce by synthesis, in bulk	28903.62	4	216.3814	60	High-tech
7268	Bookbinding machinery; parts thereof, nes	27274.98	5	230.9483	9	Medium-tech
Bottom 5 PRODY						
1212	Tobacco, wholly or partly stripped	2115.613	753	128.7319	678	Primary products
2631	Raw cotton, excluding linters, not carded or combed	2098.813	754	98.88403	748	Primary products
741	Tea	2003.272	755	105.7965	745	Primary products
2771	Industrial diamonds	1981.667	756	142.4812	598	Primary products
2634	Cotton, carded or combed	1974.082	757	125.4862	688	Primary products
Top 5 PS						
6880	Uranium depleted in U235, thorium and alloys, nes; waste and scrap	25010.42	14	243.9294	1	Resource-based
5827	Silicones	24326.98	28	237.6393	2	Medium-tech
7753	Domestic dishwashing machines	24585.14	22	237.3484	3	Medium-tech

(*continued*)

Table 10.1 (continued)

SITC	Product description	PRODY	PRODY rank	PS	PS rank	Lall's (2000) technological class
7187	Nuclear reactors, and parts thereof, nes	20562.21	94	233.9071	4	High-tech
5836	Acrylic and methacrylic polymers; acrylo-methacrylic copolymers	22150.27	59	232.5783	5	Medium-tech
Bottom 5 PS						
2320	Natural rubber latex; natural rubber and gums	5746.701	675	92.38287	753	Primary products
2232	Palm nuts and kernels	4119.705	724	91.9226	754	Primary products
711	Coffee green, roasted; coffee substitutes containing coffee	2325.538	751	91.16449	755	Primary products
2655	Manila hemp, raw or processed but not spun, its tow and waste	5093.396	701	89.62418	756	Resource-based
611	Sugars, beet and cane, raw, solid	5946.703	669	88.33054	757	Resource-based

Source: Authors elaboration

capital-intensive (PS of 176.1), and labour-intensive goods (PS of 168.9). Interestingly, petroleum now figures the second least sophisticated product (PS of 140), which highlights the superiority of this index in measuring product sophistication.

3.2 Descriptive Analysis

In order to assess the relationships between sophistication, exports, imports and productivity for different groups of industries, the proposed indexes of industry sophistication (IEXPY and IEXPS) were calculated for the 13 goods-producing EU KLEMS industries, for which high quality data on sectoral productivity is available.

Figure 10.1 shows the evolution of the diversification of the economies under investigation, dividing the productive structure into core products (machinery, chemicals and capital-intensive) and peripheral products (labour-intensive, forest products, raw materials, animal products, cereals, petroleum and tropical agriculture products). This figure shows that Germany is the country with the highest number of core products with RCA during the whole period. Nonetheless, this number has been falling since the 1980s. The same occurs with the United Kingdom, while Spain and Finland have been increasing the number of core products in which the country has RCA. The remaining countries present relatively stable figures during the period. The scenario is similar for peripheral products, with three important distinctions: (i) Germany has a much lower number of products with RCA, although this number is relatively stable; (ii) the Netherlands is the country with the highest

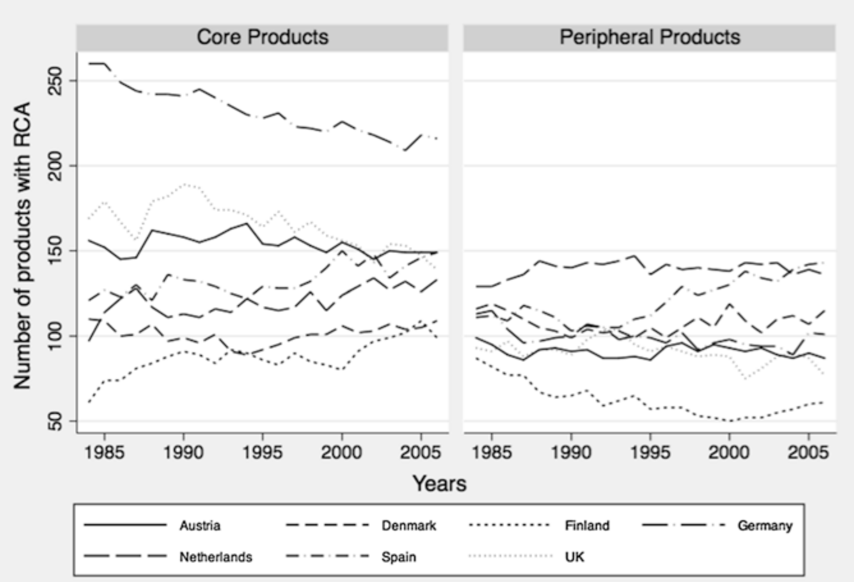

Fig. 10.1 Productive diversification of selected European countries (1984–2006) (Source: Author's own elaboration)

number of peripheral products with RCA; and (iii) Finland presents a falling number of peripheral products with RCA, which indicates the country has been moving from the production of this type of goods to the production of core goods.

Comparing the numbers shown in Fig. 10.1 with the average index of economic sophistication (ES) of the countries under analysis indicates that there is a close correlation between productive diversification (especially in core products) and economic sophistication, as found in previous works (e.g. Felipe et al. 2012). According to the ES index, the most sophisticated of these countries is Germany (ES of 0.064), followed by the United Kingdom (ES of 0.061) and Finland (0.056). The Netherlands and Austria have almost the same sophistication (ES of 0.054). Spain has the second lowest sophistication (ES of 0.051), only ahead of Denmark (ES of 0.050). Moreover, a similar ranking emerges when the average EXPY index is used, although in this case Finland figures as the most sophisticated economy. Nonetheless, when the evolution of the two indexes is compared a striking difference emerges: while according to the ES index the sophistication of all the economies has been falling during the period, the opposite holds for the EXPY index. This difference stems from the fact that the former is based on the diversification of each economy (given the ubiquity of the products produced), which tends to decrease through time, while the latter is based on the export shares of sophisticated goods, which tends to increase through time. Hence, this result indicates an important limitation of ES in comparison with EXPY, which shows that the latter is a superior index of economic sophistication.

After analysing the diversification of the economies under investigation, Table 10.2 turns to the analysis of the shares of core and peripheral products in total exports. This table shows that, although the number of core products with RCA has been falling in Germany and the United Kingdom, the share of these products has increased over the last couple of decades, and these countries possess the highest shares in this type of good. Indeed, the share of core products in total exports has been increased in all the countries. Nonetheless, Finland and the Netherlands have presented the highest increases. This suggests that increasing this share seems to be more important than diversifying the country's productive structure after a certain level of diversification is reached.

Table 10.2 Value shares in total exports: core and peripheral products

Period	1986–1989	1990–1994	1995–1999	2000–2006
Peripheral products				
Austria	0.35	0.33	0.33	0.31
Denmark	0.56	0.53	0.50	0.47
Finland	0.58	0.52	0.44	0.34
Germany	0.22	0.22	0.20	0.19
The Netherlands	0.52	0.49	0.42	0.34
Spain	0.43	0.34	0.35	0.34
United Kingdom	0.37	0.31	0.28	0.28
Core products				
Austria	0.65	0.67	0.67	0.69
Denmark	0.44	0.47	0.50	0.53
Finland	0.42	0.48	0.56	0.66
Germany	0.78	0.78	0.80	0.81
Netherlands	0.48	0.51	0.58	0.66
Spain	0.57	0.66	0.65	0.66
United Kingdom	0.63	0.69	0.72	0.72

Source: Author's own elaboration

Figure 10.2 shows the relationships between IEXPS, exports and productivity for the low-tech and the high-tech sectors. This index can be considered the preferred industry sophistication index, given that PS is a superior product sophistication index than PRODY, as argued in the previous section, while EXPY is a superior economic sophistication index than ES. Consequently, this chapter's discussion focuses on the IEXPS index, although the results found using the IEXPY index are similar.

As expected, Fig. 10.2 shows that industry sophistication is positively correlated with industry exports and productivity. Indeed, as Hausmann et al. (2007) have constructed EXPY to serve as a proxy for productivity, this is not an unexpected result. Interestingly, however, the relationship between industry sophistication and productivity is much stronger for high-tech industries than for low-tech industries. This preliminary finding shows that although productivity is positively correlated with quality in high-tech industries, this correlation seems to be less important in low-tech industries. A possible explanation is that low-tech industries rely more heavily on cost-competitiveness. Thus, as cost-competitiveness is often associated with specialization, it is not surprising that productivity

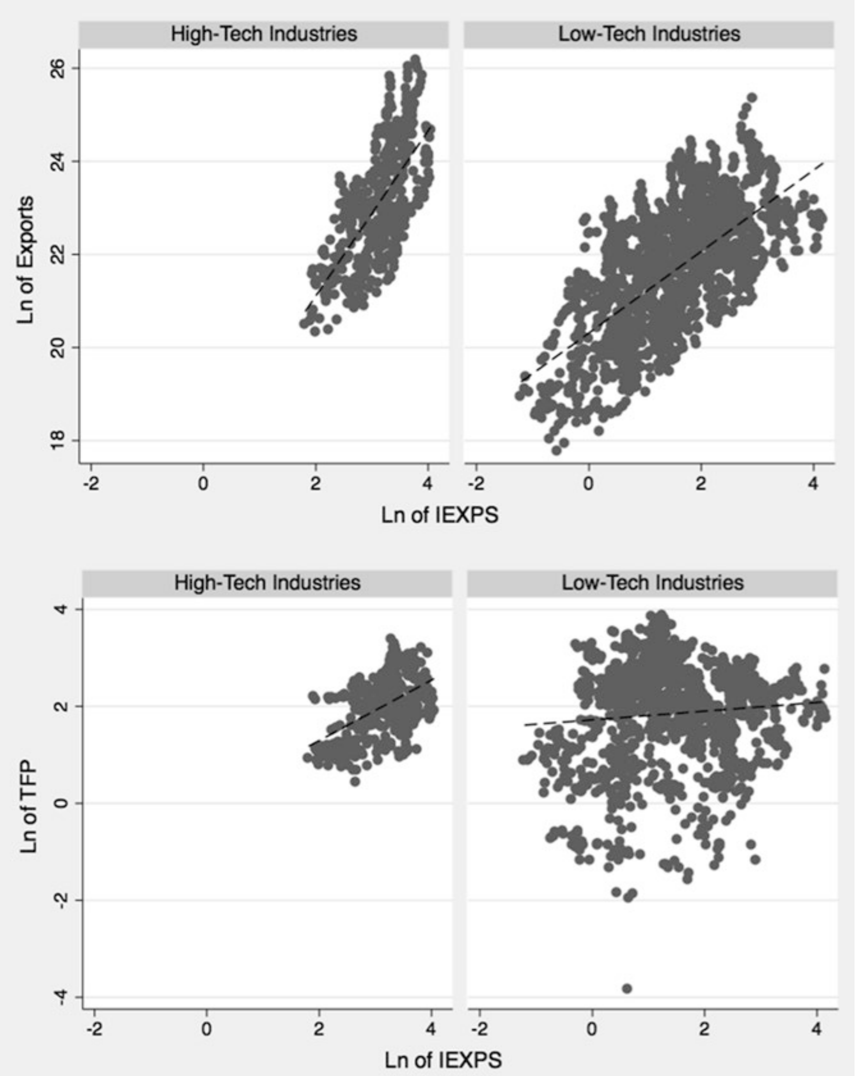

Fig. 10.2 Sophistication, exports and productivity at the industry level (Source: Author's own elaboration)

in low-tech industries is only weakly correlated with measures of sophistication, given that the latter are associated with diversification.

3.3 Estimation Method

The relationship between productivity and sophistication was tested following Hausmann et al. (2007), who estimated the impact of initial industry sophistication on subsequent productivity growth. In the tests reported in this chapter, product quality is proxied by the industry sophistication index IEXPS. Taking into account the impact of demand growth on productivity growth via Verdoorn's Law (e.g. Romero and Britto 2017), output growth was introduced as a determinant of productivity growth in each industry. Thus, the estimated equation is an expanded version of Kaldor-Verdoorn's Law:

$$T\hat{F}P_{ijt} = \beta_0 - \beta_1 \ln G_{ijt-1} + \beta_2 \ln N_{ijt-1} + \beta_3 \hat{Y}_{ijt} + u_{ijt} \qquad (10.16)$$

where TFP is total factor productivity, N is industry sophistication (i.e. IEXPS), Y is value added and G is the technology gap. The circumflexes over the variables denote growth rates. TFP growth rates ($T\hat{F}P \equiv \hat{Y} - \alpha K + \left(1-\alpha\right)\hat{L}$, where α is the share of capital in value added) were calculated using the log-level index number approach, which is more commonly used in the literature, while capital stocks were divided into information and communication technology (ICT) assets and non-ICT assets. The technology gap was calculated as the difference between the logarithms of domestic and foreign TFPs.[3] Data on real value added and capital stocks in 1995 US dollars, labour shares and number of hours worked by persons engaged in production were used to calculate TFP growth rates. Variables in constant 1995 prices were transformed from national currencies to 1995 US dollars using industry-specific PPPs from the Groningen Growth and Development Centre (GGDC) Productivity Level Database (Inklaar and Timmer 2008).

The 13 industries were split into two samples following the OECD technological classification (OECD 2003). The first sample, henceforth called low-tech industries, comprises five low-tech industries (Food, Textiles, Wood, Paper and Other Manufactures) plus three medium-low-tech industries (Plastics, Minerals and Metals). The second sample, henceforth called high-tech industries, comprises three medium-high industries (chemicals, machinery and transport) plus the high-tech industry (Electrical). The export and import demand functions estimated in this chapter follow the specifications proposed by Romero and McCombie (2017), which incorporate relative non-price competitiveness into standard export and import demand functions:[4]

$$\begin{aligned}\ln \hat{X}_{ijt} &= \beta_0 - \beta_1 \ln \hat{P}_{ijt} + \beta_1 \ln \hat{P}_{fijt} + \beta_2 \ln \hat{N}_{ijt} \\ &\quad - \beta_2 \ln \hat{N}_{fijt} + \beta_3 \ln \hat{Z}_{jt} + u_{ijt} \qquad (10.17)\end{aligned}$$

$$\begin{aligned}\ln \hat{M}_{ijt} &= \beta_5 - \beta_6 \ln \hat{P}_{fijt} + \beta_6 \ln \hat{P}_{ijt} + \beta_7 \ln \hat{N}_{fijt} \\ &\quad - \beta_7 \ln \hat{N}_{ijt} + \beta_8 \ln \hat{Y}_{jt} + u_{ijt} \qquad (10.18)\end{aligned}$$

where X is exports, M is imports, P is prices, Z is foreign income and N is quality (i.e. the product sophistication index IEXPS). Moreover, f denotes variables for the foreign economy, and i are industries in j countries at time t. 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 then transformed into EU KLEMS industries. 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 System Generalized Method of Moments (GMM) estimator was employed to control for fixed effects and simultaneity in the regressions reported in this chapter (see Blundell and Bond 2000; Roodman 2009).

3.4 Estimation Results

Table 10.3 reports estimates of the relationship between changes in sophistication and productivity growth. To assess the measures of sophistication calculated in this chapter, Hausmann et al.'s (2007) test of the relationship between initial EXPY and subsequent productivity growth

Table 10.3 Industry sophistication and productivity growth

Dependent variable	Growth rate of GDP per capita	Growth rate of TFP	Growth rate of TFP	Growth rate of TFP	Growth rate of TFP
Method	OLS	SYS-GMM	SYS-GMM	SYS-GMM	SYS-GMM
	Countries	Low-tech industries	Low-tech industries	High-tech industries	High-tech industries
Sample	(i)	(ii)	(iii)	(iv)	(v)
Ln of initial technology gap	−0.0106* (0.00436)				
Ln of initial EXPY	0.0378** (0.0117)				
Lagged technology gap		0.100 (0.206)	0.00498 (0.0815)	−0.0575 (0.0415)	−0.0638** (0.0212)
Lagged Ln of IEXPS		−0.0318 (0.0656)	−0.00314 (0.0269)	0.0473++ (0.0256)	0.0471* (0.0173)
Growth rate of value added			0.557* (0.273)		0.583* (0.240)
Constant	−0.239** (0.0768)	0.142 (0.257)	0.0202 (0.108)	−0.165 (0.112)	−0.187* (0.0666)
N. Observations	102	350	350	105	105
No. Groups		70	70	21	21
No. Instruments/ Lags		6/2–5	10/2–4	4/3	6/4
Arellano-Bond AR Test		0.753	0.662	0.653	–
Hansen's J Test		0.372	0.351	0.534	0.489

Note: 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 13 goods-producing industries, excluding the Fuel and Chemical industries. Significance: ***=0.1%; **=1%; *=5%; ++=10%; +=15%

Source: Authors' elaboration

(proxied by GDP per capita) was replicated using cross-country OLS. The test was regressed using a sample of 102 countries for which data is available for all years of the period 1996–2006. The test employed the average of each variable during the period investigated. The estimated regression is reported in column (i). The significance and magnitude of the estimated coefficients are very similar to the results of Hausmann et al. (2007).

In columns (ii) to (v) of Table 10.3, industry-level data is used to estimate the impact of sophistication on productivity growth. Hence, the growth rate of GDP per capita is replaced by the growth rate of industry TFP, and EXPY is replaced by IEXPS. Moreover, System GMM is now utilized. Arellano and Bond's (1991) AR Test and Hansen's J Test indicate that the instruments are valid at a 5% significance level in all these regressions. Columns (ii) and (iv) of Table 10.3 replicate the specification tested in column (i) using samples of low- and high-tech industries, respectively. For low-tech industries, none of the variables is significant and sophistication has a negative sign. For high-tech industries, however, initial sophistication is positive and significant, so that the results are similar to the estimates of Hausmann et al. (2007).

Finally, in columns (iii) and (v) the growth rate of value added is introduced, and an expanded Kaldor-Verdoorn's Law is estimated. The results of these regressions are similar to the estimates of Romero and Britto (2017), suggesting that returns to scale are slightly higher in high-tech industries. Nonetheless, while sophistication is positive and significant for high-tech industries, the opposite holds for low-tech industries. These results indicate once again that sophistication is more important for productivity growth in high-tech industries, while it seems to be less relevant for low-tech industries. Although not significant, the fact that sophistication has a negative sign for the latter sample might be due to the fact that this variable is calculated based on the importance of diversification. In low-tech industries, however, where cost-competitiveness seems to be more important, specialization is likely to be more relevant than diversification. Furthermore, the measure of sophistication used here is not free from problems. Hence, these results should be taken with caution.

Table 10.4 reports estimates of export demand functions by technological sectors. Arellano and Bond's (1991) AR Test and Hansen's J Test indicate that the instruments are valid at a 5% significance level in all regressions but the one reported in column (iii). Nonetheless, given that foreign and domestic sophistication are highly correlated (0.71) in this sample, the regressions that include only domestic sophistication present the most relevant results.

The elasticities of demand and of domestic sophistication are both positive and significant, except for sophistication in column (iv). Focusing on the regressions that only include domestic sophistication, it is possible to observe that the income and the sophistication elasticities of demand are slightly higher for high-tech industries. Most importantly, comparing the estimates reported in Table 10.4 with the estimates of simple export demand functions presented in columns (i) and (iv), one observes that the income elasticities of demand change when sophistication is introduced. This result is consistent with omitted variable bias, as discussed by Romero and McCombie (2017). As expected, for high-tech industries, the elasticity reduces when domestic sophistication is introduced and its effect is removed from the income elasticity, and then increases when foreign sophistication is added. These results are similar to the ones found by Romero and McCombie (2017). For low-tech industries, however, the elasticity increases with the introduction of domestic sophistication instead of decreasing.

Table 10.5 reports estimates of import demand functions by technological sectors. Arellano and Bond's (1991) AR Test and Hansen's J Test indicate that the instruments are valid at a 5% significance level only in the regressions reported in columns (i), (ii) and (iv). Hence, these results must be considered with caution. Once again, given that foreign and domestic sophistication are highly correlated (0.71) in this sample, the regressions that include only domestic sophistication present the most relevant results.

For the import demand functions, the income and the foreign sophistication elasticities of demand are again both positive and significant, while domestic sophistication is negative and significant in column (ii), as expected, but is positive in column (v). Moreover, the changes in the income elasticities observed when measures of sophistication are introduced are not the expected movements. Hence, the results found for the import demand functions are not as consistent as the results found for the export demand functions.

Table 10.4 Export demand functions by sector

Dependent variable	Ln of exports	Ln of exports	Ln of exports	Ln of exports	Ln of exports	Ln of exports
	Low-tech industries	Low-tech industries	Low-tech industries	High-tech industries	High-tech industries	High-tech industries
Sample	(i)	(ii)	(iii)	(iv)	(v)	(vi)
Ln of foreign income	1.776***	2.076***	2.215***	2.609***	2.169***	2.495**
	(0.147)	(0.189)	(0.212)	(0.398)	(0.363)	(0.739)
Ln of domestic prices	−0.842	−0.481	−2.529	2.174	0.548	1.803
	(2.389)	(0.583)	(1.928)	(1.394)	(1.121)	(3.376)
Ln of foreign prices	0.882	0.469	2.579	−0.0449	0.361	−1.035
	(2.340)	(0.597)	(1.884)	(1.613)	(1.151)	(3.882)
Ln of domestic IEXPS		0.635++	0.812*		0.850*	0.283
		(0.357)	(0.375)		(0.403)	(0.715)
Ln of foreign IEXPS			0.0252			−0.0107
			(0.346)			(0.568)
Constant	−33.18***	−43.49***	−47.95***	−54.75***	−45.44***	−53.89*
	(4.461)	(6.275)	(6.885)	(13.11)	(10.35)	(21.60)
N. Observations	420	420	420	126	126	126
No. Groups	70	70	70	21	21	21
No. Instruments/ Lags	6/2–3	11/2–4	12/3–5	6/2–3	9/3–4	10/2–3
Arellano-Bond AR Test	0.802	0.431	0.477	0.700	0.155	0.696
Hansen's J Test	0.654	0.258	0.000	0.455	0.839	0.417

Note: The estimation method used is SYS-GMM. 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 13 goods-producing industries, excluding the Fuel and Chemical industries. Significance: ***=0.1%; **=1%; *=5%; ++=10%; +=15%

Source: Authors' elaboration

Table 10.5 Import demand functions by sector

Dependent variable	Ln of imports	Ln of imports	Ln of imports	Ln of imports	Ln of imports	Ln of imports
	Low-tech industries	Low-tech industries	Low-tech industries	High-tech industries	High-tech industries	High-tech industries
Sample	(i)	(ii)	(iii)	(iv)	(v)	(vi)
Ln of domestic income	2.307***	1.001*	1.066***	2.599***	0.647*	0.951**
	(0.385)	(0.496)	(0.125)	(0.629)	(0.280)	(0.270)
Ln of domestic prices	−0.778	−1.105	9.511**	−0.551	−1.621	0.917
	(3.442)	(2.571)	(2.801)	(2.147)	(1.582)	(4.257)
Ln of foreign prices	1.097	1.152	−9.654**	−0.275	−0.737	−1.044
	(3.618)	(2.512)	(3.141)	(2.844)	(3.021)	(6.046)
Ln of domestic IEXPS		−1.250+	−1.420		2.475++	−0.0545
		(0.783)	(1.156)		(1.244)	(1.176)
Ln of foreign IESPY			1.513++			1.251+
			(0.906)			(0.777)
Constant	−39.35***	−2.781	−8.833**	−46.94*	−4.726	−6.553
	(10.14)	(14.01)	(3.122)	(18.09)	(7.183)	(8.208)
N. Observations	420	420	420	126	126	126
No. Groups	70	70	70	21	21	21
No. Instruments/ Lags	8/2–3	11/2–4	10/3–4	8/2–3	11/2–4	8/4
Arellano-Bond AR Test	0.139	0.571	0.768	0.384	0.138	0.003
Hansen’s J Test	0.356	0.114	0.002	0.940	0.046	0.012

Note: The estimation method used is SYS-GMM. 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 13 goods-producing industries, excluding the Fuel and Chemical industries. Significance: ***=0.1%; **=1%; *=5%; ++=10%; +=15%

Source: Authors’ elaboration

A possible explanation for these minor inconsistencies is the fact that the measures of sophistication are constructed based on the stringent assumption that the sophistication of a given product does not vary between countries. If this assumption does not hold, then the measures of industry sophistication will not be good measures of industry quality. Moreover, the fact that the countries in the sample are all developed countries reduced the variance of the measures of industry sophistication, given that they depend on the shares of each exported product within each industry. This reduces the explanatory power of the variable as well.

4 Summary and Conclusions

The investigation presented in this chapter indicates that changes in product sophistication influence productivity, export and import growth. This chapter's tests suggest that productivity growth is associated with improvements in industry sophistication. Hence, the findings of the present chapter corroborate the findings of Romero and McCombie (2017). Nonetheless, the positive impact of industry sophistication on productivity growth is only significant in high-tech industries. This provides evidence that productivity growth in low-tech industries is to a higher extent associated with cost reductions (efficiency) and to a lesser extent associated with quality improvements, while the opposite holds for high-tech industries. However, given the limitations of the sophistication indexes employed, the impact of quality improvements for productivity growth in low-tech industries should not be dismissed without further investigation on the topic. In spite of this, the impact of sophistication on exports is positive and significant for both groups of industries. Most importantly, the impact of sophistication on exports is higher for high-tech industries. As for imports the tests provided some evidence that sophistication has a significant impact on imports as well.

Finally, considering the Kaldorian theoretical background of this chapter, the results further strengthen the longstanding notion that the long-term path to sustained growth is one of faster growth of exports to sustain increases in imports, in which the manufacturing sector plays a central role. However, in order to be a sufficient condition, diversification of production and exports towards progressively higher-tech, more sophisticated goods, is necessary. This is the important contemporary lesson with widespread policy implications for developed and developing countries alike.

Notes

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2. The original model was also extended to account for capital flows. See Thirlwall and Hussain (1982), Barbosa-Filho (2001), Moreno-Brid (2003).
3. See Romero and Britto (2017) for more detailed discussion on the data treatment.
4. Capacity constraints are not considered in this chapter's tests.

References

Ang, J. B., Madsen, J. B., & Robertson, P. E. (2015). Export performance of the Asian miracle economies: The role of innovation and product variety. *Canadian Journal of Economics, 48*(1), 273–309.

Araujo, R. A., & Lima, G. T. (2007). A structural economic dynamics approach to balance-of-payments-constrained growth. *Cambridge Journal of Economics, 31*(5), 755–774.

Archibugi, D., & Coco, A. (2005). Measuring technological capabilities at the country level: A survey and a menu of choice. *Research Policy, 34*, 175–194.

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.

Bahar, D., Hausmann, R., & Hidalgo, C. (2014). Neighbors and the evolution of the comparative advantage of nations: Evidence of international knowledge diffusion? *Journal of International Economics, 92*, 111–123.

Balassa, B. (1965). Trade liberalization and revealed comparative advantage. *Manchester School of Economics and Social Studies, 33*, 99–123.

Barker, T. (1977). International trade and economic growth: an alternative to the neoclassical approach. *Cambridge Journal of Economics, 1*(2), 153–172.

Blundell, R., & Bond, S. (2000). GMM estimation with persistent panel data: An application to production functions. *Econometric Reviews, 19*(3), 321–340.

Boschma, R., Balland, P.-A., & Kogler, D. F. (2013). Relatedness and technological change in cities: The rise and fall of technological knowledge in U.S. metropolitan areas from 1981 to 2010. *Papers in Evolutionary Economic Geography*, *13*(16). Utrecht University.

Davies, R. (1976). *On the relation between product differentiation and international trade flows*. Discussion paper. University of Bath.

Fagerberg, J. (1988). International competitiveness. *Economic Journal, 98*(391), 355–374.

Feenstra, R., & Romalis, C. (2014). International prices and endogenous quality. *Quarterly Journal of Economics, 129*(2), 477–527.

Felipe, J., McCombie, J. S. L., & Naqvi, K. (2010). Is Pakistan's growth rate balance-of-payments constrained? Policies and implications for development and growth. *Oxford Development Studies, 38*(4), 477–496.

Felipe, J., Kumar, U., Abdon, A., & Bacate, M. (2012). Product complexity and economic development. *Structural Change and Economic Dynamics, 23*, 36–68.

Felipe, J., Kumar, U., Usui, N., & Abdon, A. M. (2013). Why has China succeeded? And why it will continue to do so. *Cambridge Journal of Economics, 37*, 791–818.

Freeman, C. (1979). Technological innovation and British trade performance. In F. Blackaby (Ed.), *De-industrialization, national institute of economic and social research*, *Economic policy papers 2*. London: Heinemann.

Fujita, M., Krugman, P., & Venables, A. J. (1999). *The spatial economy*. Cambridge, MA: MIT Press.

Furtado, C. (1964). *Development and underdevelopment*. Berkley: University of California Press.

Gouvêa, 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*, 171–206.

Greenhalgh, C. (1988). *Innovation and the structure of UK trade 1951–81: An exploration* (Applied economics discussion paper, n. 63). Institute of Economics and Statistics, University of Oxford.

Greenhalgh, C. (1990). Innovation and trade performances in the United Kingdom. *Economic Journal, 100*(400), 105–118.

Hausmann, R., Hwang, J., & Rodrik, D. (2007). What you export matters. *Journal of Economic Growth, 12*(1), 1–25.

Hausmann, R., Hidalgo, C. A., Bustos, S., Coscia, M., Chung, S., Jimenez, J., Simões, A., & Yildirim, M. A. (2011). *The atlas of economics complexity – Mapping paths to prosperity*. Hollis: Puritan Press.

Hidalgo, C., & Hausmann, R. (2009). The building blocks of economic complexity. *Proceedings of the National Academy of Sciences of the United States of America, 106*(26), 10570–10575.

Hidalgo, C., Klinger, B., Barabasi, A. L., & Hausmann, R. (2007). The product space conditions the development of nations. *Science, 317*, 482–487.

Hirschman, A. (1958). *The strategy of economic development*. New Haven: Yale University Press.

Hufbauer, G. C. (1970). The impact of national characteristics & technology on the commodity composition of trade in manufactured goods. In R. Vernon (Ed.), *The technology factor in international trade, NBER Books*. NBER: New York.

Kaldor, N. (1966). *Causes of the slow rate of economic growth of the United Kingdom*. Cambridge: Cambridge University Press.

Kravis, I. B., & Lipsey, R. E. (1971). *Price competitiveness in world trade*. New York: National Bureau of Economics Research.

Krugman, P. (1991). *Geography and trade*. Cambridge, MA: MIT.

Kuznets, S. (1966). *Modern economic growth*. New Haven: Yale University Press.

Leamer, E. (1984). *Sources of international comparative advantage: Theory and evidence*. Cambridge, MA: MIT Press.

Lewis, A. (1955). *The theory of economic growth*. Homewood: Irwin.

Linder, S. B. (1961). *An essay on trade and transformation*. New York: Wiley.

Mayes, D., Buxton, T., & Murfin, A. (1988). *R&D innovation and trade performance*. Unpublished. NEDO.

McCombie, J. S. L., & Thirlwall, A. P. (1994). *Economic growth and the balance-of-payments constraint*. London: Macmillan Press.

Muendler, M. A. (2009). *Converter from SITC to ISIC*. Unpublished mimeo. University of California-San Diego.

OECD. (2003). *OECD science, technology and industry scoreboard*. Paris: OECD Publishing.

Pavitt, K., & Soete, L. (1980). *Technical innovation and British economic performance*. London: Macmillan.

Posner, M. V. (1961). International trade and technical change. *Oxford Economic Papers, 13*(3), 323–341.

Prebisch, R. (1962). The economic development of Latin America and its principal problems. *Economic Bulletin for Latin America, 7*, 1–22. United Nations.

Reis, J. G., & Farole, T. (2012). *Trade competitiveness diagnostic toolkit*. Washington, DC: The World Bank.

Romero, J. P., & Britto, G. (2017). Increasing returns to scale, technological catch-up and research intensity: An industry-level investigation combining EU KLEMS productivity data with patent data. *Cambridge Journal of Economics, 41*, 391–412.

Romero, J. P., & McCombie, J. S. L. (2016). Differences in increasing returns between technological sectors. *Journal of Economic Studies, 43*, 863–878.

Romero, J. P., & McCombie, J. S. L. (2017). Thirlwall's law and the specification of export and import demand functions. *Metroeconomica,* 00:1–30. https://doi.org/10.1111/meca.12185

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

Schott, K., & Pick, K. (1984). *The effects of price and non-price factors on U.K. export performance and import penetration* (Discussion paper, 84-01). Department of Political Economy, University of London.

Setterfield, M. (2011). The remarkable durability of Thirlwall's law. *PSL Quarterly Review, 64*(259), 393–427.

Thirlwall, A. P. (1979). The balance of payments constraint as an explanation of international growth rates differences. *Banca Nazionale del Lavoro Quarterly Review, 128*, 45–53.

Vernon, R. (1966). International investment and international trade in the product cycle. *Quarterly Journal of Economics, 80*(2), 190–207.

Wells, J. T. (1969). Test of a product cycle model of international trade: U.S exports of consumer durables. *Quarterly Journal of Economics, 83*(1), 152–162.

Wells, J. T. (1972). International trade: The product life cycle approach. In *The product life cycle and international trade*. Cambridge, MA: Harvard University Press.