Papers in Evolutionary Economic Geography

13.10

Export variety, technological content and economic performance: The case of Portugal

Francisco Rebelo and Ester Gomes da Silva

Utrecht University
Urban & Regional research centre Utrecht

Export variety, technological content and economic performance: The case of Portugal

Francisco Rebelo

Faculdade de Economia, Universidade do Porto

Ester Gomes da Silva[*]

Faculdade de Letras/ISFLUP; CEF.UP, Universidade do Porto

Abstract

Although the analysis of the relationship between international trade and economic growth has an important tradition in the economic literature, the specific focus on a related matter, the link between export variety and economic growth, remains a relatively unexplored field of research. Recently, a few studies have approached this issue, adopting a neo-Schumpeterian framework. In line with this general frame of analysis, in this paper we investigate the impact of export variety on economic growth, cross-relating the variety dimension with technological upgrading.

Cointegration econometric results based on the Portuguese experience over the past four decades (1967-2010) show that increased related variety has led to a significant growth bonus, but only in the case of technology advanced sectors. The impact of export variety on economic performance seems, therefore, to be conditioned by the technological intensity of the products involved.

Keywords: Trade; variety; economic growth; technical change; Portugal.

JEL-Codes: F10; O11; O30; O52.

[*] Corresponding author. Email: esilva@letras.up.pt.

1. Introduction

Since the industrial revolution, the level of variety of the economic system has increased markedly, with the emergence of many new objects and activities (Saviotti and Frenken, 2008). This trend of increasing variety has been addressed by several streams of research in the economic literature, including international trade studies. Notwithstanding, the study of the relationship between international trade variety and economic growth remains a relatively unexplored topic of analysis.

Recently, some empirical studies have approached the issue for a number of countries, finding in most cases a positive and significant impact of variety in economic growth (e.g., Funke and Ruhwedel, 2005; Boschma *et al.*, 2012). To our knowledge, the inter-relatedness of variety and technology dimensions has not, however, been addressed yet in the literature.[1] Due to the well-know role played by technological upgrading over growth (e.g. Fagerberg, 2000; Fagerberg *et al.*, 2007), it can be conceived that changes in variety have different effects over economic growth, depending on the technological profile of the products involved. In this paper we explore this issue, focusing on a country which experienced substantial change in both the volume and the composition of international trade during the period under analysis. In the last half a century, Portugal experienced a significant increase in trade openness, which accompanied the country's transition from an agricultural to an industry-based economy, with several studies stressing the role played by increasing economic integration as an important source of economic growth (e.g., Afonso and Aguiar, 2005; Mateus, 2006; Cabral, 2008). We undertake a more detailed analysis of this link, examining the specific role played by qualitative change in Portuguese exports on the country's economic record. The investigation is theoretically grounded within neo-Schumpeterian arguments, which stress the dynamic,

[1] A recent exception is the work from Hartog *et al.* (2012), but in this case the analysis is based on employment, rather than productivity growth.

cumulative, and path-dependent features of economic development (Amendola and Gaffard, 1998; Kruger, 2008).

Econometric testing is carried out using highly disaggregated annual export data (ISIC 4-digit industry level) from the CHELEM database, which allows for a thorough assessment of variety. By performing a longitudinal study, an approach that has been rather scarce in the literature, we provide a more comprehensive account of the inter-relatedness features of history, technology, trade and growth. In fact, although longitudinal and cross-section studies are complementary, the degree of attention to detail is hardly the same. The analysis of a wide set of countries may uncover a number of *stylised facts*, but the economic history and the individual country's specificities are necessarily overlooked.[2]

The empirical analysis is performed using cointegration techniques, which allow for the estimation of long-run parameters in a relationship that includes non-stationary variables. Export variety is measured with recourse to entropy measures, which are crossed with technology and innovativeness dimensions, by using sectoral classification schemes (OECD, 2002; Tidd and Bessant, 2009). We include also a number of control variables, providing a more rigorous account of the role played specifically by our main explaining factor.

The paper is organized as follows. Section 2 provides a brief account on the relationship between variety and economic growth, describing major theoretical and empirical results. Section 3 presents the economic background, providing an overlook of economic growth and export variety in Portugal between 1967 and 2010. Section 4 presents the econometric framework and the estimation results. Section 5 concludes, providing a synthesis of results and presenting some policy implications.

[2] We recall in this respect Pack's contention according to which *"the challenge for empirical work is to test the implications of the new theory more directly (…) this means testing its insights against the economic evolution of individual countries using time series data"* (Pack, 1994, p. 70).

2. Export variety and economic growth: theory and empirical findings

Variety is related to the notion of structural change, which is typically seen as representing changes in the number and relative weights of the sectors that compose an economic system, driven either by changes in demand or supply-side factors (Saviotti and Frenken, 2008; Kruger, 2008; Silva and Teixeira, 2008). Variety differs, however, from structural change, as it can take place at lower levels of aggregation (i.e., within sectors), representing changes that are not necessarily related to the emergence, extinction or changing weights of sectors (Saviotti and Pyka, 2004).

The concept of variety is therefore included within the broad notion of *qualitative change*, being defined by Saviotti and Frenken (2008, p. 205) as *"the number of actors, activities and objects required to describe the economic system"*. Variety increases whenever new objects are produced and new activities are required to produce those new objects, being thus a *"measure of the extent of differentiation of the economic system"* (Saviotti, 2003: 226).

Product variety can assume different forms, taking place both within sectors (*related variety*), and between sectors (*unrelated variety*) (Frenken *et al.*, 2007; Saviotti and Frenken, 2008). The former is termed *related*, since products and services from a specific sector are likely to be more closely connected by sharing similar characteristics, than products and services belonging to different sectors (Saviotti and Frenken, 2008). Unrelated variety, on the other hand, refers to the variety between the main sectors of the economy, representing the entry of new products and services that are unrelated to the pre-existing ones. Capabilities required to produce related variety are similar to the already existing on the economy, and thus easier to acquire than the capabilities necessary to the production of unrelated varieties. Moreover, as the capabilities and institutions of a specific sector can be easily transferred to related sectors, an increase in related variety is easier to accomplish than an increase in unrelated variety (Saviotti and Frenken, 2008).[3]

The aforementioned notion of variety is mostly related to neo-Schumpeterian and evolutionary streams of research. According to some views expressed within this theoretical frame, three major types of relationships can be envisaged between variety and economic growth (Frenken *et al.*, 2007). The first type, centred on the inter-relatedness features of variety, knowledge *spillovers* and economic growth, states that *spillovers* can occur not only between firms within a sector but also between sectors. This means that the composition of the economy may affect growth, with countries specializing in a particular composition of complementary sectors experiencing higher growth. A second type of relationship sees variety within the context of a portfolio strategy that can be used to protect a country from external shocks. Because unrelated variety refers to sectors that do not possess substantial input-output linkages, in the presence of a sector-specific shock, the economy is less likely to be disturbed as a whole (Boschma and Iammarino, 2009). The third type of relationship, stemming from Pasinetti's (1981, 1993) seminal work on the relationship between growth and structural change, addresses the long-term effect of variety over the economic system. Labour that has become redundant in pre-existing sectors of an economy, due to productivity increases and demand saturation, can only be absorbed by the emergence of new sectors, which promotes growth in the long-run.

Based on this latter type of relationship, Saviotti and Frenken (2008) put forward two main hypotheses regarding the links between variety and the economic performance of countries. The first one states that *"growth in variety is a necessary requirement for long-term economic development"*, whereas the second claims that *"variety growth, leading to new sectors, and*

[3] The conceptual distinction between related and unrelated variety is reflected in their measurement, with the former being generally measured at lower levels of aggregation.

productivity growth in pre-existing sectors, are complementary and not independent aspects of economic development" (Saviotti and Frenken, 2008: 206). The rationale behind these hypotheses lies on the imbalance between productivity growth and demand growth, as derived in Pasinetti's (1981, 1993) work. In fact, assuming that the set of activities of an economy remains constant over time, the combination of growing productivity with the tendency towards demand saturation would inevitably lead to structural unemployment, as it would be possible to produce all goods and services with a decreased proportion of inputs (including labour). The emergence of new sectors thus works as a means to compensate for the release of resources determined by productivity growth. Moreover, search activities, *"activities that scan the external environment in order to find either alternatives to existing routines or completely new routines"* (Saviotti and Mani, 1998: 255), are required to generate new goods and services, which means that an increase in the efficiency of pre-existing sectors is required, in order to allocate resources to these activities (Saviotti and Frenken, 2008).

In the context of an open economy, however, the problem of demand saturation may not constitute such a significant bottleneck, at least in the short run (Saviotti and Frenken, 2008). Countries that gain market shares with international trade can continue to specialize in a number of sectors, provided that exports in these sectors keep growing. Either way, as new sectors keep emerging worldwide, the share of trade of a country's sectors of specialization will ultimately decrease, even if it achieves a monopoly in one or more sectors. Specialization in pre-existing sectors will likely run into diminishing returns, and therefore, even in the context of an open economy, export variety growth is still expected to promote long-run economic growth (Saviotti and Frenken, 2008).

Typically, the evidence found in studies theoretically framed within neo-Schumpeterian lines corroborates the existence of a positive (and significant) relationship between variety and growth. Frenken *et al.* (2007), in a study based on the Dutch economy, find that related variety is a source of Jacobs externalities, due to knowledge *spillovers* that enhance growth and employment. The authors also find that unrelated variety is negatively related to unemployment growth, which confirms the “portfolio effect” described above. Saviotti and Frenken (2008), on their turn, using data from 20 OECD economies, find that faster growing countries present also the highest levels of export variety. The results are sensitive, however, to the type of variety considered: whereas related variety emerges as a determinant of growth in the short run, unrelated variety is only significant in a broader time horizon.

A different impact of related and unrelated variety is also found in Boschma *et al.* (2012) and Boschma and Iammarino’s works (2009). In the former, based on data from Spanish regions over the 1995-2007 period, the authors find that only the related variety component influences positively growth. In the study focusing on the Italian experience (Boschma and Iammarino, 2009), related variety has always a positive impact on value-added growth, whereas unrelated variety has a positive and significant effect only in two specifications. Very recently, Hartog *et al.* (2012) conclude also that only related variety among high-tech industries has a positive and significant effect on regional employment growth, taking into account the Finnish case.

The impact of unrelated variety on economic growth is therefore less clear-cut. Unrelated variety plays an important role in employment, dampening the effects of sector-specific shocks on unemployment growth, but its impact on productivity growth is not readily apparent, since knowledge *spillovers* are more likely to occur when firms are cognitively proximate (Nooteboom, 1999).

Cross-relating the variety dimension with technological upgrading, and since the latter plays an important effect over economic growth (Fagerberg, 2000; Fagerberg *et al.*, 2007), it can be conceived that changes in variety impact differently on economic growth, depending on the technological content of the products involved. Knowledge *spillovers* are expected to be more relevant in technological intensive industries, since firms in these industries are more capable to absorb and exploit existing information (O'Mahony and Vecchi, 2009; Heindenreich, 2009; Santamaría *et al.*, 2009).

Summing up, the theoretical positive relationship between export variety and growth has been confirmed by several studies focusing on different countries' experiences. There is, however, some ambiguity with respect to the role played by unrelated variety, which in many cases has an insignificant impact on economic growth.

3. The economic background: growth and export variety in Portugal, 1967-2010

The changes operated with respect to international trade flows and overall patterns of Portuguese economic growth may be better understood by resorting to temporal delimitations, as described in Table 1.

Table 1: Evolution of Portuguese exports, GDP, trade openness and trade balance (1967-2010)

	1967-1973	**1974-1985**	**1986-2000**	**2001-2010**
Export growth (annual av. growth rates)	9.7%	7.4%	8.3%	2.8%
GDP growth (annual av. growth rates)	6.9%	2.4%	4.1%	0.5%
Trade Openness (average)	19.1%	21.3%	45.3%	66.6%
Trade Balance/GDP (average)	-2.1%	-2.1%	-5.3%	-8.7%

Note: Time intervals chosen according to conventional cut-off dates of Portuguese economic history (e.g., Lopes, 1996, 2004)
Source: European Commission (AMECO database) and own calculations; data at 2005 constant prices

The first phase, from 1967 until 1973, included in Portugal's Golden Age (Lopes, 1996), is characterized by rapid growth and increased trade liberalization following the country's integration into the European Free Trade Association (EFTA), and the establishment of the Free Trade Agreement with the European Economic Community (EEC) in 1972; the second phase, from 1974 until 1985, is marked by political and economic unrest in the outbreak of the "Carnation Revolution" and of the severe international crisis leading to two IMF agreements; the third phase, initiated with Portugal's admission into the European

Community, and which is broadly characterized by political stability, and economic convergence, especially during the second half of the 1980s; and finally, the period from 2000 onwards, marked by the introduction of the Euro, is characterized by slow growth and severe national debt problems, which culminated in the negotiation of an economic stabilization agreement with the IMF and the EU (Lopes, 2004; Leite, 2010; Fernandes and Mota, 2011).

Phases of faster growth were usually accompanied by strong increases in exports. The strong relevance of exports' growth as a source of Portuguese economic growth is acknowledged in several studies, which refer to the growing openness to international trade as one inescapable feature in the development path pursued by the Portuguese economy after the Second World War (e.g., Afonso and Aguiar, 2005; Amador *et al.*, 2007). In the present study, we analyze the relationship between international trade and economic growth in Portugal between 1967 and 2010, taking into account the qualitative changes in the composition of exports.

Export variety is assessed by computing entropy measures, in line with recent literature in the field (cf. Frenken *et al.*, 2007; Saviotti and Frenken, 2008; Boschma and Iammarino, 2009; Boschma *et al.*, 2012). The entropy coefficient (*H*) refers to the expected information content or uncertainty of a probability distribution (Frenken, 2007), being calculated by the following expression:

$$H = \sum_{i=1}^{n} p_i \ \log_2\left(\frac{1}{p_i}\right) \qquad (1)$$

where n is the number of sectors of composing the economic system and p_i stands for the share of sector i in total exports.

An important advantage stemming from the use of the entropy coefficient is that it can be decomposed at each sectoral level, which avoids collinearity problems (Jacquemin and Berry, 1979). The minimum value of the entropy index (0) represents total specialization, in which exports are totally concentrated in one sector ($p_i = 1, i = 1; p_i = 0, i = 2, \dots, n$), whereas higher values of this index indicate greater relative diversification. The highest value corresponds to the situation of equal shares ($p_i = 1/n, \forall\, p_i$).

Unrelated variety, which accounts for variety between sectors, is measured at higher levels of aggregation. Export shares at these aggregation levels (P_g) are obtained by summing the shares at lower levels of aggregation (p_i), where S_g stands for a sector at a higher level of aggregation:

$$P_g = \sum_{i \in S_g} p_i \qquad (2)$$

Thus, a measure of unrelated variety (*UV*), or between-group entropy, is given as follows:

$$UV = \sum_{g=1}^{G} P_g \log_2\left(\frac{1}{P_g}\right) \qquad (3)$$

Related variety (*RV*), which accounts for variety within sectors, is computed as the weighted average of the entropy values within groups (H_g):

$$RV = \sum_{g=1}^{G} P_g H_g \qquad (4)$$

where

$$H_g = \sum_{i \in S_g} \frac{p_i}{P_g} \log_2\left(\frac{1}{\frac{p_i}{P_g}}\right) \qquad (5)$$

Unrelated variety is computed at the two-digit sectoral level, whereas related variety is computed as the weighted sum of the entropy at the four-digit level within each two-digit category. Since no mutual information exists between related and unrelated variety, that is, the two dimensions do not tend to co-occur, total entropy equals the sum of related and unrelated variety:[4]

$$H = RV + UV \tag{6}$$

Figure 1 depicts the results obtained from the computation of the entropy coefficient. In line with the analysis earlier performed, it can be seen that Portuguese export variety has increased since 1967, although this increase has been essentially produced during the last two decades. Total entropy increased in the seventies but experienced a decline in the following decade, reaching a trough in 1987. From this period onwards (coincidental with Portugal's entry in the EU), there has been a systematic increase in export variety, which reaches its maximum in 2010.

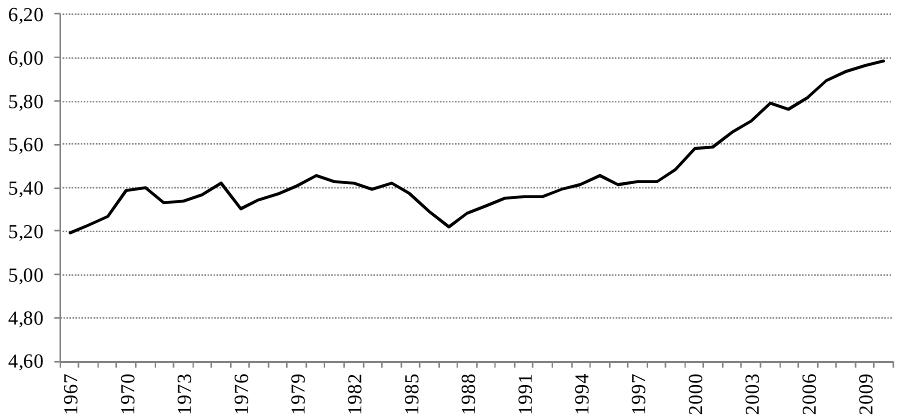

Figure 1: Total export variety (Portugal, 1967-2010)

Source: CHELEM database and own calculations

Distinguishing between related and unrelated variety, it can be seen furthermore that they behave quite differently over time (Figures 2 and 3). More precisely, whereas unrelated variety shows an upward trend during the whole period under study, related variety decreases from the beginning of the sample until the late 80s, increasing afterwards. Export variety within sectors increases only in the last two decades, reaching in 2010 values slightly above those registered in the beginning of the period.

[4] See Theil (1972) and Frenken (2007) for more details on the properties of entropy indices.

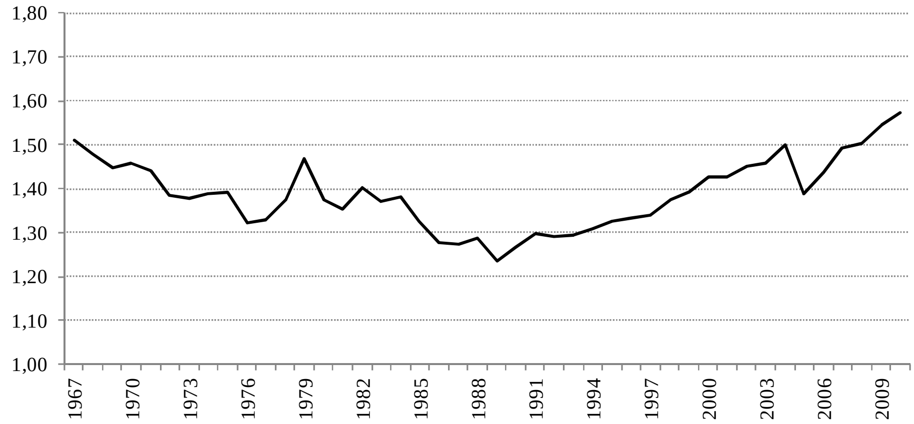

Figure 2: Related variety (Portugal, 1967-2010)

Source: CHELEM database and own calculations

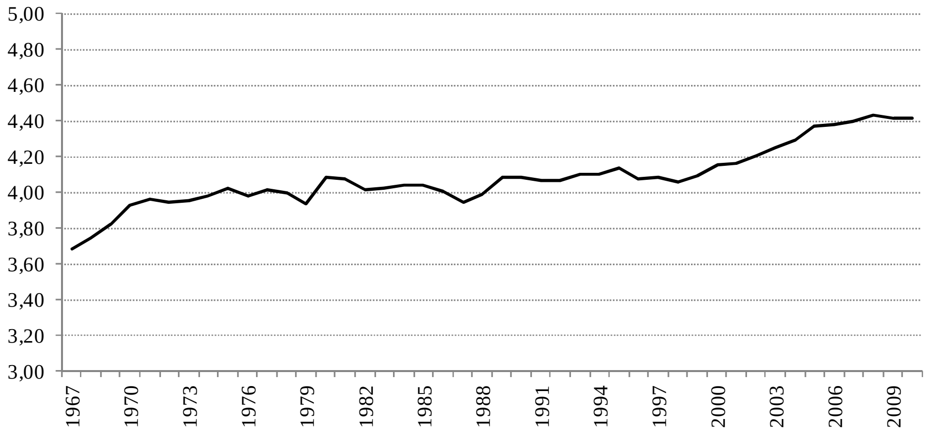

Figure 3: Unrelated variety (Portugal, 1967-2010)

Source: CHELEM database and own calculations

An assessment of changes in the technological content of Portuguese exports can be made by using the OECD (2002) and Tidd and Bessant's (2009) sectoral classification schemes.[5] The OECD classification considers four major categories of industries, corresponding to different R&D intensity levels: *low-tech*, *medium low-tech*, *medium high-tech* and *high-tech industries*. Despite the advantages in using the OECD taxonomy, due to its inherent simplicity and high coverage, this classification has a number of important weaknesses - Kleinknecht *et al.* (2002)

[5] Although sectoral taxonomies hold some caveats, as they can overlook heterogeneity within categories and neglect countries' specificities (Peneder, 2003; Lall *et al.*, 2005), they remain an important tool for empirical analysis. The classification of industries according to the two taxonomies is available in the appendix (Table 7).

point out that it neither considers the output side of innovation (the commercial use of new products, services or processes), since R&D expenditure can reflect different levels of efficiency, nor includes other inputs that also characterize the innovation process, such as design activities, market research or the training of workers. In order to overcome these limitations, we consider additionally a refined version of the well-known Pavitt (1984) taxonomy, which takes into account the innovation potential of industries, developed by Tidd and Bessant (2009). This classification considers the following categories: *supplier-dominated sectors*, *scale-intensive sectors, science-based sectors, specialized supplier sectors*, and finally, *information-intensive sectors*.

Recalling the previously outlined theoretical arguments, knowledge *spillovers* are more likely to occur between cognitively proximate firms, stimulating productivity growth, whereas the impact of unrelated variety is essentially produced over employment. Since we are interested in analysing the impact of variety on economic growth, the decomposition of variety in the aforementioned technological and innovative categories is restricted to the related variety part.

Related variety among low-tech industries has decreased markedly since the beginning of the period (Figure 4), although a slight recovery took place over the last years under analysis. A decreasing trend is also found since the late 1970s in Tidd and Bessant (2009) least innovative category, supplier-dominated industries (Figure 5). Related variety in scale-intensive sectors declined markedly between 1967 and 1990 but it increased afterwards, reaching figures similar to those observed at the beginning of the period.

Medium-low and medium-high-tech industries, on the other hand, show an upward trend in related variety, which is particularly strong in the case of the latter category. Tidd and Bessant (2009) categories with higher innovative potential also show an increase in related variety since the beginning of the period, which was stronger in the case of specialized supplier industries, despite the decrease that took place in the more recent years.

Related variety among high-tech industries suffered minor changes during the period under study, showing a slight tendency of increase from the mid-1990s until 2006, but declining afterwards. The more recent years present figures similar to the ones registered during the seventies and early eighties.

An analysis of the decomposition of entropy in the end of the period reveals that low-tech and medium-low-tech industries as a whole still account for the more than a half of related variety, despite the fact that the highest value is now registered in medium-high-tech sectors. A similar conclusion is drawn using Tidd and Bessant (2009) taxonomy, with supplier-dominated and the scale-intensive industries, the lowest categories in technological and innovative potential, representing approximately 60 per cent of export related variety.

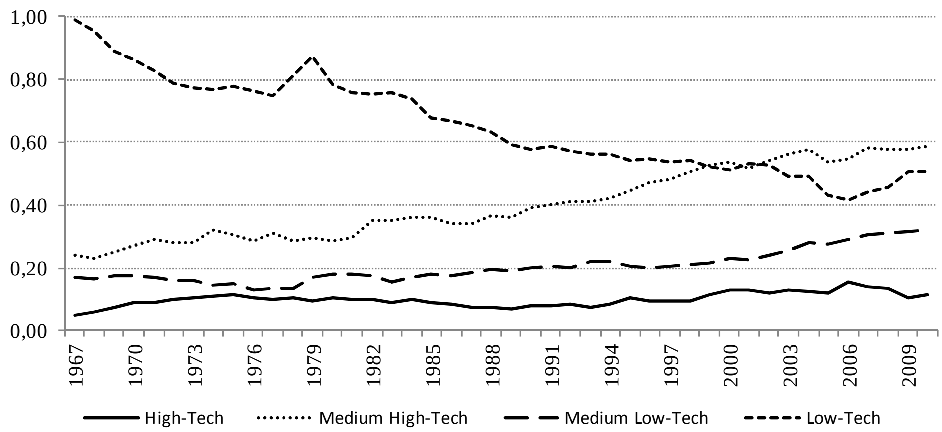

Figure 4: Related variety by technological content (Portugal, 1967-2010)

Source: CHELEM database and own calculations

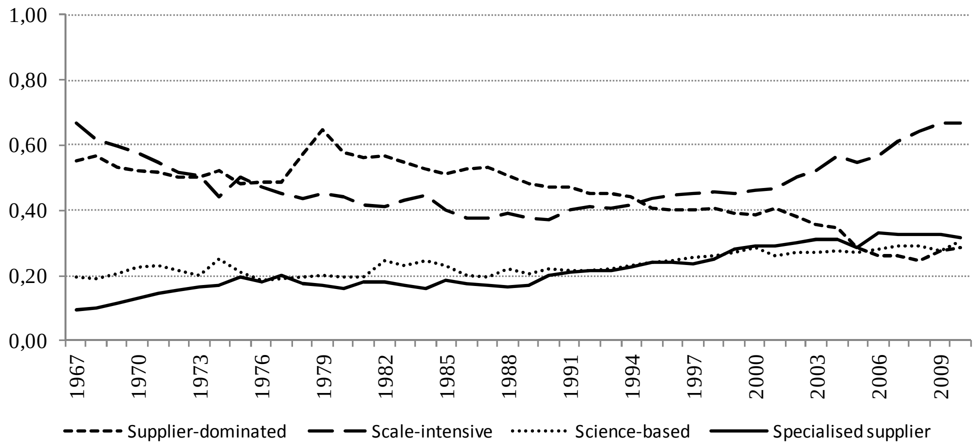

Figure 5: Related variety using Tidd and Bessant's (2009) industry groups

Source: CHELEM database and own calculations

4. Econometric analysis

4.1. Model specification and data

The general econometric specification used in the estimations performed to assess the impact of export variety on Portuguese economic growth is defined in Equation 7.

$$y_t = \beta_0 + \beta_1 \, UV_t + \beta_2 \, RV_t + \beta_3 \, CV_t + \varepsilon_t \qquad (7)$$

In this expression, y_t is the natural logarithm of labour productivity, defined as GDP per hour worked in period *t*, *UV* and *RV* are the main explanatory variables, representing, respectively, the unrelated and related variety components computed in the earlier section, *CV* is a vector of control variables which may influence productivity growth, and ε_t is the error term.

Since we are interested in crossing the variety and technology dimensions, we also estimate Equation 7 using the decomposition of related variety according to the innovation and technology industry categories defined earlier. More precisely, we decompose related variety into the high-tech (*RVHT*), medium-high-tech (*RVMHT*) and medium-low-tech and low-tech (*RVMLTLT*) categories, and into specialized supplier (*RVSS*), science-based (*RVSB*) and supplier-dominated and scale-intensive (*RVSDSI*) categories. These latter specifications allow us to investigate if the impact of related variety on productivity growth differs across the different technology groups, providing in this way a better grasp on the relationship between variety, technology and growth.

Following the theoretical arguments outlined in Section 2, we expect a positive relationship between related variety and labour productivity growth. If a country specializes in a particular composition of complementary sectors, knowledge *spillovers* will be more likely to occur between them, and the country will probably benefit from higher growth rates. Moreover, a positive impact on productivity growth is expected from technology-intensive sectors (OECD taxonomy) and from science-based and specialized supplier industries, the Tidd and Bessant's (2009) categories with higher innovative potential. In contrast, in the least innovative categories the relationship is expected to be more moderate, particularly in supplier-dominated industries. Actually, this category corresponds to a great extent to low-tech industries, such as textiles, wearing apparel or wood and wood products, among others.[6]

Regarding the control variables, we include a proxy of the human capital stock (*HC*), defined as the average number of years of formal education of the working age population. The importance of human capital on growth is reflected on the fundamental role played by the so-called "social capabilities", which determine the country's capacity to assimilate more advanced technologies from other economies (Abramovitz, 1986).[7] Moreover, according to the non-linear model of convergence developed by Verspagen (1991), countries with larger

[6] As pointed out by Pavitt (1984: 356), "*supplier dominated firms can be found mainly in traditional sectors of manufacturing*" and they "*make only a minor contribution to their process or product technology*". Moreover, according to the classification of industries presented in the Appendix, there is a close correspondence between these two categories.

[7] The term "social capabilities" was originally introduced by Okawa and Rosovsky (1973: 212), "*to designate those factors constituting a country's ability to import or engage in technological and organizational progress*".

technological backwardness and lower levels of intrinsic learning capability – which, among other variables, depends on the education of the labour force – are more likely to widen their development gaps. In empirical terms, although results are not unanimous in this respect, a vast number of studies have successfully established a (positive) relationship between human capital and economic growth (e.g., Temple, 1999; Agiomirgianakis *et al.*, 2002; Ciccone and Papaioannou, 2009).

To account for the influence of physical capital accumulation, the share of investment in GDP (*INV*) is also included in the regression. Equipment investment may translate into high social returns, as shown by the central role played by mechanization in the economic history of countries and by the external economies generated by equipment investment (De Long and Summers, 1991; Herrerias and Orts, 2012).

Data on labour productivity, expressed in 1990 US dollars converted at Geary Khamis PPPs, are taken from *The Conference Board Total Economy* database, available on-line at http://www.conference-board.org/data/economydatabase.

Data on export flows are taken from the CHELEM database, which provides detailed information regarding export and import flows, both at the macroeconomic and industry levels of analysis, over a rather long time span (from 1967 to 2010).

With regard to the control variables, data on education are taken from Bassanini and Scarpetta (2001) for the period between 1971 and 1998, and from Silva and Teixeira (2011) for the period between 1999 and 2003. We extend the computations from these latter authors up to 2009, applying the same methodology and using data from OECD *Education at a Glance* (several issues). Furthermore, we extrapolate these values, considering the annual average growth rate from 1971 to 2009, to obtain data for the years 1967-1970 and 2010. Data on gross fixed capital formation are taken from the PORDATA database, available on-line at http://www.pordata.pt/ .

4.2. Estimation method and results

The variables used in the regression display strong trends, as depicted in Figures 2-8, evolving over time and showing no tendency to revert to their mean levels. In other words, they are non-stationary.

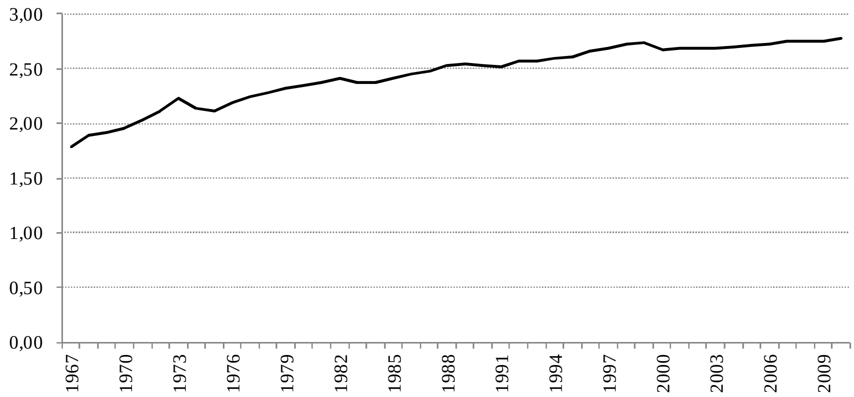

Figure 6: Portuguese GDP per hour worked
(1990 US dollars converted at Geary Khamis PPPs; natural logarithms)
Source: The Conference Board Total Economy Database

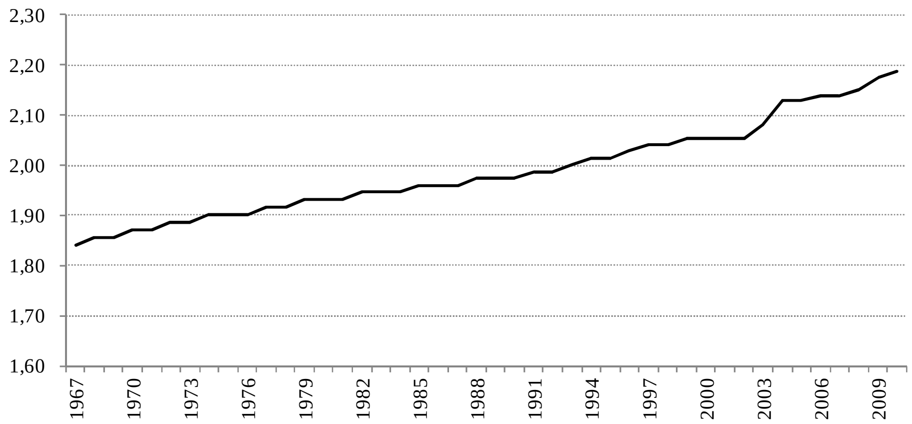

Figure 7: Average number of years of formal education of the working age population (Portugal, 1967-2010, semilog scale)
Sources: Bassanini and Scarpetta (2001), Silva and Teixeira (2011), OECD *Education at a Glance*.

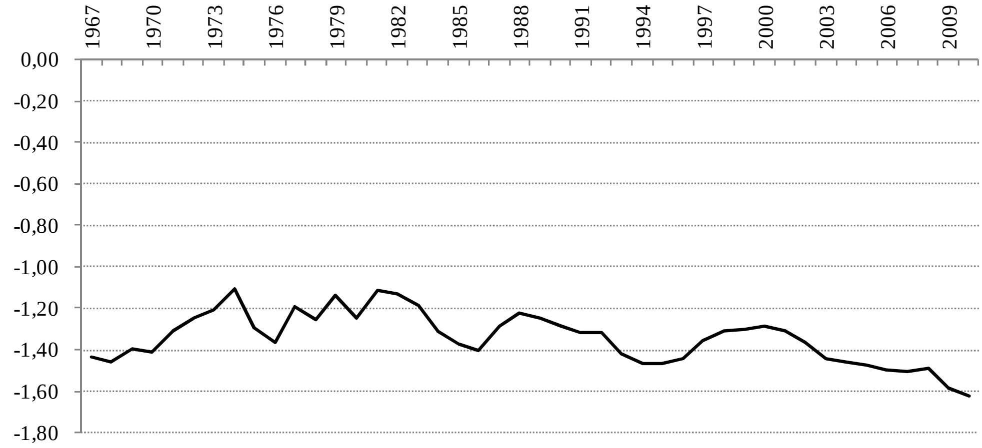

Figure 8: Share of investment in GDP (Portugal, 1967-2010, semilog scale)

Sources: PORDATA database and own calculations

Given the non-stationarity of the variables, resorting to classical estimation techniques could lead to spurious regressions (Granger and Newbold, 1974). In fact, if the means and variances change over time, the computed statistics of a regression model will be also dependent on time, and consequently, they will not converge to the population values as the sample increases to infinity. Furthermore, hypothesis testing will be biased towards the rejection of the null hypothesis (Rao, 1994). The use of cointegration techniques is thus required in order to get reliable estimates (e.g. Granger, 1981; Engle and Granger, 1987). Two or more variables are cointegrated if, albeit being individually non-stationary, one or more linear combinations of them are stationary, becoming stable around a fixed mean in the long-run (Dickey *et al.*, 1991).

In order to obtain a cointegration relationship between a specific group of variables, the variables must be integrated of the same order. We thus start by performing the *Augmented Dickey-Fuller* (ADF) (Dickey and Fuller, 1979; 1981) and the *Phillips-Perron* (PP) (Phillips and Perron, 1988) unit root tests in order to assess the stationarity of the variables under study. The results are presented in Tables 2 and 3.

Table 2: Unit root tests – variables in levels

Series	ADF	PP
Y	0.1915 (0)	0.0930 (21)
UV	0.2319 (0)	0.1908 (5)
RV	0.7946 (0)	0.8722 (3)
RVHT	0.0843 (0)	0.0843 (0)
RVMHT	0.2652 (0)	0.2769 (1)
RVMLTLT	0.6148 (0)	0.5772 (1)
RVSDSI	0.5189 (0)	0.5657 (3)
RVSB	0.1040 (0)	0.1209 (2)
RVSS	0.5133 (0)	0.5133 (0)
HC	1.0000 (0)	1.0000 (4)
INV	0.2737 (0)	0.4093 (5)

Notes: For the *Augmented Dickey-Fuller* (ADF) and *Phillips-Perron* (PP) tests, we present MacKinnon (1996) one-sided *p*-values. For series Y, UV, RV, RVMHT, RVMLTLT, RVSDSI, RVSB, RVSS and INV we specify a random walk with drift and time trend, while for series RVHT we use a random walk with drift and for series HC we use a random walk. For the ADF test we use the Schwarz Information Criterion, with an upper bound of 9 lags (figures enclosed in parentheses in the ADF column are the lag length). For the PP test, bandwidth selection was made according to the Newey-West (1994) method, using Bartlett kernel (figures enclosed in parentheses in the PP column represent the Newey-West bandwidth).

Table 3: Unit root tests – variables in first differences

Series	ADF	PP
Y	0.0001 (0)	0.0000 (41)
UV	0.0000 (0)	0.0000 (11)
RV	0.0000 (0)	0.0000 (4)
RVHT	0.0000 (0)	0.0000 (3)
RVMHT	0.0000 (0)	0.0000 (3)
RVMLTLT	0.0000 (0)	0.0000 (2)
RVSDSI	0.0001 (1)	0.0000 (6)
RVSB	0.0000 (0)	0.0000 (3)
RVSS	0.0000 (0)	0.0000 (4)
HC	0.0000 (0)	0.0000 (8)
INV	0.0002 (2)	0.0000 (3)

Notes: For the *Augmented Dickey-Fuller* (ADF) and *Phillips-Perron* (PP) tests, we present MacKinnon (1996) one-sided *p*-values. For series Y, RV, RVMLTLT, RVSDSI and HC, we specify a random walk with drift and time trend, while for series UV, RVMHT and RVSS we use a random walk with drift and for series RVHT, RVSB and INV we use a random walk. For the ADF test we use the Schwarz Information Criterion, with an upper bound of 9 lags (figures enclosed in parentheses in the ADF column are the lag length). For the PP test, bandwidth selection was made according to the Newey-West (1994) method, using Bartlett kernel (figures enclosed in parentheses in the PP column represent the Newey-West bandwidth).

As expected, the variables in levels are all non-stationary, that is, the null hypothesis of the existence of a unit root is not rejected at the 1% significance level. When taken at first differences, they all become stationary, which indicates that they are integrated of the same order [I(1)]. A cointegrating relationship may therefore exist among the variables under study. To test for the cointegration of the series, we use the Johansen cointegration test (Johansen, 1988, 1991; Johansen and Juselius, 1990).[8] The vectors of potentially endogenous variables (z_t) and the normalized cointegrating vectors β's for the three econometric specifications can be represented as follows, employing cointegration notation:

$$z_t = (Y_t\ UV_t\ RV_t\ HC\ INV_t)\ ,\ \beta_i = 1 - \beta_{1i} - \beta_{2i} - \beta_{3i} - \beta_{4i} \tag{8}$$

$$z_t = (Y_t\ UV_t\ RVHT_t\ RVMHT_t\ RVMLTLT_t\ HC_t\ INV_t)\ ,$$
$$\beta_i = 1 - \beta_{1i} - \beta_{2i} - \beta_{3i} - \beta_{4i} - \beta_{5i} - \beta_{6i} \tag{9}$$

$$z_t = (Y_t\ UV_t\ RVSDSI_t\ RVSB_t\ RVSS_t\ HC_t\ INV_t)\ ,$$
$$\beta_i = 1 - \beta_{1i} - \beta_{2i} - \beta_{3i} - \beta_{4i} - \beta_{5i} - \beta_{6i} \tag{10}$$

The cointegration test should be preceded by the determination of the number of lags for an unrestricted VAR model. Using the Akaike information criterion, we set the lag order of the first econometric specification to 1, and the lag order of the second and third econometric specifications to 3 (cf. Table 4). Furthermore, we allow for a linear deterministic trend in the level data, but only an intercept (no trend) in the cointegrating equations.

[8] We opted in favour of this method, instead of the Engle and Granger (1987) approach, as the Johansen and Juselius' test is able to detect more than one cointegrating relationship. Another difference between the two tests is that the Johansen test derives maximum likelihood estimators of the cointegration vectors, whereas the Engle and Granger procedure estimates the cointegrating regression using the OLS technique, and tests the residuals for a unit root using the ADF test.

Table 4: Lag length selection

Number of lags	Specification 1	Specification 2	Specification 3
0	-13.1191	-23.8336	-20.0762
1	-20.4486	-32.2746	-27.8101
2	-20.1128	-31.3003	-27.5798
3	-20.2467	-32.2795	-28.1172

Notes: Akaike information criterion values.

Table 5 reports the results of the Johansen's cointegration test for the first econometric specification which takes variety as a whole (Equation 8). The Trace test does not reject the existence of one cointegrating vector at the 5% significance level, whereas the Maximum-Eigenvalue test presents a *p*-value of 6.5%.[9] Given these outcomes, we consider the existence of one cointegrating vector. Choosing $r = 1$, we obtain the estimates for the normalized cointegrating coefficients, that is, the long-run equilibrium relationship between the variables, presented in Table 6.

The results show that all variables are statistically significant. The coefficients of the control variables present the expected (positive) signs, evidencing a positive effect of both human and physical capital over long-run labour productivity. In contrast, both related and unrelated variety are negatively related to labour productivity growth.

The finding of a negative relationship between increasing related variety and productivity growth, contrary to what could be expected, seems to be related to the consideration of a rather crude measure of variety, disconnected from the technology/innovation content of exports. In fact, the theoretical arguments previously put forward, which acknowledge the

[9] The null hypothesis of the Trace test is that the number of cointegrating vectors is less than or equal to the number of vectors (r), against the alternative hypothesis that there are more than r cointegrating vectors, whereas in the Maximum Eigenvalue test the null hypothesis states that the number of cointegrating vectors is r, against the alternative hypothesis that there are $r + 1$ vectors.

existence of a positive relationship between the two variables, are based on the benefits accruing from the diffusion of knowledge *spillovers*, which are notoriously higher in the case of technology advanced industries (e.g., Heidenreich, 2009; Santamaría *et al.*, 2009). In these circumstances, a more accurate test of the relationship between export variety and economic growth must take into account simultaneously the variety and technology dimensions, as expressed in Equations 9 and 10.

The results of the Johansen's cointegration test for these latter econometric specifications are also presented in Table 5. With respect to Equation 9, both the Trace and the Maximum-Eigenvalue tests indicate the existence of five cointegrating equations at the 5% level. The normalized estimates for the "most significant" cointegrating vector, the one which is more in line with the underlying economic theory (Dibooglu and Enders, 1995; Handa, 2009), are presented in Table 6. Once again, all variables are statistically significant and the control variables have the expected signs. Unrelated variety maintains a long-run negative relationship with labour productivity per hour worked. High-tech related variety has a positive impact on labour productivity, whereas the opposite happens for related variety among medium-high-tech industries, and among the bottom technological categories.

Table 5: Johansen's cointegration test results

	Number of vectors (r)	**Trace Statistic**	***p*-value**	**Maximum-Eigenvalue Statistic**	***p*-value**
Econometric specification 1	None	72.5155	0.0300	32.8890	0.0652
	At most 1	39.6266	0.2361	17.6342	0.5258
	At most 2	21.9923	0.2989	11.0975	0.6376
	At most 3	10.8948	0.2180	8.8235	0.3011
	At most 4	2.0714	0.1501	2.0714	0.1501
Econometric specification 2	None	284.7446	0.0000	102.6119	0.0000
	At most 1	182.1327	0.0000	61.1512	0.0001
	At most 2	120.9815	0.0000	54.4266	0.0001
	At most 3	66.5549	0.0004	33.0306	0.0090
	At most 4	33.5243	0.0178	22.5462	0.0314
	At most 5	10.9782	0.2128	7.7322	0.4066

Econometric specification 3	None	260.1490	0.0000	87.0596	0.0000
	At most 1	173.0896	0.0000	67.0009	0.0000
	At most 2	106.0886	0.0000	44.6015	0.0018
	At most 3	61.4871	0.0016	32.0015	0.0126
	At most 4	29.4856	0.0543	20.0663	0.0699
	At most 5	9.4193	0.3280	8.6346	0.3178

Notes: MacKinnon *et al.* (1999) *p*-values.

Table 6: Normalized cointegrating coefficients

Variable	Equation 8	Equation 9	Equation 10
Y	1.0000	1.0000	1.0000
UV	1.3058 (0.1839)	2.4454 (0.1641)	1.3501 (0.1091)
RV	0.7480 (0.1523)		
RVHT		-4.0272 (0.5876)	
RVMHT		4.1081 (0.3151)	
RVMLTLT		1.4031 (0.1237)	
RVSDSI			0.9703 (0.1298)
RVSB			1.6394 (0.5258)
RVSS			-1.4464 (0.4075)
HC	-5.6158 (0.3508)	-9.8511 (0.4655)	-5.0665 (0.2877)
INV	-0.8683 (0.1210)	-0.4613 (0.0571)	-0.8237 (0.0680)

Notes: Figures in parenthesis are the estimated standard errors.

The results of Trace and Maximum-Eigenvalue tests regarding Equation 10 point to four cointegrating relationships at the 5% significance level. The normalized estimates of the "most significant" cointegrating vector are presented in Table 6. All variables are statistically significant and the coefficients of control variables show the expected signs.

In this case, the separation of related variety according to Tidd and Bessant (2009) taxonomy indicates a long-run positive impact of one of the categories with higher innovative potential on labour productivity growth, specialized supplier industries, whereas the opposite is found for Tidd and Bessant (2009)'s least innovative categories and for science-based industries.

The negative impact of related variety in science-based industries can be related to the aforementioned specific characteristics of this group of industries in the Portuguese case, namely, the strong share of assembly-line production firms, such as “TV & radio receivers, recorders”, which are in fact characterized by low intensity of R&D and innovation activities.[10] It also probably reflects the fact that the highest increase in variety within this group of industries takes place precisely in a period of deceleration of overall labour productivity growth (from the late 1990s onwards).

Looking at the results as whole, it can be seen therefore that export variety is only relevant for economic growth when it occurs in a number of industries, most notably those more technology/innovation intensive (high-tech industries, in the first taxonomy, and specialized supplier industries, in the latter).[11]

How do our results compare with previous findings on the relationship between export variety and economic growth? As indicated earlier, most empirical studies focusing on the impact of export variety on productivity (whether measured in levels or growth rates) were based on cross-section data, and therefore a direct comparison of results cannot be undertaken. In these cases, a positive relationship between export variety and growth was generally observed, especially when the related variety component was considered (cf. Saviotti and Frenken, 2008).

Focusing on the Portuguese case, our findings do not confirm the existence of a positive relationship between (broad) related variety and labour productivity. In fact, the opposite and seemingly counter-intuitive result is found, which seems to be related to the fact that a significant part of export related variety in the Portuguese case took place in low technology

[10] See, in this respect, Hobday (1995).

[11] There is a strong connection between the shares of high-tech and specialized supplier industries: the ISIC-4 specialized supplier industries hold a considerable share of high-tech exports (approximately 40% in 2010).

and innovation branches. In this scenario, the potential role that increasing diversification in exports could have had in promoting significant knowledge *spillovers* has not been accomplished.

This latter assertion seems to be confirmed by the econometric results derived from the specifications crossing technology and variety dimensions, in which a positive relationship between export related variety and labour productivity is found precisely in the industry groups more intensive in technology and innovation.[12] This is in line with the theoretical arguments stating that inter-industry knowledge *spillovers* and product innovations are especially relevant in high-tech sectors.

Taken as a whole, our findings suggest therefore that, in general, increases in export variety are not conducive to higher growth, but only when they take place in related technology advanced industries.

5. Conclusion

In this paper we analyse the joint impact of variety and change in the technology content of exports on Portuguese economic growth over the last four decades. During this period, the Portuguese economy underwent considerable change. International trade flows, in particular, experienced strong transformation, acting simultaneously as recipients and drivers of macroeconomic change. Both imports and exports increased substantially, particularly the former, with a considerable imbalance between them being found in virtually the whole period under study.

[12] Hartog *et al.* (2012) have also reached a similar conclusion for Finland, although for a different dependent variable (employment). The authors find that only related variety among high-tech industries had a positive and significant effect over regional employment growth.

According to our findings, Portuguese total export variety, measured by the entropy coefficient, increased markedly in the last two decades. Notorious differences arise, however, with respect to the evolution of its related and unrelated components. Whereas unrelated variety displays a positive trend over the whole period, related variety decreased from the beginning of the sample until the late 80s, exhibiting a positive trend ever since. Decomposing related variety according to the technology and innovation taxonomies, it can be seen furthermore that the largest part of related variety is accounted by low-tech and medium-low-tech industries, and supplier-dominated and scale-intensive categories, although there is a marked tendency of increase in variety in the top technology and innovation categories.

The investigation of the impact of export variety on productivity growth shows a negative relationship between increasing (broad) export variety and labour productivity growth. This finding, contrary to theoretical reasoning, is shown to be related to the use of a relatively coarse measure of variety. In fact, using a more accurate measure, which crosses technology and variety dimensions, it is shown that the effect of increasing variety on productivity growth is conditioned by the technological content and innovative potential of industries. More precisely, an increase in export related variety of technology and innovation intensive industries is positively related to productivity growth, whereas the opposite stands for low-tech, low-innovation sectors.

These findings suggest that the diversification of the export structure matters for growth, but only when it takes place in the related high-tech and innovative intensive segments of the economy. In open economies which are still far below the technology frontier, as it is the case of Portugal, our results seem to indicate that policy action directed to educational and technology improvement may be required to foster economic growth. More precisely, policies involving the increase of the technological infrastructure and business R&D, as well as the attraction of FDI may be in order to increase the country's absorption of advanced technologies and sustain growth.

The analysis performed provides rather clear results regarding the inter-relatedness features of export variety, technology and growth. Still, it may be substantiated or extended in a number of ways. First, alternative measures can be used to proxy the degree of relatedness between industries, besides the hierarchy of the International Standard Industrial Classification. Among others, such measures can rely on clusters (Porter, 1998), export profiles (Hidalgo *et al.*, 2007), production knowledge (Bryce and Winter, 2009) or skills, captured by labour flows between industries (Neffke and Henning, 2009). Second, in order to overcome the heterogeneity that exists within each category, product or even between firms, information could be obtained directly from firm data, or using classifications that take into account the Portuguese specificities, which would allow for a more accurate classification of the technological content of exports. Third, the analysis of the impact of export variety and its technological content on economic growth could be replicated in other countries for comparative purposes; in particular, it would be enlightening to see if the results obtained with respect to the Portuguese case also applied in other countries lying below the technological frontier.

References

Abramovitz, M. (1986), Catching up, forging ahead, and falling behind, *The Journal of Economic History*, 46 (2), pp. 385-406.

Afonso, O.; Aguiar, A. (2005), A internacionalização da economia in Lains, P.; Silva, A. F., (eds.*)*, *História Económica de Portugal 1700-2000. O Século XX*, Lisboa, Portugal: Instituto de Ciências Sociais da Universidade de Lisboa.

Agiomirgianakis, G.; Asteriou, D.; Monastiriotis, V. (2002), Human capital and economic growth revisited: a dynamic panel data study, *International Advances in Economic Research*, 8 (3), pp. 177–187.

Amador, J.; Cabral, S.; Maria, J.R. (2007), International trade patterns over the last four decades: how does Portugal compare with other cohesion countries?, *Working Papers*, 14/2007, Banco de Portugal.

Amendola, M.; Gaffard J.L. (1998), *Out of Equilibrium*, Oxford: Clarendon Press.

Bassanini, A.; Scarpetta, S. (2001), Does human capital matter for growth in OECD countries?: Evidence from pooled mean-group estimates, *OECD Economics Department Working Papers*, No. 282, OECD Publishing.

Boschma, R.; Iammarino, S. (2009), Related variety, trade linkages, and regional growth in Italy, *Economic Geography*, 85 (3), pp. 289-311.

Boschma, R.; Minondo, R.; Navarro, M. (2012), Related variety and regional growth in Spain, *Papers in Regional Science*, 91 (2), pp. 241-257.

Bryce, D.; Winter, S. (2009), A general interindustry relatedness index, *Management Science*, 55 (9), pp. 1570-1585.

Cabral, M.H.C. (2008), Export diversification and technological improvement: recent trends in the Portuguese economy, *GEE Papers*, No. 6, Gabinete de Estratégia e Estudos, Ministério da Economia e da Inovação.

Ciccone, A.; Papaioannou, E. (2009), Human capital, the structure of production, and growth, *The Review of Economics and Statistics*, 91 (1), pp. 66-82.

De Long, J.B.; Summers, L.H. (1991), Equipment investment and economic growth, *The Quarterly Journal of Economics*, 106 (2), pp. 445-502.

Dibooglu, S.; Enders, W. (1995), Multiple cointegrating vectors and structural economic models: an application to the French Franc/U.S. Dollar exchange rate, *Southern Economic Journal*, 61 (4), pp. 1098–1116.

Dickey, D.; Fuller, W. (1979), Distribution of the estimates for autoregressive time series with a unit root, *Journal of the American Statistical Association*, 74 (366), pp. 427–431.

Dickey, D.; Fuller, W. (1981), Likelihood ratio statistics for autoregressive time series with a unit root, *Econometrica*, 49 (4), pp. 1057–1072.

Dickey, D.; Jansen, D.; Thornton, D. (1991), A primer on cointegration with an application to money and income, in Rao, B. (ed.), *Cointegration: for the Applied Economist*, Basingstoke, UK: Palgrave Macmillan.

Engle, R.; Granger, C. (1987), Co-integration and error correction: representation, estimation, and testing, *Econometrica*, 55 (2), pp. 251-276.

Fagerberg, J. (2000), Technological progress, structural change and productivity growth: a comparative study, *Structural Change and Economic Dynamics*, 11, pp. 393-411.

Fagerberg, J.; Srholec, M.; Knell, M. (2007), The competitiveness of nations: why some countries prosper while others fall behind, *World Development*, 35 (10), pp. 1595-1620.

Fernandes, A. L. C.; Mota, P. R. (2011), The roots of the Eurozone sovereign debt crisis: PIGS vs non-PIGS, *Panoeconomicus*, 58 (5), pp. 631-649.

Frenken, K. (2007), Entropy statistics and information theory, in Hanusch, H.; Pyka, A. (eds.*), Elgar Companion to Neo-Schumpeterian Economics*, Cheltenham, UK: Edward Elgar.

Frenken, K.; Van Oort, F.; Verburg, T. (2007), Related variety, unrelated variety and regional economic growth, *Regional Studies,* 41.5, pp. 685–697.

Funke, M.; Ruhwedel R. (2005), Export variety and economic growth in East European transition economies, *Economics of Transition*, 13 (1), pp. 25–50.

Granger, C. (1981), Some properties of time series data and their use in econometric model specification, *Journal of Econometrics*, 16, pp. 121-130.

Granger, C.; Newbold, P. (1974), Spurious regressions in econometrics, *Journal of Econometrics*, 2, pp. 111-120.

Handa, J. (2009), *Monetary Economics*, New York, USA: Routledge.

Hartog, M.; Boschma, R.; Sotarauta, M. (2012), The Impact of Related Variety on Regional Employment Growth in Finland 1993–2006: High-Tech versus Medium/Low-Tech, *Industry and Innovation*, Vol. 19, Iss. 6, pp. 459-476.

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

Heidenreich, M. (2009), Innovation patterns and location of European low- and medium-technology industries, *Research Policy*, 38, pp. 483-494.

Herrerias, M. J.; Orts, V. (2012), Equipment investment, output and productivity in China, *Empirical Economics*, 42 (1), pp. 181-207.

Hidalgo, C.A.; Klinger, B.; Barabási, A.-L.; Hausmann, R. (2007), The product space conditions the development of nations, *Science*, 317 (5837), pp. 482-487.

Hobday, M. (1995), East Asian latecomer firms: learning the technology of electronics, *World Development*, 23 (7), pp. 1171-1193.

Jacquemin, A.; Berry, C. (1979), Entropy measure of diversification and corporate growth, *The Journal of Industrial Economics*, 27 (4), pp. 359-369.

Johansen, S. (1988), Statistical analysis of cointegration vector, *Journal of Economic Dynamics and Control*, 12, pp. 231–254.

Johansen, S. (1991), Estimation and hypothesis testing of cointegrating vectors in Gaussian vector autoregressive models, *Econometrica*, 59 (6), pp. 1551-1580.

Johansen, S.; Juselius, K. (1990), Maximum likelihood estimation and inference on cointegration with application to the demand for money, *Oxford Bulletin of Economics and Statistics*, 52 (2), pp. 169-210.

Kleinknecht, A.; Montfort, K.; Brouwer, E. (2002), The non-trivial choice between innovation indicators, *Economics of Innovation and New Technology*, 11 (2), pp. 109-121.

Kruger, J. (2008), Productivity and structural change: a review of the literature, *Journal of Economic Surveys*, 22 (2), pp. 330-363.

Lall, S.; Weiss, J.; Zhang, J. (2005), The sophistication of exports: a new measure of product characteristics, *QEH Working Paper Series*, No. 123, Queen Elizabeth House, Oxford University.

Leite, A.N. (2010), A internacionalização da economia portuguesa, *Relações Internacionais*, 28, pp. 119-132.

Lopes, J.S. (1996), *A Economia Portuguesa desde 1960*, Lisboa, Portugal: Gradiva.

Lopes, J.S. (2004), *A Economia Portuguesa no Século XX*, Lisboa: Portugal: Instituto de Ciências Sociais da Universidade de Lisboa.

Loschky, A. (2008), Reviewing the nomenclature for high-technology trade - the sectoral approach, *STD/SES/WPTGS*, 2008/9, OECD.

MacKinnon, J. (1996), Numerical distribution functions for unit root and cointegration tests, *Journal of Applied Econometrics*, 11 (6), pp. 601–618.

MacKinnon, J.; Haug, A.; Michelis, L. (1999), Numerical distribution functions of likelihood ratio tests for cointegration, *Journal of Applied Econometrics*, 14 (5), pp. 563–577.

Mateus, A. (2006), *Economia Portuguesa: Crescimento no Contexto Internacional (1910-2006)*, Lisboa, Portugal: Editorial Verbo.

Neffke, F.; Henning, M. (2009), Skill-relatedness and firm diversification, *Papers on Economics and Evolution*, Jena, Germany: Max Planck Institute of Economics.

Newey, W.; West, K. (1994), Automatic lag selection in covariance matrix estimation, *Review of Economic Studies*, 61, pp. 631–653.

Nooteboom, B. (1999), Innovation and inter-firm linkages: new implications for policy, *Research Policy*, 28 (8), pp. 793-805.

O'Mahony, M.; Vecchi, M. (2009), R&D, knowledge spillovers and company productivity performance, *Research Policy*, 38, pp. 35-44.

OECD (2002), *The Measurement of Scientific and Technological Activities. Proposed Standard Practice for Surveys on Research and Experimental Development – Frascati Manual*, Paris, France: OECD Publications.

Okawa, K.; Rosovsky, H. (1973), *Japanese Economic Growth: Trend Acceleration in the Twentieth Century*, Stanford, California, USA: Stanford University Press.

Pack, H. (1994), Endogenous growth theory: intellectual appeal and empirical shortcomings, *Journal of Economic Perspectives*, 8 (1), pp. 55-72.

Pasinetti, L. (1993), *Structural Economic Dynamics: A Theory of the Economic Consequences of Human Learning*, Cambridge, United Kingdom: Cambridge University Press.

Pasinetti, L., (1981), *Structural Change and Economic Growth: a Theoretical Essay on the Dynamics of the Wealth of Nations*, Cambridge, United Kingdom: Cambridge University Press.

Pavitt, K. (1984), Sectoral patterns of technical change: towards a taxonomy and a theory, *Research Policy*, 13, pp. 343-373.

Peneder, M. (2003), Industry classifications: aim, scope and techniques, *Journal of Industry, Competition and Trade*, 3 (1/2), pp. 109-129.

Phillips, P.; Perron, P. (1988), Testing for a unit root in time series regression, *Biometrika*, 75 (2), pp. 335–346.

Porter, M.E. (1998), Clusters and the new economics of competition, *Harvard Business Review*, 76 (6), pp. 77-90.

Rao, B. (1994), *Cointegration: for the Applied Economist*, Basingstoke, UK: Palgrave Macmillan.

Santamaría, L.; Nieto, M.J.; Barge-Gil, A. (2009), Beyond formal R&D: Taking advantage of other sources of innovation in low- and medium-technology industries, *Research Policy*, 38, pp. 507-517.

Saviotti, P.P.; Frenken, K. (2008), Export variety and the economic performance of countries, *Journal of Evolutionary Economics*, 18, pp. 201-218.

Saviotti, P.P.; Mani, G.S. (1998), Technological evolution, self-organization and knowledge, *The Journal of High Technology Management Research*, 9 (2), pp. 255-270.

Saviotti, P.P.; Pyka, A. (2004), Economic development by the creation of new sectors, *Journal of Evolutionary Economics*, 14, pp 1-35.

Silva, E.G.; Teixeira, A.A.C. (2008), Surveying structural change: seminal contributions and a bibliometric account, *Structural Change and Economic Dynamics*, 19, pp. 273-300.

Silva, E.G.; Teixeira, A.A.C. (2011), Does structure influence growth? A panel data econometric assessment of 'relatively less developed' countries, 1979-2003, *Industrial and Corporate Change*, 20 (2), pp. 433-455.

Tamura, S.; Sheehan, J.; Martinez, C.; Kergroach, S. (2005), Promoting innovation in services in OECD (ed.*), Enhancing the Performance of the Services Sector*, Paris, France: OECD Publishing.

Teixeira, A.A.C.; Fortuna, N. (2010), Human capital, R&D, trade, and long-run productivity. Testing the technological absorption hypothesis for the Portuguese economy, 1960–2001, *Research Policy*, 39, pp. 335-350.

Temple, J. (1999), A positive effect of human capital on growth, *Economic Letters*, 65, pp. 131-134.

Theil, H. (1972), *Statistical Decomposition Analysis: with Applications in the Social and Administrative Sciences*, Amsterdam, The Netherlands: North Holland.

Tidd, J.; Bessant, J. (2009), *Managing Innovation: Integrating Technological, Market and Organizational Change*, 4th ed., Chichester, UK: John Wiley & Sons Ltd.

Verspagen, B. (1991), A new empirical approach to catching up or falling behind, *Structural Change and Economic Dynamics*, 2 (2), pp. 359-380.

Appendix

Table 7: Classification of industries

ISIC rev. 3	Industry	OECD (2002)	Tidd and Bessant (2009)
01	Agriculture, hunting & related	Non manufactured products	Supplier-dominated
02	Forestry, logging & related activities	Non manufactured products	Supplier-dominated
05	Fish, products of fish hatcheries	Non manufactured products	Supplier-dominated
10-14	Mining and quarrying	Non manufactured products	Scale-intensive
15-16	Food products, beverages & tobacco	Low-tech	Scale-intensive
17	Textiles	Low-tech	Supplier-dominated
18	Wearing apparel; fur	Low-tech	Supplier-dominated
19	Leather products (inc. footwear)	Low-tech	Supplier-dominated
20	Wood and products of wood and cork	Low-tech	Supplier-dominated
21	Paper and paper products	Low-tech	Supplier-dominated
22	Publishing, printing & reproduction of recorded media	Low-tech	Supplier-dominated
23	Man. of coke, refined petroleum prod. & nuclear fuel	Medium-low-tech	Scale-intensive
24-2423	Chemicals exc. Pharmaceuticals	Medium-high-tech	Science-based
2423	Pharmaceuticals	High-tech	Science-based
25	Rubber and plastics products	Medium-low-tech	Specialized supplier
26	Other non-metallic mineral products	Medium-low-tech	Scale-intensive
27	Basic metals	Medium-low-tech	Scale-intensive
28	Man. of fabricated metal prod., exc. mac. & equipment	Medium-low-tech	Scale-intensive
29	Machinery & equipment n.e.c.	Medium-high-tech	Specialized supplier
30	Office and computing machinery	High-tech	Specialized supplier
313	Insulated wire and cable	Medium-high-tech	Specialized supplier
31-313	Elect. machinery & apparatus, exc. ins. wire and cable	Medium-high-tech	Science-based
321	Electronic valves and tubes	High-tech	Specialized supplier
322	TV & radio transmitters & telephone	High-tech	Specialized supplier
323	TV & radio receivers, recorders	High-tech	Science-based
331	Scientific instruments	High-tech	Specialized supplier
33-331	Other instruments	High-tech	Specialized supplier
34	Motor vehicles and trailers	Medium-high-tech	Scale-intensive
351	Ships and pleasure boats	Medium-low-tech	Scale-intensive
353	Aircraft and spacecraft	High-tech	Scale-intensive
352+359	Railroad and other transport equipment nec	Medium-high-tech	Scale-intensive
36-37	Furniture, manufacturing nec; recycling	Medium-low-tech	Supplier-dominated
40	Electricity, gas and steam	Non manufactured products	Scale-intensive
741-3	Legal, technical and advertising	Non manufactured products	Specialized supplier
749	Other business activities, nec	Non manufactured products	Information-intensive
92	Leisure, cultural & sport products	Non manufactured products	Supplier-dominated
93	Products of other service activities	Non manufactured products	Supplier-dominated

Sources: Loschky (2008) and Silva and Teixeira (2011)