R&D, innovation and international performance:
A model and a test on European industries

Dario Guarascio*

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Abstract

In this article we propose an explanation of the divergent dynamic of EU "core and periphery" which focuses on the role and the interactions of technology and international competitiveness. We extend Pianta & Bogliacino (2012, 2013) model by integrating the mechanism of the Schumpeterian "engine of progress" with variables capturing the role of exports and international competitiveness. The objective of this extension is to test for the existence and the magnitude of a virtuous circle in the core (Germany, Netherlands and United Kingdom) European countries and a vicious one in the periphery (Italy, Spain and France). We investigate empirically -at the industry level- three key relationships affecting the dynamics of innovation and international performances: first, the capacity of firms to translate their R&D efforts in successful innovations; second, the role of innovation as a driver of higher export market shares; third, the increase in export market share as a determinant of new R&D investments. We develop a simultaneous three equation model in order to inquire the existence of feedbacks and self-loops between industries' R&D intensity, share of product innovators and export market share. The model is tested for 38 manufacturing and service sectors on six European countries over three time periods from 1995 to 2010. The results are twofold: on one side, the model effectively accounts for the dynamics of R&D efforts, innovation and international performance of European industries; on the other side, the existence of two distinct and divergent dynamics in the core and peripheral area are detected.

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*Phd School of Economics, Sapienza University of Rome

dario.guarascio@uniroma1.it

1. Introduction

The European economy is still in crisis with the exception of a circumscribed area commonly known as the EU "core". As already detected (Stockhammer 2012, 2014; Landesmann, 2013) two elements are crucial to explain the actual crisis: the European export-led growth model and the associated North-South (here core-periphery) divide. These two elements are linked to the fact that the degree of openness of the European area as a whole is much smaller than the average of the openness of its member states because most of the trade of the member states is within Europe. In the Euro-area, extra-EU exports and imports accounts for only 11.6% and 12.9% of GDP respectively (Stockhammer 2012).

Relying on Pianta & Bogliacino model (2012, 2013) this work aims to investigate the role that technology, beside cost and demand factors, has played in the actual scheme of crisis and divergence within the European economy. In order to do this, the interconnection of three fundamental processes are highlighted. Adopting a Schumpeterian perspective (Schumpeter, 1942) we investigate, for first, the cumulative nature of R&D, supported by *demand-pull*, *technology push* factors (Schmokler, 1966; Scherer, 1982) and by the commitment of firms to consolidate their successful performances (here considered in terms of export market share since trade openness is commonly recognized as a pushing factor for product sophistication and quality enhancing) through new investment in R&D. Second, the ability of industries' R&D to lead to successful innovations, combining developments on the supply and the demand side. Third, the determinants of export growth by combining a search for technological innovation, the pursuit of a cost competitiveness through a minor labor cost and the use of different inputs, domestically produced or imported (see Montobbio, 2003; Soete, 1981) .

Much economic research has investigated these issues either considering externalities and spillovers as major channels for the diffusion of knowledge and technologies (Griliches, 1979, 1992 and 1995; Griffith et al. 2004), or focusing on R&D driven technological change that leads to endogenous growth (see Aghion and Howitt 1998 for a general discussion of the literature). Here the aim is to enlarge the picture, considering the diversity of innovative efforts – that include not just R&D, but also innovative investment, adoption of new technologies, learning processes, etc. -, the uncertainty of technological change – addressing innovative outputs as well as inputs, such as R&D – and the feedback effects that may exists among the different relationships. Moreover, another key question is addressed inside this picture. The extent to which the use of different inputs as well as technological and cost competitiveness strategies (for a discussion of this distinction see Pianta, 2001) can determine exchange in export market share beside labor cost factors.

A few number of papers have explored the links between innovation and economic performance by breaking down this sequence of relationships and estimating empirically different phases: the decision to invest in R&D, the relationship between inputs and outputs and the effect of R&D on economic performance (Crépon et al. 1998; Parisi et al. 2006). Moreover, little attention has been dedicated to the role of international production and competitiveness as key components of economic performance in such a scheme. Nevertheless, a wide literature has already investigated, both theoretically and empirically, the relation between innovation and international competitiveness as well as the role of intermediate input mix. (among the others see Amendola et al., 1993, Carlin et al., 2001 and Landesmann & Pfaffermayr 2010 for the former while Bas and Strauss-Kahn, 2010 and Colantone and Crinò, 2014 for the latter issue)

Such complex and interconnected relationships are modeled and empirically tested. Using industry level data for 21 manufacturing and 17 service two-digits sectors coming from different sources (production and demand variables from STAN-OECD and WIOD I-O databases while innovation related variables from Eurostat Community Innovation Surveys) a simultaneous three equation model (3SLS) has been developed. This model allows to account for correlation among errors belonging to different equations, cleaning at the same time endogenous regressors through instrumental variables technique. By this way the searched feedbacks and self-loops are detectable ensuring also efficiency in estimations.

The paper is organized as follows. The next section is dedicated to a theoretical overview of the model considering singularly each equation among those that are included in it. In the third section data are descripted and some descriptive evidence is presented. In the fourth section the econometric strategy is illustrated. In the fifth section the results are shown and in the sixth we provide the conclusions and some general considerations are derived.

2. Theoretical framework

The model formalize a circular loop of self-reinforcing relations which has the following dynamic: R&D efforts bring to successful innovations; successful innovations bring to the acquisition of new export market shares; the acquisition of new export market share bring to enhanced R&D efforts. Beside the variables which lead to the proposed circular loop a set of other exogenous but not less theoretically relevant components are considered. In the following subsections we first present the advantages of the analysis at the industry level then illustrating the theoretical basis of each equation and discussing the linkages with the existing literature.

2.1 The relevance of the analysis at the industry level

Studies on the topics addressed above have been carried out both at the firm and at the industry levels. It is important to point out the differences between these two approaches and the specific value of a sectoral approach such as the one we develop in this article.

Firm level studies have attracted increasing attention as a result of the emphasis on micro units of analysis that has emerged both in mainstream microeconometrics addressing causality issues, and in evolutionary approaches focusing on the heterogeneity of economic actors. While we share both concerns, we argue that firm level approaches cannot account for a number of explanatory factors in the analysis of innovation and performance that only emerge when the industry level is considered.

(a) Firm level studies are usually based on panels including a relatively small number of firms that, in most cases, are not representative of the universe; they usually focus on manufacturing alone disregarding services activities. Moreover, when a panel is followed over some time, by definition it excludes firms exiting and entering the market – events where innovation, or the lack of it, is likely to play a major role. Therefore, the results of firm level studies are relevant for the firms concerned only, and can hardly be generalized to other firms, or assumed to be relevant for the economy as a whole. Conversely, industry level studies account for the totality of business in a given sector, leveling off gains and losses that may occur at the firm level, showing the changes in the structure of the economy and making links possible to overall macroeconomic patterns.

(b) Neo-Schumpeterian and evolutionary approaches have widely documented the importance of industry-specific technological trajectories and sectoral systems of innovation; firms belonging to an industry are likely to share – to a large extent - the same technological opportunities, nature of knowledge, appropriability conditions and market structure (Dosi, 1982, 1988; Pavitt, 1984; Breschi et al 2000, Malerba, 2004). Industry level approaches are therefore capable to account for the technological heterogeneity of sectors in an effective way, while in firm level studies such heterogeneity is generally expressed in a limited way by inadequate indicators of industries' technological characteristics, or is left unexplored and bundled with all sorts of other factors in industry dummies.

(c) There is a fundamental asymmetry between micro and industry-level studies when the role of demand is considered. An individual firm can always grow and increase its market share at the expense of competitors; a perfectly elastic demand can be assumed. Conversely, an industry's demand has a downward slope and results from the part of aggregate demand directed to the products and services of a given sector. Therefore, at the firm level innovation can easily result in improved economic performance, while at the industry level this is likely to happen only when a simultaneous expansion of demand (relative to other industries) is also taking place.

These fundamental differences between firm and industry level studies imply that the results obtained at one level cannot be automatically transferred to the other. The key differences found at distinct levels of analysis are examined below.

The relationship between R&D and innovative performance is the least controversial one. A large literature on both firms and industries – using a variety of models and approaches - has found that greater research efforts are generally associated to better innovative outcomes (see for instance Mairesse and Mohen, 2010 and Loof and Heshmati, 2006, for firm level studies, and Crespi and Pianta, 2007, for industry approaches).

The effect of innovation on profits is less simple to disentangle. At the industry level the link clearly emerges, as sectors with higher innovation – through both direct effects and spillovers – end up showing higher profit dynamics (see Pianta and Tancioni, 2008). Conversely, at the firm level a high heterogeneity is found; a few firms have innovative success, market expansion and high profits; others may innovate without obtaining significant profits, due to firm-specific factors (business strategies, cost structures, etc.) or to market conditions (competition, etc.); others may yet show high profits that result more from market power than from innovation.

The relationship between profits and R&D is more controversial. At the industry level we can capture both the presence of (generally large) incumbent firms that finance their R&D from retained profits - as in the Schumpeter Mark II model (Breschi et al. 2000) - and the influence of high industry profits in attracting the entry of new firms with high research efforts. Conversely, studies at the firm level can capture the former effect only, and results are affected by the same firm- and market-specific factors pointed out above. It is therefore not surprising that mixed evidence has been found.

2.2 The decision to carry out R&D efforts

Remaining close to the set up proposed by Pianta and Bogliacino (2012, 2013), the commitment of firms to keep up R&D investments is explained in the following way. Firstly, we follow evolutionary approaches to R&D efforts in firms and industries. R&D is considered here as a path dependent process because the paradigm (and trajectory) related development of technology makes the process of search eminently localized (Atkinson and Stiglitz, 1969; Nelson and Winter, 1982; Dosi, 1982 and 1988). R&D is also affected by *demand pull* (Schmokler, 1966; Scherer, 1982) and *technology push* effects (Mowery, 1979). According to the former perspective, innovation is brought to the market when firms anticipate strong demand; in the latter view innovation is supported by science-related developments and is triggered by relative prices in a feasible production set. Moreover, innovation is persistently characterized by the presence of specific technological and production capabilities (Pavitt, 1984; Dosi, 1988; Malerba, 2005; Metcalfe, 2010).

Deepening the role of *demand pull* factors affecting R&D the role of export market share is mainly inquired since acquiring and consolidating international positions is commonly shared as an enhancing factor for the dynamism of firms investments. Such enhancing factor could be partially explained with the relative protection of internal markets compared to the strong competition on prices and products quality characterizing international markets. In this light, the differences in R&D investment figures observed within European countries and, in particular, between core and periphery, could find an interesting explanation also considering the heavy competition over European export market share conducted by the major EU economies until the crisis.

Moreover, R&D could be financially constrained (Hall, 2002) due the intangible nature of R&D which is difficult to collateralize and also due to informational problems, namely the "radically uncertain" nature of research and the asymmetric distribution of information (Stiglitz and Weiss, 1981). With this conceptualization in mind, the acquisition of new export market share could represent successful economic performance as well as a source of resources crucial in financing R&D.

The first equation of the model is specified as follows (1) :

$$R\&D_{ijt} = \beta_0 + \beta_1 * R\&D_{ijt-1} + \beta_2 * DP_{ijt} + + \beta_3 * SIZE_{tij} + \beta_4 PROF_{ijt-1} + \beta_5 XMS_{ijt-1} + \varepsilon_{ijtt} \quad (1)$$

Where, i stands for sector at two digits level, j for country and t for time. R&D is research and development (thousands of euros per employee in our data), and is affected by its lag; DP stands for demand pull and reflects the potential for the introduction of new products, captured by the objective of opening up new markets reported by innovation surveys (CIS), $MKTSH$ is the lagged export market share (computed following Carlin et al., 2001 as the ratio between sector ij's real exports and the sum of real exports for that industry and period for all the countries included in the sample). The last term is the standard error. Another strand of literature has tried to identify the effect of firm size on R&D (Cohen and Levin, 1989; Cohen, 2010). Since the introduction of the Schumpeter Mark II model the greater concentration of R&D expenditures in larger firms has been detected as a stylized fact. Nevertheless, this line of research has been criticized for being unclear on whether it is innovation input or output that is affected by size and for the risk of endogeneity, given that both market structure and innovation are codetermined by the fundamental features of the sector (appropriability, cumulativeness and the knowledge base, see Breschi et al. 2000). Relying on the contributions (Schumpeter, 1942; Brown et al. 2009) which already underlined the importance of past economic performances as a main driver of new R&D investments, we emphasized the role of the past position in export market as a key element in determining R&D efforts among EU countries. Using data at the industry level could also allow to overcome the controversial evidence emerged from firm level studies (Greeve, 2003) about the association of past economic performances and R&D efforts. From this point of view, considering the past improvement in export market share as performance variable allow to take into account both the commitment of firm to exploit the results of their past performances as well as the perspective of higher external demand as drivers of R&D. The consideration of this demand component as an R&D determinant allows a step further than firm level studies which normally assume a perfectly elastic demand for individual firms avoiding any consideration of the existence of demand constraints. At the industry level, on the other hand, the dynamics of demand is constrained – it is defined by the distribution across industries of the growth of aggregate demand – and a consideration of the different sources of demand becomes important (for a discussion, see Bogliacino and Pianta, 2010).

2.3 The product innovation equation

Good economic performances as well as the capacity to penetrate new markets are linked to successful innovations more than to R&D expenditures itself. In order to formalize this distinction we followed a scheme already proposed in literature (Crépon et al., 1998; Parisi et al., 2006 and Bogliacino & Pianta, 2010) adding a second equation to the model with the attempt of identifying all the determinants of product innovation. The analysis of the determinants and the characteristics of innovation and their linkages with economic dynamics are at the root of evolutionary economics. One of the main contribution of this evolutionary literature is related to the conceptualization of innovation as a multimodal process assuming different shapes and intensities depending on the trajectories of each sector (Pavitt, 1984; Dosi, 1988; Malerba 2002 and 2004 among the others).

Further, deepening the set of determinants of innovation I referred to the distinction pointed out by Pianta (2001) about the Schumpeterian product and process innovation. This kind of distinction is quite fruitful in terms of analysis since the effects and the feedbacks between growth, employment, distribution and innovation could be strongly different if we carry out the analysis breaking down the latter in such a way. More precisely I rely on the concepts of *technological* and *cost competitiveness* to summarize on the one hand innovation strategies focusing on new markets, new products and R&D, as opposed to efforts directed at labor saving new machinery, efficiency gains and cost reductions.

Technological competitiveness is represented in my second equation by past R&D efforts. On the other side, attempts for cost competitiveness are represented by expenditure for machinery and equipment directed to optimize the production process and reducing costs.

Finally we include demand distinguishing between internal final consumption, internal intermediate consumption and exports.
The specification of the product innovation equation, the second of the system, is the following (3):

$$INNO = \beta_0 + \beta_1 * R\&D_{t-1} + \beta_2 * DEMAND_t + \beta_3 EXMACH_t + \varepsilon_t \quad (3)$$

where, $INNO$ stands for the share of product innovators firms in the sector, $R\&D_{t-1}$ is the lagged R&D expenditure (estimated in the first equation), $DEMAND$ is the growth of each demand component, $EXMACH$ is the expenditure in thousands of euros employee for machinery and equipment, and ε the usual error term.
As commonly shared the capacity of new R&D expenditure to result in successful innovations take some time and for this reason R&D variable (in the 3SLS system is the variable estimated in the previous equation) is inserted with one period lag. Successful innovation leading to new products and new markets requires R&D inputs and - as in the Schumpeterian "mark II" models – could also be characterised by the presence of large firms with strong capabilities for exploiting knowledge, and oligopolistic market structures, where high incentives to generate product innovations exists. Finally, demand may play a role in several ways. The demand pull perspective and the literature on structural change (Pasinetti, 1981) emphasises the positive effect that a strong demand dynamics has on the development and diffusion of new products. This is a complementary approach to the Schumpeterian analysis of the way major innovations change the economy. However, when an economy – or an industry - operates in the Schumpeterian "circular flow", without major innovations, current demand for standard products may reduce the incentive to develop new products and delay their introduction. Therefore, demand that matches relevant technological change – the most dynamics components of demand, such as exports – is likely to support the introduction of new products in a virtuous circle between capabilities, innovations and markets (as in the "learning by exporting" hypothesis, see Crespi et al., 2008). Conversely, demand that is related to the activity of industries where a "circular flow" prevails – such as demand for consumption and for intermediate goods – may lead to less incentives for the introduction of new products.

2.4 The export market share equation

A substantial body of literature is concerned since the 80s about the relationships between R&D, innovation and international competitiveness (see for example Pianta & Archibugi 2001). Nevertheless, neoclassical trade theory hardly took into account differences in technological performances in explaining trade flows between countries, supposing that every country has access to the same technology set and concentrating on factor endowments and hence on factor prices, instead (Amable & Verspagen, 1995). For a long time this led many applied economists and analysts to concentrate on price as the only aspect of competitiveness. Joseph Schumpeter described the shortcomings of that misleading simplifications. The true nature of capitalist competition, he stated, is not price competition, as envisaged in traditional textbooks, but technological competition: "..But in capitalist reality as distinguished from its textbook picture, it is not that kind of competition that counts but the competition from the new commodity, the new technology, the new source of supply, the new type of organization (…) – competition which commands a decisive cost or quality advantage and which strikes not at the margins of the profits and the outputs of the existing firms but at their foundations and their very lives.." (Schumpeter 1943, p. 84).
By the way, many authors have started to stress the importance of non-price factors in determining international competitiveness both on the neoclassical and on the heterodox side. With respect to the former, Paul Krugman working on the "new trade theory" pointed out the importance of product differentiation and quality on the supply side and of preference for variety on the demand side (Krugman, 1990). Innovation lead to the generation of new products and R&D become a strategic variable to maintain past market positions. R&D and innovation are also important in growth theory where comparative advantages may

become endogenous and research policy and trade could have an effect on specialization and growth (Grossman & Helpman, 1991).
Similar arguments are considered in a wide Post Keynesian literature (Thirlwall, 1979; Kaldor, 1981) where a lot of emphasis is devoted to non-price factors of international competitiveness. In the evolutionary approaches (Dosi et al. 1981, Amendola et al. 1993, Verspagen, 1993) technological differences among countries and industries can provide basis for trade which is considered as a dynamic process of competition.
On the empirical side, the need to account for non-price factors affecting competitiveness and the acquisition of new market shares has been manifested since the 70s (Kaldor, 1978; Kelman, 1983). Those studies, for the major part conducted at the macro level, shown that price effect on market shares seems to be rather weak or, even sometime perverse.
Anyway, looking at the actual dynamics of international trade another important piece of the story is missing. The international integration of production has grown over the past decade (Hummels et. al, 2001) and has increased the channels of firm competitiveness. The role of Global Value Chains and of intermediate inputs, both imported and home produced, is grown rapidly in terms of importance in the last years. With this respect, imported intermediate inputs are not perfect substitutes to domestic inputs: on the one hand, by using more varieties of intermediate goods or through the technology embodied in these inputs, firms can increase the qualitative content of their products and improve their technological competitiveness (Bas and Strauss-Kahn, 2010). On the other hand, they can have access to lower input prices and increase their cost competitiveness.
A large literature has focused on the impact of imported inputs on employment (Feenstra and Hanson, 1996); recent empirical works have underlined a positive relationship between imported inputs and firm productivity at the firm, sectoral and macro level (see the review in Olsen, 2006; Daveri and Jona-Lasinio, 2007). Few studies have stressed the role of imported inputs on export performances (Bas and Strauss-Kahn, 2010; Colantone and Crinò, 2014).
The specification of the market share equation, the third of the system, is the following (4):

$$XMS_{ijt} = \beta_0 + \beta_1 UNITLC_{ijt} + \beta_2 INNO_{ijt} + \beta_3 INT\_lt_{ijt} + \beta_4 INT\_ht_{ijt} + \beta_5 IMPINT\_lt_{ijt} + \beta_6 IMPINT\_ht_{ijt} + \varepsilon_{ijt} \quad (4)$$

where, XMS_{ijt} is the export market share of sector i in country j with respect to the total of the exports of the same sector for the whole sample, $INNO_{ijt}$ is the share of product innovators over the whole firms of the sector i (in our system is the variable estimated in the product innovation equation), INT_lt_{ijt} is the average annual rate of variation of low tech intermediate inputs coming from the domestic market for sector i in country j, INT_ht_{ijt} is the average annual rate of variation of high tech intermediate inputs coming from the domestic market, $IMPINT\_lt_{ijt}$ is the average annual rate of variation of imported high tech intermediate inputs, INT_ht_{ijt} is the average annual rate of variation of imported high tech imported intermediate inputs and finally ε_{ijt} is the error term. The export market share as well as UNITLC is computed for each country's sector as in Carlin et al. (2001) (5) and (6):

$$\frac{REXP_{ijt}}{\sum_{j}^{j\in\{1,..,6\}} REXP_{ijt}} \quad (5)$$

$$i \in \{NACE\}, j \in \{Ger, Es, Fr, It, Nl, Uk\},$$

$$UNITLC_{ijt} = \frac{(W_{ijt} / E_{ijt})}{(VA_{ijt} / N_{ijt})} \quad (6)$$

where in (6) the numerator is the wage per employee in real terms divided by the number of employee in the same sector while the denominator is the ratio between industry's value added and the number of total engaged. This equation is the crucial one in our model since we can highlight the differences in terms of relevance of price and non-price competitiveness variables. Moreover, the estimated coefficients of this equation within our simultaneous system are at the base of the core/periphery divide we would like to highlight in this work. Finally, the full system is (7):

$$\begin{cases} R\&D_{ijt} = \beta_0 + \beta_1 * R\&D_{ijt-1} + \beta_2 * DP_{ijt} + \beta_3 * FR_{ijt} + \beta_4 * MKTSH_{tij-1} + \varepsilon_{ijt} \\ INNO = \beta_0 + \beta_1 * R\&D_{t-1} + \beta_2 * OUTPUT_t + \beta_3 EXMACH_t + e_{ijt} \\ XMS_{ijt} = \beta_0 + \beta_1 UNITLC_{ijt} + \beta_2 INNO_{ijt} + \beta_3 INT_{lt_{ijt}} + \beta_4 INT_{ht_{ijt}} + \beta_5 IMPINT_{lt_{ijt}} + \beta_6 IMPINT_{ht_{ijt}} + \eta_{ijt} \end{cases} \quad (7)$$

3. Preliminary data description

The database used in this paper is the result of a merge from two different sources of data. For innovation and production variables – R&D expenditure, share of firms developing product innovations, expenditure for machineries, share of firms adopting labor saving innovations, wages, total employees and total engaged - I rely on the Sectoral Innovation Database (SID) developed at the University of Urbino (see Pianta et al, 2011 for a comprehensive assessment of data) that includes data from three European Community Innovation Surveys - CIS 2 (1994-1996), CIS 3 (1998-2000), CIS 4 (2002-2004) and CIS 6 (2006-2008) - matched with data at the industry level from the OECD-STAN Isic Rev. 3 database. For other production and demand variables I used the National Annual Tables (NIOT) of the World Input Output Database (WIOD) (Timmer, 2012) converting the original data in euros and in real terms. Data are available for the two-digit NACE classification for 21 manufacturing and 17 service sectors; all data refer to the total activities of industries.

Using Input-Output tables allows to deepen the linkages between different types of domestic and imported inputs and industries (Yamano and Ahmad, 2006). Indicators are computed as the sum of the expenditure devoted by each industry to the acquisition of different types of inputs, all divided by the total production output of each user sector. In particular, we distinguish among inputs according to the technological intensity of sectors, taking into account inputs coming from high (aggregating intermediate input data related to Science Based and Supplier Specialized sectors) and low-tech (Scale intensive and Supplier Dominated sectors) industries aggregating using the Pavitt Classification (Pavitt, 1984).

The country coverage of the database includes six major European countries – Germany, France, Italy, Netherlands, Spain, and United Kingdom - that represent a large part of the European economy. The selection of countries and sectors has been made in order to avoid limitations in access to data (due to the low number of firms in a given sector of a given country, or to the policies on data released by national statistical institutes).

Time periods are the following. Economic and demand variables are calculated for the periods 1995-2000, 2000-2005 and 2005-2010. The export market shares variable is computed each industry for years 2000, 2005 and 2010. Innovation variables refer to 1994-1996 (used for the lagged R&D variable in equations 1 and 2); 1998-2000 (linked to the first period of economic variables); 2002-2004 (linked to the second period of economic variables) and 2006-2008 (linked to the third period of economic variables). The variables used are listed in Table 1.

Table 1. List of Variables

Variable	Unit	Source
In-house R&D expenditure per employee	Thousands euros/empl	CIS
New Machinery expenditure per employee	Thousands euros/empl	CIS
Share of product innovators	%	CIS
Share of firms innovating with the aim of opening new markets	%	CIS
Average firm size	Number empl. per firm	CIS
Compound rate of growth of Exports	annual rate of growth	WIOD I-O Tab.
Compound rate of growth of Interm. Demand	annual rate of growth	WIOD I-O Tab.
Compound rate of growth of Final Demand	annual rate of growth	WIOD I-O Tab.
Compound rate of growth of Imported Int. Inputs (high and low-tech)	annual rate of growth	WIOD I-O Tab.
Compound rate of growth of Domestic Int. Inputs (high and low tech)	annual rate of growth	WIOD I-O Tab.
Distance in labor productivity from the frontier	%	WIOD I-O Tab.
Compound rate of growth of production	annual rate of growth	WIOD I-O Tab
Compound rate of growth of Wages	annual rate of growth	STAN Isic Rev.3

All the economic variables are deflated using the sectoral Value Added deflator from OECD-STAN (base year 2000) corrected for PPP (using the index provided in Stapel et al. 2004). As known, the difference in log approximates the rate of change, thus we express both dependent variable and regressors in rate of variation. Instead of considering long difference, we compute the compound annual growth rate, shares of firms in the sector, shares of turnover or expenditure per employee. This can be justified considering innovative efforts as dynamic and capturing the change in the technological opportunity available to the industry. CIS innovation data are representative of the total population of firms and are calculated by national statistical institutes and Eurostat through an appropriate weighting procedure.

The dataset is a panel dataset over two periods covering a time span comprehended between 1995 to 2010 across 6 major European countries. This kind of industry level-dataset is strongly valuable since it allows to settle the complexity of innovation at the sectoral level as well as to consider both supply and demand determinants of economic and innovative performances. A synthetic scheme of the strength of this dataset are listed below:

- The industry level detail of the dataset allows to stress the specificity of industries in terms of their innovation patterns and growth trajectories, considering both manufacturing and service sectors

- The availability of consistent exports, value added, employees and total engaged data allows for the construction of reliable competitiveness indicators by industry

- The detailed nature of CIS database give the possibility to take into account different innovation strategies (cost and technological competitiveness) as well as different aims for innovation

- The National Input-Output database allows to distinguish the intermediate inputs used by a specific sector by their technological intensity (identified by the two digit NACE sector of origin of the inputs) and between their domestic or imported nature

To use these data in panel form, we need to test that the sample design or other statistical problems in the gathering of data are not affecting their reliability. Besides considering the time-effects capturing macroeconomic dynamics, we have examined the stability of the database. A very detailed empirical investigation on the characteristics of the database has been already carried out (Bogliacino & Pianta, 2010b) and I report in the following Table the main descriptive statistics:

Table 2. Descriptive statistics

Variables	Mean	SD Overall	SD Between	SD Within
In-house R&D expenditure per employee	2.65	4.86	4.36	2.07
New Machinery expenditure per employee	1.70	2.69	2.51	1.44
Share of product innovators	35.03	43.15	61.83	13.28
Share of firms innovating with the aim to open new markets	25.58	15.88	13.36	9.33
Average firm size	0.364	1.90	1.51	1.38
Compound rate of growth of Export	2.07	26.25	18.97	18.17
Compound rate of growth of Intermediate Demand	0.77	8.89	5.41	7.06
Compound rate of growth of Household Final Demand	0.09	17.19	11.12	13.13
Export Market Shares	0.16	0.14	0.13	0.04
Operating Surplus per employee (Profits)	38.63	102.94	100.79	21.63
Compound rate of growth of Unit Labor Cost	-0.63	8.49	4.38	7.28

3.1 Export market shares, cost end technological competitiveness: some descriptive evidence

One of the main objectives of this paper is to analyze the connections and the feedbacks between innovation, labor cost and economic performances in terms of export market shares. Moreover, the divergent economic dynamic across Europe's core and periphery is a subject of this analysis and in what follows some descriptive evidence would be provided. The following tables (Tab. 3 & Tab.4) contains the averages by countries of the key economic and innovation variables used for the subsequent econometric analysis.

Table 3. Production Variables, descriptive statistics by country (1995-2010)

Country	Productivity (%)	Exports (%)	Unit Labor cost. (%)	Export Market Share	Operating Surplus /employee
Germany	8.05	6.73	-3.05	0.29	46.34
Netherlands	1.42	1.42	1.90	0.11	39.86
UK	1.51	5.92	0.11	0.23	8.07
Core	3.66	4.69	-0.34	0.63	31.42
Spain	-0.09	5.14	-1.49	0.06	38.83
France	3.40	-8.91	-2.15	0.14	43.55
Italy	0.24	2.14	0.88	0.13	55.11
Periphery	1.18	-0.05	-0.92	0.37	45.83

Notes: Labour Cost is the compound average annual rate of change of the indicator computation shown in (6), Exp. Market Shares is the average over the sample period. All the variables are in euros and in real terms.

Table 4. Innovation Variables, descriptive statistics by country (1995-2010)

Country	R&D exp	Prod. Inno	Proc. Inno	New Market Obj.
Germany	3.87	60.05	3.84	35.32
Netherlands	3.08	36.79	1.19	26.50
UK	2.06	25.23	2.35	33.94
Core	3.06	41.08	2.71	33.00
Spain	0.99	25.23	0.68	16.79
France	4.84	36.60	0.80	26.89
Italy	1.37	29.04	1.42	16.00
Periphery	2.38	30.24	0.99	19.85

Notes: R&D expenditure variable and Process Innovation (Expenditure for Machineries and Equipments) are in thousands of euros for employee. New market objectives is a share variable computed dividing the respondents who declared that opening a new market is their main aim to innovate over the whole population of firms. Data at the 3rd CIS (1998-2000), 4th CIS (2002-2004) and 6th CIS wave (2006-2008). All the variables are in euros and in real terms.

The statistics contained in Tab. 3 provide the first information about the dynamics of competitiveness and economic performances for each country considered in the analysis. Core and periphery figures could also give a first depiction of the core/periphery divide across the EU. First, looking at the R&D expenditure figures, the efforts for R&D seems to be bulling in all sample's countries with the exception of Spain and Italy. Regarding the product innovation performances, the differences between core and periphery are more striking. In particular, Germany contributes substantially to the increase in the core/periphery divide in terms of product innovation.

The comparison between the dynamics of product, process innovation and labor cost would be quite important to highlight the weight of price and non-price competitiveness across EU countries. Unit labour cost figures show a tendency towards decreasing for all the countries apart from Italy, Netherlands and UK. An interesting element emerging from the numbers in Tab. 3 is that all the countries where characterized by a relatively higher export market shares took place are also characterized by a high share of product innovators within firms. The Italian case deserve some particular attention. Although Italy is the only peripheral country where unit labor cost is grown over the considered time span its export market share is above the periphery average which is 0.11. This fact could be explained looking at the figures of both product and process innovation for Italy. Italy remains near to the periphery average for product (21.35 against an average of 23.57 in the periphery for product and 1.57 against 1.01 for process innovation) and above it for process innovation. This could have partially counterbalanced the negative effect on competitiveness which the increase in unit labor cost has presumably determined. Similar arguments about Italian performances in the last years have been pushed forward by A. Triffin (Triffin, 2014) in a recent IMF report whose goal was to detangle the "Italian Productivity Puzzle".

Regarding the core periphery divide in terms of numbers, the divergence appears dramatic in particular with respect to product innovation and export market shares. As expected Germany is the main driver of core EU dynamics while Italy has the inverse role in the peripheral case.

In the Appendix a more detailed descriptive analysis of the variables is provided. The final step of this preliminary data inspection regards the role played by intermediate inputs distinguishing them in terms of technological content and source. Tab. 5 reports the share of each intermediate input over the total industry production computed by country.

Table 5. Intensity in the use of domestic and imported inputs by country (1995-2010). Expenditures for the acquisition of input as a share of total production, average values.

Country	Domestic Low tech	Domestic High tech	Foreign Low tech	Foreign High tech
Germany	.20	.17	.07	.05
Netherlands	.19	.19	.11	.10
UK	.23	.14	.06	.05
Core	.21	.17	.08	.05
Spain	.26	.15	.06	.05
France	.24	.18	.06	.05
Italy	.32	.17	.06	.04
Periphery	.27	.17	.06	.05

Notes: High Tech intermediate inputs are those originating sectors belonging to SB and SS Pavitt categories while Low Tech ones are those coming from SI and SD sectors.

The numbers in Tab. 5 depict a situation where there is a little variability across countries in spite of a tendency towards the national market of intermediate inputs for peripheral countries. Domestic low-tech intermediate inputs seems to play a major role in Italy where their share over total production is .32, five points over the periphery average and ten over the core. The final Table (Tab. 6) reports the intensity in the use of domestic and imported inputs by Pavitt Categories for the period 1995-2010.

Table 6. Intensity in the use of domestic and imported inputs by Pavitt Category (1995-2010). Expenditures for the acquisition of input as a share of total production, average values.

Pavitt Category	Domestic Low tech	Domestic High tec	Foreign Low tech	Foreign High tec
SB	.19	.20	.04	.10
SD	.27	.14	.07	.03
SI	.26	.17	.11	.05
SS	.18	.19	.03	.08

Notes: High Tech intermediate inputs are those originating from sectors belonging to SB and SS Pavitt categories while Low Tech ones are those coming from SI and SD sectors.

As expected the variability across Pavitt Categories is higher than the one observed among countries. Sectors belonging to Science Based and Supplier Specialized categories rely mostly on high tech intermediate inputs and their openness to the foreign market is also remarkable. On the contrary, Scale Intensive and Supplier Dominated sectors are characterized by an intensive use of low tech inputs originating principally from the domestic market. More detailed descriptive statistics could be found in the appendix.

A substantial divergence in terms of economic and innovative performances across our sample's countries emerges form this first data inspection. Moreover, technological factors turn out as a crucial piece of the explanation of competitiveness dynamics for the EU countries we have considered.

4. Econometric Modelling Strategy

The estimation strategy adopted is the following. First, aiming to verify the validity of the hypothesized relationships we implement the POLS estimation equation by equation carrying out all the needed diagnostics. Second, in order to depict the feedbacks and self-loops among our variables we use a model suitable for the estimation of systems of equations. We have chosen the Three Stages Least Squares model (3SLS) since it allows to estimate a simultaneous system of equations addressing at the same time all the endogeneity issues. Third, we replicate the 3SLS estimation adopting the interaction terms technique so to check for the existence and the magnitude of a divergent dynamics between core and periphery.

The 3SLS method generalizes the two-stage least-squares (2SLS) method to take account of the correlations between equations in the same way that Seemingly Unrelated Regression (SUR) generalizes OLS. 3SLS requires three steps: first-stage regressions to get predicted values for the endogenous regressors; a two-stage least-squares step to get residuals to estimate the cross-equation correlation matrix; and the final 3SLS estimation step. The 3SLS method goes one step further the 2SLS by using the 2SLS estimated moment matrix of the structural disturbances to estimate all coefficients of the entire system simultaneously. The method has full information characteristics to the extent that, if the moment matrix of the structural disturbances is not diagonal (that is, if the structural disturbances have nonzero "contemporaneous" covariances), the estimation of the coefficients of any identifiable equation gains in efficiency as soon as there are other equations that are over-identified. Further, the method can take account of restrictions on parameters in different structural equations (Zellner & Theil, 1962).

Two relevant methodological points must be addressed here before going towards the interpretation of our results. The use of weighted regressions and the estimation technique. The industry data we use are grouped data of unequal size, so we cannot expect all industries to provide the same contribution in terms of information; as a result, the consistency of the estimation is affected. A way to guarantee consistency is the use of weighted least squares (WLS) that allows taking the relevance of industries into account (see the discussion in Wooldridge, 2002, Ch. 17). The use of a correct weight becomes crucial and the choice is usually limited to value added and number of employees. Statistical offices tend to use the latter since the former is more unstable and subject to price variations, and we follow them in the use of employees as weights.

In order to control for endogeneity, our baseline strategy is to use the lag structure; since our time lags are of three to five years, the autoregressive character of variables is considerably softened. Moreover 3SLS is a proper estimation technique to account for endogeneity when dealing with systems of equations. Anyway, there is always a trade-off between consistency and efficiency in choosing an estimator. Due to modest sample size (inevitable with industry level data), we solve the trade-off relying on consistency instead of efficiency. In fact, with 3SLS we only have to care about orthogonality inside each equation, without taking care of what is happening elsewhere in the system (ibid., 199). As a result, we can focus on the choice of instruments equation by equation in order to guarantee identification.

In the Appendix we discuss diagnostic tests in detail. We controlled for the presence of multicollinearity and heteroscedasticity. All tests confirm the robustness of the approach we have followed.

5. Results

The results of our estimates are presented separately for each equation in the three tables below. We implemented the model on all manufacturing and service industries (38 sectors, Nace Rev. 1), using dummy variables in order to control for core and periphery specificities as well as for differences in technological trajectories between sectors. To carry out a first robustness check we implement the model including country dummies to control for country specific effects.

5.1 Pooled ordinary least squares estimations

Developing the OLS estimation we do not find a particular diagnostic problems. Multicollinearity in particular is not an issue. We have conducted the VIF test over each of the three equations obtaining respectively the following factors: 1.32 for the first equation, 1.26 for the second and 2.55 for the third. Since the critical value for the VIF statistic in order to detect multicollinearity among regressors is near to ten we can exclude the presence of multicollinearity in our regressions. Moreover, the results of the Breush-Pagan test for heteroskedasticity conduct for each regression to reject the null of constant variance we carried out all the estimations with robust standard errors.

Table 7. The R&D equation

Dependent Variable: In-house R&D expenditure per employee.

WLS with robust standard errors and weighted data (weights are the numbers of employee).
t-stat in brackets.
* significant at 10%, ** significant at 5%, *** significant at 1%.

	(1) **Baseline Model**	**(2)** **Baseline with country & Pavitt dummies**
Lagged R&D expenditure	0.58 [8.35]***	0.51 [6.90]***
Firm Size	11.42 [6.66]***	12.05 [6.98]***
New Markets Obj.	0.03 [1.64]	0.02 [0.93]
Profits (first lag)	0.026 [2.25]**	0.03 [2.26]**
Export Market Share (first lag)	3.68 [1.68]*	4.04 [1.71]*
Core dummy	-1.82 [-1.75]*	
Periphery dummy	-0.68 [-0.76]*	
Science Based dummy	1.98 [2.48]**	2.66 [3.21]***
Supplier specialized dummy	1.17 [2.30]**	1.43 [2.79]***
Germany dummy		-0.58 [-0.61]
Spain dummy		-0.45 [-0.55]*
France dummy		1.45 [1.91]*
Italy dummy		-0.19 [0.78]
Netherlands dummy		-0.58 [-0.47]
UK dummy		-0.95 [-0.79]***
Constant	-1.01 [-0.94]	-1.88 [-3.06]***
N.observations	179	179
R2 (Adj)	0.73	0.73

The results of the R&D equation contained in Tab. 6 depict that the explanation of R&D efforts is quite in line with the theoretical scheme built up in section 2. Both the baseline and the model with country dummies show that actual R&D efforts are explained by the cumulative nature of R&D, identified by the coefficient the lagged R&D expenditure. The *demand pull* factor, proxied by a CIS variable computed dividing the number of firms innovating with the aim of entering in new markets by the total population of firms in a specific sector is neither significant in the baseline model nor in the country dummy equation. A possible explanation for the poor relevance of this variable could be found in the major role played by lagged profit and export market share. The latter in particular can easily capture the motivation to invest in R&D related to the opening of new markets making superfluous the *New Markets Obj.* variable.

Supporting the Schumpeterian assumption of R&D efforts driven by big firms able to earn monopolistic profits, *Size* variable is significant and positively related to the dependent variable in both the baseline and the country dummy equation. Moreover, going further in the Schumpeterian tradition, *lagged profits* seems to have an important role in determining new R&D investment. Finally, the *lagged export market share* is significant and positive in both the cases. The magnitude of coefficients should be pointed out; the estimated elasticities imply that a one percent increase in R&D expenditure can be the result of a two percent increase in past R&D expenditure, of an increase of ninety percentage points of lagged gross profits or of an increase of 0.20 percentage points of the export market share.
Regarding the dummy variables inserted in the two equation, *core-periphery* and *country dummies* do not seems to play a clear role in the case of R&D efforts while *Pavitt dummies* coefficient (we decide to include in our equations the dummies associated to the two most technologically driven Pavitt categories, SB and SS, in order to control for specific trajectories and capabilities of sectors belonging to those categories) are both positive and significant. The interpretation of the coefficients associated to *Pavitt dummies* is straightforward since we can expect that sectors characterized by an intensive use of technological inputs are also those where R&D efforts are relatively higher. Including country dummies in our baseline model do not harm the significance of the estimated coefficients so we can go further analyzing the Innovation equation.

Table 8. The Innovation equation

Dependent Variable: Share of firms carrying out product innovation.

WLS with robust standard errors and weighted data (weights are the numbers of employee).
t-stat in brackets.
* significant at 10%, ** significant at 5%, *** significant at 1%.

	(1) **Baseline Model**	**(2)** **Baseline with Country & Pavitt Dummies**
Lagged R&D expenditure	1.57 [6.23]***	1.60 [6.28]***
Expenditure for Mach. & Equipments	-0.45 [-0.69]	-1.16 [-1.73]*
Final Demand (Rate of Growth)	-0.28 [-0.38]	-0.24 [-0.33]
Demand of int. goods (Rate of Growth)	-0.55 [-2.88]***	-0.47 [-2.49]**
Exports (Rate of Growth)	0.01 [0.70]	0.009 [0.41]
Core dummy	3.99 [1.66]*	
Periphery dummy	-12.87 [-4.63]***	
Science Based dummy	14.73 [5.32]***	14.54 [5.38]***
Supplier specialized dummy	-7.49 [-4.34]**	-8.14 [-4.80]***
Germany dummy		15.52 [3.19]***
Spain dummy		-8.17 [-1.72]*
France dummy		-5.03 [-1.07]
Italy dummy		-1.03 [-0.29]
Netherlands dummy		7.56 [2.40]***
UK dummy		-0.27 [-0.06]
Constant	37.79 [11.14]***	30.04 [6.75]***
N.observations	286	286
R2 (Adj)	0.55	0.57

The results in Tab. 7 show that innovative performances are mainly driven by technological competitiveness strategies. The coefficient associated with past R&D efforts is positive and significant in both the baseline and the country dummy equation. On the contrary the coefficient associated to the process innovation variable *Expenditure for new machineries and equipment* which is a proxy for cost competitiveness strategies is in both cases negative and significant in the country dummy specification. Here demand variables do not seems to have a positive impact on innovation with the exception of the *rate of growth of exports* whose coefficient is always positive although it is not statistically significant. An explanation of the negative sign of demand variables referring to internal demand for consumption and investment could be explained by the lack of dynamism of domestic demand with respect to exports in terms of innovation stimulus. Such a result is in line with the previous findings of Pianta & Bogliacino (2013) where with an analogous specification they found that only exports out of the complete set of demand components are able to explain innovative performances.

Dummy variables seems to play an important role here. In the baseline model, the core dummy is significant and has a positive relation with innovation. In the country dummy specification Germany and Netherlands have a positive and strongly significant role in explaining innovative performances in our sample. Looking at the *technology dummies*, Science Based and Supplier Specialized, the former captures the relative higher propensity to innovate of sectors belonging to that Pavitt Category in both model' specifications. The relevance of dummy variables in this equation is twofold: on one side, *Core*, *Germany* and *Netherlands* dummies begin to delineate the divergent dynamic of the two blocks of countries within the sample, on the other, the presence of those variables is an important robustness check for the our coefficients given the relevance of technological and country specific effects in this equation.

Table 9. The Export Market Share Equation

Dependent Variable: Export Market Share.

WLS with robust standard errors and weighted data (weights are the numbers of employee).
t-stat in brackets.
* significant at 10%, ** significant at 5%, *** significant at 1%.

	(1) **Baseline Model**	**(2)** **Baseline with Country & Pavitt Dummies**
Lagged Product Innovation	0.0015	-0.0004
	[2.88]***	[-0.03]
Expenditure for Mach. & Equipments	0.014	0.01
	[2.41]***	[1.83]*
Unit Labour Cost (Rate of Growth)	-0.005	-0.004
	[-3.39]***	[-3.07]
Domestic Interm. Inputs, low tech (Rate of Growth)	-0.012	-0.12
	[-3.51]***	[-3.80]***
Domestic Interm. Inputs, high tech (Rate of Growth)	-0.004	-0.002
	[-1.43]	[-0.81]
Imported Interm. Inputs, low tech (Rate of Growth)	0.002	0.003
	[1.02]	[1.77]*
Imported Interm. Inputs, high tech (Rate of Growth)	0.015	0.011
	[5.31]***	[3.98]***
Science Based dummy	-0.07	-0.04
	[-3.03]***	[-1.59]
Supplier specialized dummy	-0.011	-0.022
	[-0.11]	[0.11]
Core dummy	0.22	
	[10.12]***	
Periphery dummy	0.07	
	[6.38]***	
Germany dummy		0.31
		[9.96]***
Spain dummy		0.08
		[3.61]***
France dummy		0.12
		[6.04]***
Italy dummy		0.13
		[7.14]***
Netherlands dummy		0.19
		[3.40]***
UK dummy		0.26
		[9.17]***
N.observations	287	287
R2 (Adj)	0.79	0.81

As assumed the ability to obtain new export market shares is determined at the same time by both price and non-price factors. In particular innovation and the *growth of labour cost* are both significant with respectively a positive and a negative impact on the dependent variable. In the baseline model product innovation, proxied by the *share of product innovators*, and process innovation, proxied by the *expenditure for new machineries and equipment*, have both a positive impact on the acquisition of new export market share. Nevertheless, including country dummies in the second specification of the model leads to a loose in significance of product innovation variable. This fact could be explained by the dramatic role of country specificities as determinants of export market share.

Results show that intermediate input mix is also relevant to explain performances of sectors in terms of export market share. Industry export performance is supported by the imports of inputs from high-technology sectors. The use of these inputs, combined with a strategy that would lead to greater technological competitiveness, can ameliorate competitiveness in industries. In particular, in both the specifications imported high tech inputs have a positive and significant effect on export market shares while domestic low tech inputs has a negative impact. This result is in line with the findings of authors who have already analyzed the relation between imported inputs and export performances (Bas and Strauss-Kahn, 2010; Colantone and Crinò, 2014).

The included dummies are all significant and, also in this case, the coefficient associated to Germany has the highest positive impact on the dependent variable than the other country dummy coefficients.

In the next subparagraph the results of the full system estimation and the test for the presence of the core-periphery divide are reported.

5.1 The relationships between R&D, New Products and Export Market Shares

Table 10. The results of the system: the relationships between R&D, New Products and Export Market Shares
Three Stage Least Squares. Standard Errors in brackets, * significant at 10%, ** significant at 5%, *** significant at 1%.

	(1) R&D per employee	(2) Share of Product Innovators	(3) Export Market Share
R&D per employee (First lag)	0.57 [0.61]***	**0.5** **[0.28]*****	
Rate of growth of profits (First Lag)	0.03 [0.01]***		
New Market Objective	0.05 [0.02]**		
Size	10.02 [1.65]***		-0.14 [0.08]*
Export market share	**4.64** **[2.69]*****		
Rate of growth of export		0.93 [0.32]***	
Rate of growth of final consumption		-0.047 [0.06]	
Rate of growth of intermediate demand		-0.49 [0.20]**	
Share of Product Innovators			**0.0034** **[0.0006]*****
New machinery per employee		2.26 [0.70]***	0.028 [0.006]***
Rate of Growth of Unit Labour Cost			-0.006 [0.001]***
Rate of growth of Domestic Interm. Input (low-tech)			-0.0081 [-0.004]*
Rate of growth of Domestic Interm. Input (high-tech)			-0.005 [0.003]
Rate of growth of Imported Interm. Input (low-tech)			0.004 [0.003]
Rate of growth of Imported Interm. Input (high-tech)			0.009

			[0.003] ***
Core dummy	-3.32	28.70	0.13
	[0.87]***	[2.40] ***	[0.02] ***
Periphery dummy	-1.89	15.72	0.03
	[0.43] ***	[10.42] ***	[0.14] **
Science Based dummy	1.78	24.63	-0.12
	[0.85]***	[4.24] ***	[0.02] ***
Supplier Specialized dummy	0.98	15.72	-0.02
	[0.5]**	[1.50]***	[0.02]
Obs	172	172	172
RMSE	2.40	13.14	0.09
Chi-2	870.78	1741.75	1594.93
(p-value)	(0.00)	(0.00)	(0.00)

The results of the system are consistent with the previous version of this model Pianta & Bogliacino (2012, 2013) and the assumed recursive system of relations is detected. In the R&D equation *past R&D* and *past profits* support R&D efforts (1) that are pulled by the presence of a potential market for new products. Moreover, *size* of firms have a positive and significant impact on R&D efforts supporting the "Schumpeter Mark II" perspective. Lagged *export market shares* are also crucial in determining new R&D investments. This result meets our assumption of efforts in R&D devoted mainly to the acquisition or the consolidation of new export market shares.

In the product innovation equation (2), *past R&D* have a positive and significant impact, confirming newly the assumptions of the "Schumpeter mark II" perspective. Demand variables have, as expected, different effects on new products. *export growth* is associated to a higher presence of product innovators, in line with the "learning by exporting" hypothesis (Crespi et al. 2008); a high *growth of household consumption* and *intermediate demand*, conversely, is associated to lower product innovation (a result already detected in the simple OLS estimation); an increase in such components of demand may lower the need to introduce new products, a relationship that is typical of "traditional" industries and services with little R&D, more standard goods and less international openness.

Finally, export market shares (3) are positively explained by *product* and *process innovation* while negatively by the growth of *unit labor cost*. As already detected in the OLS estimation, a growth in *imported intermediate inputs*, in this case both high and low tech, has a positive impact on export performances. The latter results could be due to the knowledge content of high-tech imported inputs on one side while by an international integrated cost competitiveness perspective on the other - the adoption of low cost (and low-tech) inputs from abroad. *Firms size* is negatively related to Export Market Share performances contrarily to what happens in equation (1). This could mainly be related to the greater dynamism of little firms especially in sectors with high technological intensity allowing those firms to gain more easily new international positions.

The variables in bold are the key drivers of our system of feedbacks and self-loops. Coherently with the 3SLS estimation technique, the dependent variables estimated and instrumented at the first steps are then used as regressors in the next steps. Such technique allow us to increase estimation consistency and highlights the role of those three key variables as engines of the proposed recursive system. In order to check the robustness of our estimations, we need to address potential problems linked to a not adequate control for technology push factors. In order to manage this point we also included time dummies in the R&D equation, but the results are unchanged, and the dummies are not significant. Indeed, the use of long differences, industry level data, average rate of change and autoregressive specification is a satisfactory strategy to account for time varying production possibilities frontier.

Once detected this system of feedbacks between R&D, innovation and economic performance variables we can go a step further checking for the existence and the magnitude of two divergent loops affecting the core and the periphery of the EU (with the obvious constraint represented by the limited number of European countries that we had to consider for this analysis due to the lack of data). In order to achieve our objective we used the interaction terms technique. In this sense we are able to estimate the different slope of each variable according to the countries grouping in core and periphery. The interaction model allows different slopes for the constant and for all the variables considered in the model.

Table 11. The results of the system: the relationships between R&D, New Products and Export Market Shares within the Core-Periphery divide
Three Stage Least Squares. Standard Errors in brackets, * significant at 10%, ** significant at 5%, * significant at 1%.**

	(1) R&D per employee	(2) Share of Product Innovators	(3) Export Market Share
R&D per employee (First lag) - CORE	1.17. [0.13]***	**1.85 [0.36]*****	
PERIPHERY	0.58 [0.06]***	**1.45 [0.32]*****	
Rate of growth of profits (First Lag) – CORE	0.01 [0.01]		
PERIPHERY	0.04 [0.01]***		
New Market Objective - CORE	.006 [0.01]		
PERIPHERY	0.07 [0.018]**		
Size - CORE	4.39 [2.23]**		-0.07 [0.16]
PERIPHERY	10.69 [4.91]**		-0.05 [.09]
Export market share – CORE	**6.53 [2.53]****		
PERIPHERY	**4.88 [2.64]***		
Rate of growth of export – CORE		1.77 [0.46]***	
PERIPHERY		-0.64 [0.48]	
Rate of growth of final consumption - CORE		-0.31 [0.21]	
PERIPHERY		-0.04 [0.07]	
Rate of growth of intermediate demand - CORE		-0.89 [0.31]***	
PERIPHERY		-0.30 [0.35]	
Share of Product Innovators - CORE			**.002 [.0005]*****
PERIPHERY			**-0.0004 [0.0006]**
New machinery per employee - CORE		0.50 [0.86]	0.017 [0.007]***
PERIPHERY		-1.90 [1.56]	-0.03 [0.01]
Rate of Growth of Unit Labour Cost - CORE			-0.008 [0.001]***
PERIPHERY			-0.001 [0.002]
Domestic Intermediate Input (low-tech) - CORE			-0.0008 [-0.006]
PERIPHERY			-0.007 [-0.006]
Domestic Interm. Input (high-tech) - CORE			-0.012 [0.003]***
PERIPHERY			0.004 [0.005]
Imported Interm. Input (low-tech) - CORE			0.001 [0.004]
PERIPHERY			0.008 [0.005]
Imported Interm. Input (high-tech) - CORE			0.008 [0.004]**
PERIPHERY			0.003 [0.005]
Science Based dummy	1.63 [0.85]***	23.01 [3.98]***	-0.09 [0.02]***
Supplier Specialized dummy	0.83 [0.5]**	12.02 [1.15]***	-0.03 [0.02]
Obs	172	172	172
RMSE	2.40	13.14	0.09
Chi-2	870.78	1741.75	1594.93
(p-value)	(0.00)	(0.00)	(0.00)

The core periphery divide emerges clearly from the results of our 3SLS system estimation. The introduction of interaction terms modifies our coefficient relatively to their magnitude and significance. In the R&D

equation (1) the *technology push* effect is more than doubled in the core than in the periphery despite it remains significant for both. On the contrary, the *demand pull* effect identified by the *New Market Obj.* CIS variable remains significant only for the periphery. In the Innovation performance equation (2) the positive role of exports as explanatory variable persists only for the core area, as expected. This fact, on one side, confirms the prevalence of exports among the other demand components in determining innovative performances and, on the other, shows how a better performance in terms of exports allows the core to do the same also in terms of innovative outcome.

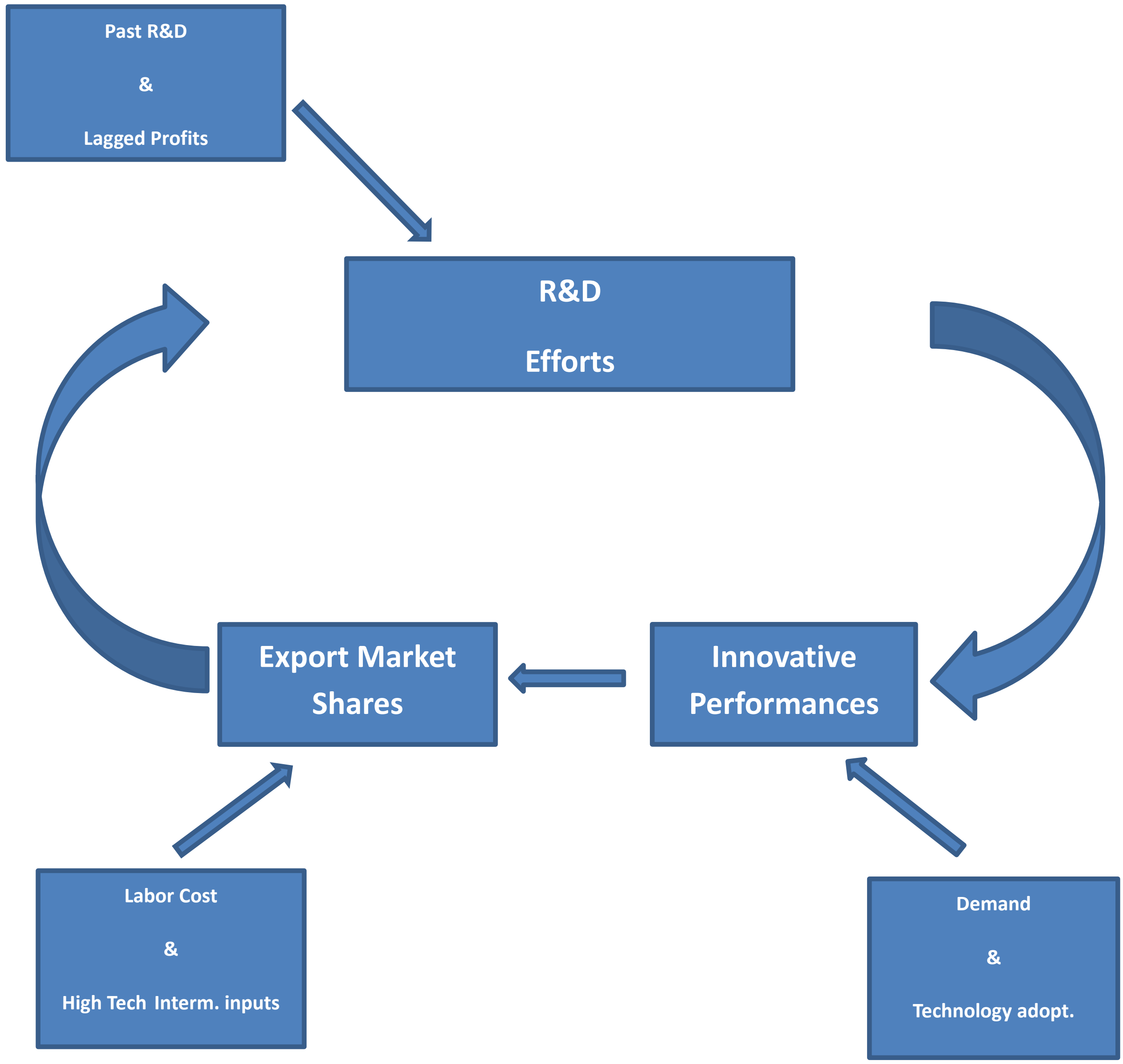
The export market share equation is the one where the cycle of feedback lo breaks-up for the periphery. In fact, the key relationship between *export market share* and the *share of product innovators* no longer holds for the periphery while it remains significant in the core. Also the coefficient associated to the cost competitiveness variable is still positive and significant only for the core. The growth of *unit labor cost* still have a negative impact on export market share but it continues to be significant only for the core.

The variables capturing the average growth in the usage of intermediate inputs maintain magnitude, signs and significance but also in this case only for the core area. Finally, technological dummies are positive and significant in the first and in the second equation while negative in the third one. The latter result could be explained by the fact that even if technology is an important factor determining export performances of industries, country effects or better the core-periphery divide absorbs the major part of the other effects.

6. Conclusions

The results of our model – focusing on the industry level - are capable to account for important dimensions of the interconnected engines of economic change in a Schumpeterian perspective. The results derived from the system of three equation support empirically some of the main elements of evolutionary literature. The following figure depicts the circular and cumulative relationships we have identified.

Figure 1. The circular scheme of relations



First, the cumulative nature of research and knowledge, the demand pull effect of the potential for new products, lagged profits and obtaining new export market shares play a significant role in explaining R&D intensity. Moreover, the size of the firm is important to explain R&D efforts on the supply side.
Regarding product innovation, the cumulative nature of R&D is important on the supply side, while demand factors either stimulate the introduction of new products, in the case of strong export growth, or may delay it when consumption and intermediate demand characterize industries' markets.

In the export market share equation we find a direct effect of product innovation - the importance of which reflects a strategy of technological competitiveness in line with the literature which previously investigated the connection between technology and exports – in addition to significant effects of gains in cost competitiveness – through process innovations introducing new machinery. High tech imported intermediate results also an important and positive factor affecting export market shares. Three improvements on the existing literature emerge from our model and findings.

First we corroborate the evidence provided by Pianta & Bogliacino (2012, 2013) strengthening the reliability of their results through an enlargement of the time span (their analysis was limited up to 2005) and using data form different sources. In this way we are able to recognize that the recursive scheme of relations depicted in Fig. 1 is observable over a wider time span. Furthermore, we enriched the traditional evolutionary literature adding demand factors to explain innovative performances.

Second, we improved the model substituting the profits equation used in Pianta & Bogliacino with the export market shares one, pointing out the fundamental role of international competitiveness among the other performance variables as factors explaining innovative strategies and performances. With respect to the export market share equation we also add some empirical evidence to the recent literature investigating international integration of production with a specific attention to the role of intermediate inputs.

Third, we highlight the presence of two distinct dynamics across the European Union with respect to our cumulative and recursive relations. Introducing the core-periphery interaction terms in our three equation system we recognize a break-up in the circular flow for countries belonging to the periphery consistently with what the descriptive analysis in section 3.1 provides.

This diversity of outcomes from different components of demand may have relevant policy implications, emphasizing the importance of the “virtuous circle” between R&D efforts, innovation in products, technological competitiveness, export growth – that in last decades has been the most dynamics demand component for EU economies - and new export market shares – rather than from a restructuring driven by labour saving new processes. This approach is able to model these complex relationships in an integrated way, with appropriate lags and feedback effects, and to test them empirically. Identifying a break in the virtuous circle for the peripheral area of the EU may serve as an explanation for the observed divergent dynamics in terms of economic performance and, in particular, international competitiveness between the different areas of the Union.

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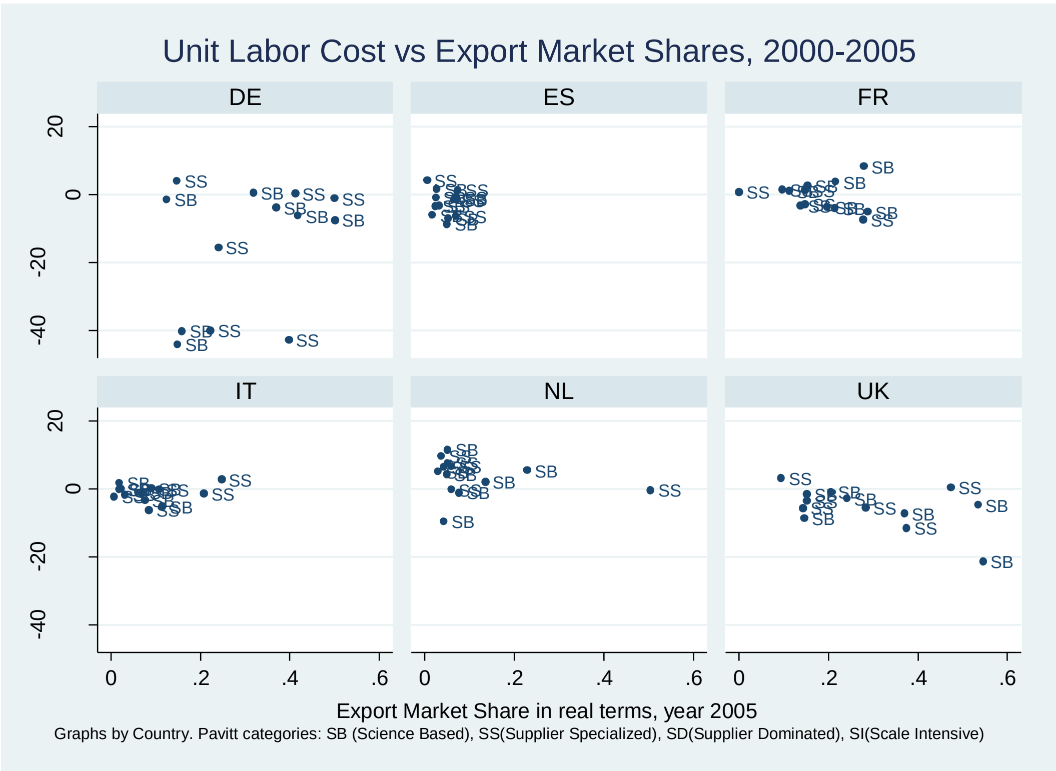
8. Appendix

8.1 Descriptive statistics

The following scatter plot relates labor cost and innovation for the more innovation prone sectors – those belonging to Science Based and Supplier Specialized Pavitt categories - in order to graphically inspect the role of each component of competitiveness. SB and SS are those sectors for whom innovation is considered to be one of the key factors in determining economic performance. It is therefore important to verify the role played by labor costs and innovation for the achievement of export market shares by the various sectors of ache country. Figure 1 presents the trend over the period 2000-2005 for export market share and relative unit labor cost for each of the six countries considering only Science Based and Supplier Specialized sectors.

Figure 2. Unit Labor Cost vs Export Market Shares



Italy and France show an ability to maintain significant export market share despite an increase in labor costs. Core countries, Germany and the UK in particular, seems to have benefited most from the reduction in labor costs even more so if we consider that SB and SS sector are traditionally less sensitive to price factors. The next figure (Fig. 2) shows clearly how in the core EU countries, sectors where the share of product innovators is high are also those detecting a relevant export market share. In the periphery, on the contrary, and especially in Italy and Spain having a lot of product innovators do not seems to guarantee also a high export market share. Finally, Fig. 3 highlights the same relationship as Fig. 2 with respect to process innovation. Also process innovation is remarkable for those sectors in the core characterized by an high export market share. Nevertheless, the only country where the role of process innovation seems to be comparable with the product one is the UK while in Germany product innovations appear to have the highest weight.

Figure 2. Product Innovation vs Export Market Shares

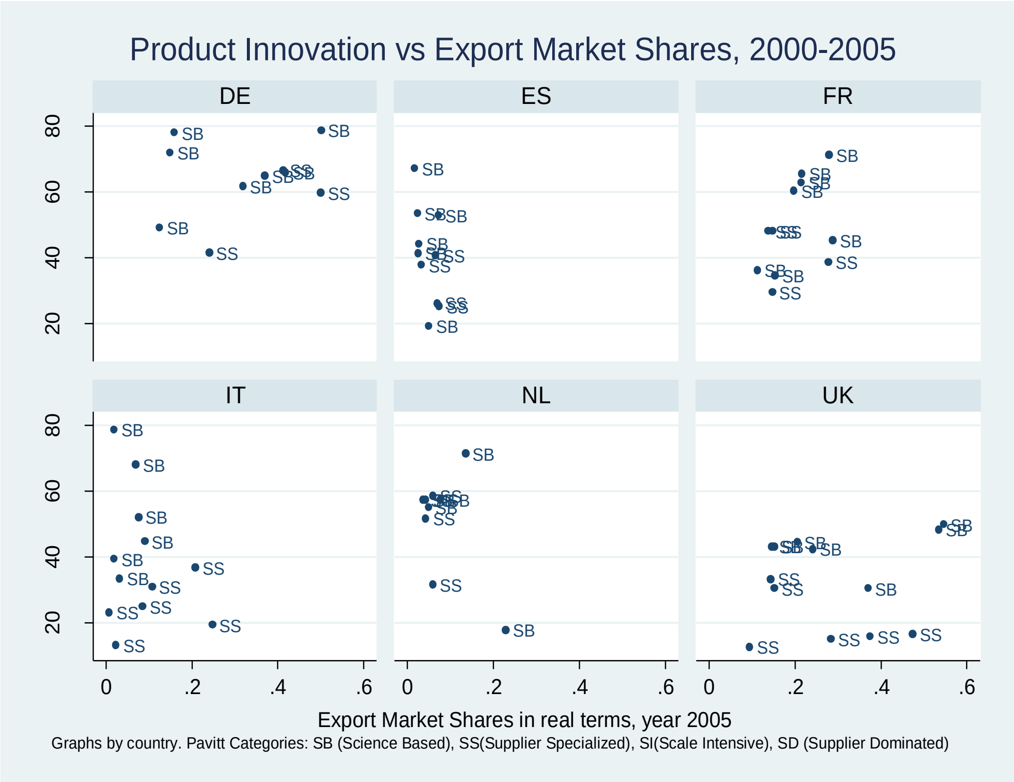
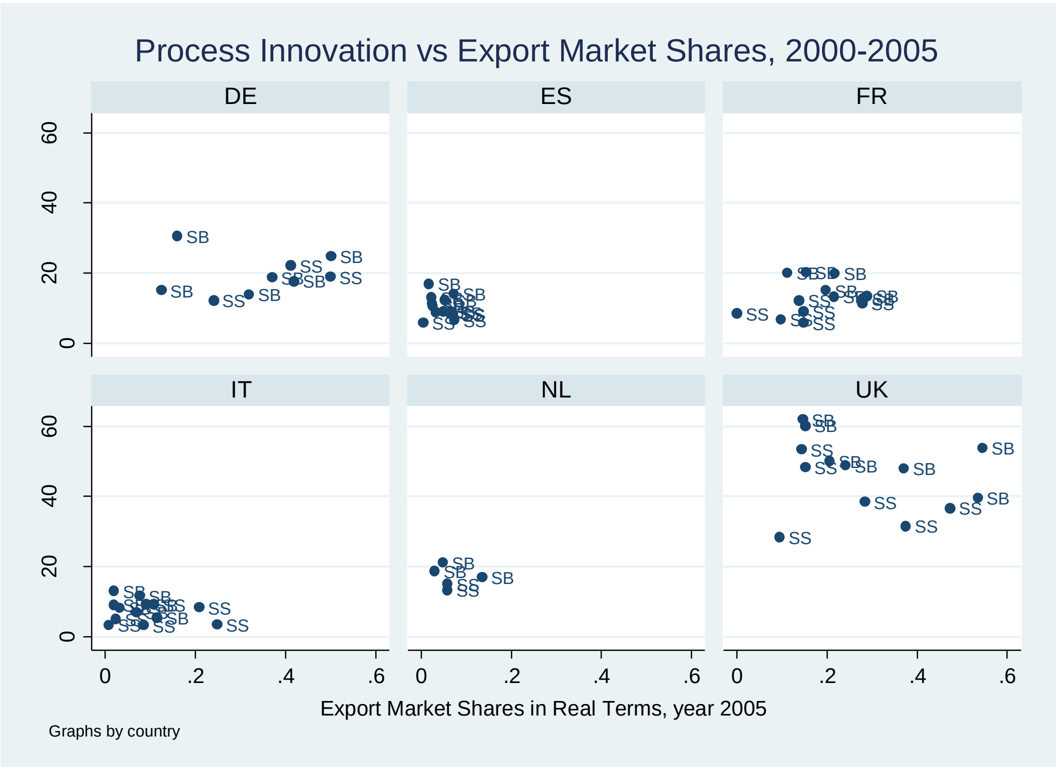


Figure 3. Process Innovation vs Export Market Shares



8.2 Model diagnostics

The standard diagnostic tests are examined here equation by equation. We try to detect the presence of heteroscedasticity and/or multicollinearity. To check for them we respectively use a Breusch-Pagan test and a Variance Inflation Factor (VIF, calculated on the baseline OLS regression).

Table A1. R&D equation

Breusch-Pagan Test	
Chi2(1)	107.30
p-value	0.0009
Multicollinearity	
Average Variance Inflation Factor	1.32

Table A2. Innovation equation

Breusch-Pagan Test	
Chi2(1)	46.76
p-value	0.0000
Multicollinearity	
Average Variance Inflation Factor	1.26

Table A2. Innovation equation

Breusch-Pagan Test	
Chi2(1)	35.92
p-value	0.0000
Multicollinearity	
Average Variance Inflation Factor	2.55

The results are the following ones: we have to estimate robust standard errors since the Breusch-Pagan rejected the null hypothesis of homoscedasticity, explanatory variables are orthogonal to the error term, and multicollinearity is not an issue; usually VIF is considered worrisome if it is higher than four (or higher than ten, according to different sources), and these thresholds are four to ten times higher than the value of our sample statistics. We cannot reject our formulation of WLS with robust standard errors.