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SECTORAL SYSTEMS OR DISTANCE-TO-THE-FRONTIER EFFECTS IN INNOVATION? A COMPARISON OF THREE MEDIUM-TECHNOLOGY SECTORS IN GERMANY, ITALY AND SPAIN

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Abstract

This study analyzes empirically whether the Sectoral Systems of Innovation or the Distance-to-the-Frontier perspective more accurately describe the patterns of innovation in medium-technology sectors in Germany, Italy and Spain. While the Sectoral Systems of Innovation predicts the existence of technology-related similarities in innovative patterns in the same sectors across countries, the Distance-to-the Frontier suggests the existence of important differences related with the level of technological development of each national sector. Using Community Innovation Survey data and applying an econometric strategy specifically devised for innovations survey I am able to test a set of hypotheses directly related with each of the two theories. The results of the econometric analysis show that relevant differences across countries exist with respect to the intensity of R&D activities and the economic impact of different types of innovations, confirming the Distance-to-the-Frontier hypothesis, while great cross-country similarity emerges among the sources of knowledge used to develop new innovations, in line with the Sectoral Systems of Innovation framework. The results highlight the importance to take into account both frameworks for a useful analysis of innovation within sectors.

Keywords: Sectoral Systems of innovation, Distance-to-the-Frontier, R&D and productivity

Jel code: L60, O31

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1. Introduction

Firms active in the same sectors are likely to use similar technologies and hence adopt also similar innovative behaviors. However together with technological characteristics also competitive conditions influence innovative behavior. For this reason firms active in the same sector but in different countries, under different competitive conditions, often display very heterogeneous innovation strategies. Two distinct streams of literature have analyzed the determinants of innovation behavior within sectors and have provided very different predictions about the existence of similarities or differences in technological patterns in the same sectors across countries.

According to the literature related with the Technological Regimes and the Sectoral Systems of Innovation frameworks (henceforth SSI) firms in the same sector are likely to use a similar knowledge-base to produce similar goods. Since the specific knowledge-base and opportunity conditions influence the type of innovations being introduced, it is expected that also similar innovative behaviors will be observed among firms active in the same sector. One of the outcomes of this theoretical framework hence is the prediction that within-sector similarities in innovative behavior will exist across countries (Malerba, Orsenigo, 1996, 1997).

Conversely the Distance-to-the-Frontier literature (henceforth DTF) identifies the distance to the world technology frontier as the main factor which influences the strategic behavior of innovating firms (Gerschenkron, 1962). This literature suggests that innovation will differ according to the level of technological development that a country or a national sector has reached. When a national sector is a leading sector in the international competition, the major efforts of firms will be devoted to "shift" the frontier. On the contrary, in national sectors that are lagging behind or are still catching up, these efforts will be directed towards the adoption of already existing technologies. According to this perspective substantial within-sector differences in innovative activity will exist across countries, since firms will follow innovation strategies that are more profitable only locally.

In this paper I address the following question: which of the two perspectives introduced above is better able to describe innovative patterns in medium-technology sectors in Germany, Italy and Spain? Following the two streams of literature presented I put forward a set of hypotheses in order to empirically test whether cross-country differences or similarities exist in the innovation-oriented features of firms active in these sectors. In order to test them I implement an econometric procedure devised by Griffith, Huergo, Mairesse and Peters (2006) to allow cross-country comparisons in innovation behavior, addressing the usual endogeneity problems that arise in innovation surveys. The paper contributes to the existing literature by showing how this methodology can be usefully adapted to test empirically the relevance of key implications of the SSI and DTF literatures.

Comparing these two streams of literature is useful because it shows how the two theoretical frameworks can be implemented to provide a more complete picture of the innovative process within sectors. The comparison of these two theoretical perspectives seems also particularly relevant for the implementation of sector-based industrial policies, especially at the European level. Indeed, if within-sector similarities are the most relevant feature of innovation, a European innovation policy should strongly rely on the transfer of best-practices across national sectors. If on the contrary innovation activities depend crucially on the relative distance to the technological frontier, public policies should put more emphasis on the fine-tuning of each intervention, according to the specific economic environment of each country.

The ideal way to address this research question empirically is to analyze data on innovation activities of firms active in the same sector in different countries and check whether similarities or differences in innovative behaviors emerge. In the paper I use data from the Harmonized Community Innovation Survey 4 (CIS4), which is the most appropriate source to compare data on firms' innovation activities at the European level. I focus my analysis on three medium-low technology sectors in Germany, Italy and Spain: the Rubber and Plastics Sector, Other Non-Metallic Minerals, and Fabricated Metal Products. The three countries are chosen because although they all are advanced European economies, they display substantial differences in their levels of economic development: therefore they seem an appropriate sample to test the relevance of the two theoretical frameworks. The analysis is performed on a set of three 2-digit sectors instead than on only one sector in order to have a sufficient number of observations for each national sample. As a consequence the three specific sectors are chosen in order to provide the highest possible degree of homogeneity among them. Indeed they are usually grouped together in many industrial taxonomies, because of their similar economic and technological features. Medium-low tech sectors are chosen because firms in these sectors are more close to an "average" European firm with respect to high-tech companies: the latter indeed account for quite little shares of value added and employment in European economies.

The results of the econometric analysis show that relevant differences across countries exist with respect to the intensity of R&D activities and the economic impact of different types of innovations, confirming the Distance-to-the-Frontier hypothesis, while great cross-country similarity emerge in the sources of knowledge used for innovation outputs, in line with the Sectoral Systems of Innovation framework. The results highlight the importance of taking into account both frameworks for a useful analysis of innovation within sectors.

The paper is organized as follows: Section 2 reviews the two streams of literature and introduces some hypotheses about the existence of within-sector similarities or differences across countries in innovation behaviors, Section 3 explains the methodology used for the empirical analysis and the data used, Section 4 describes the results of the econometric analysis and finally Section 5 is dedicated to conclusions and policy implications.

2. Background literature and hypotheses

The hypothesis concerning the existence of within-sector similarities across countries in innovative activities has been developed within the theoretical framework of the Technological Regimes (Nelson, Winter, 1982) and further refined by the Sectoral Systems of Innovation (SSI) literature (Malerba, 2004). According to this literature the existence of these similarities depends crucially on the role of specific features of knowledge, such as opportunity, appropriability and cumulativeness conditions, together with the characteristics of the relevant knowledge-base (Sutton, 1996; Breschi, Malerba, Orsenigo, 2000). These features are considered as fundamental constraints of technological change and they also have important effects on the competitive environment that prevails within a sector. Following this perspective, in their early contributions Malerba and Orsenigo (1996, 1997) have linked the characteristics of knowledge to the prevalence of some stylized types of competition, identified with the well-known concept of Schumpeter Mark I and Mark II patterns. Building on the evidence coming mainly from patent data they have put forward the hypothesis that the conditions that affect learning and knowledge accumulation would determine similar innovative behaviors within the same sectors across countries. Their results confirmed such patterns, showing how, within the same sectors in different countries, both the indicators concerning market structures and those concerning knowledge features displayed similar values.

Over time the SSI framework has evolved, including a larger set of factors that affect the evolution of sectors and of their technology: in more recent works Malerba (2005) highlighted the importance of institutions, demand factors, the variety of economic actors and the networks that exist between them. As a consequence the SSI literature has gradually included some of the features of the National Systems of Innovation framework (Freeman, 1987; Lundvall, 1993), in which idiosyncratic national characteristics are identified as crucial elements of the innovative performances of countries. Recent empirical contributions have shown indeed the importance of country-specific features in order to explain the innovation patterns of national sectors both in developed (Castellacci, 2007, 2009) and in developing countries (Jung, Lee, 2010; Malerba, Mani, 2009; Malerba, Nelson, 2011). Even if these recent contributions have introduced the possibility to observe relevant cross-country differences in innovative strategies in the same sector, they have attributed them mainly to the effect of different institutions and networks between economic actors. These works instead did not explore in depth the existence of specific competitive incentives for firms to differentiate their innovative activities according to the economic environment in which they are embedded.

Such a perspective has been instead central in many related contributions that I will refer to as the Distance-to-the-Frontier (DTF) literature, even if this stream of literature may not be considered a proper fully-formed theoretical framework, such as the SSI. This literature has its roots in the studies on development and technological capabilities and specifically in the seminal work of Gerschenkron (1962) and Atkinson and Stiglitz (1969). In these works it has been argued that innovation activities should be adapted to the specific level of technological development of a national sector. In the original formulation Gerschenkron (1962) argued that the closer is a country or a sector from the world technology frontier and the more it should rely on brand new research and innovation in order to be able to "shift" the frontier itself. On the contrary firms belonging to sectors which are lagging behind or catching up with respect to the world technological frontier should invest in the adoption of technologies produced elsewhere. More recently Acemoglu, Aghion and Zilibotti (2006) have adopted and renewed this perspective by including in the framework also the level of selection of firms and managers as a further element which influences the choice of different innovative strategies: selection will be lower in sectors which are far from the frontier, where adoption is more frequent, while when a sector is close to the frontier only high-skilled managers able to actually innovate will be capable to bring their firms to economic success. It is hence more likely to observe truly innovative and R&D-based firms in technologically advanced national sectors rather than in backward sectors.

At the empirical level Acemoglu, Aghion and Zilibotti (2006), using sector-aggregated data for a bunch of OECD countries, have shown the existence of a positive and statistically significant relation between the proximity to the frontier and the level of R&D intensity. Other studies have provided evidence on the relevance of the DTF hypothesis. Kneller and Stevens (2006), using a sample of nine manufacturing industries in twelve OECD countries found that R&D is very effective for the creation of new knowledge able to shift the frontier in technologically advanced industries. Also Madsen *et al*. (2010) found that among OECD countries R&D affects positively the growth of aggregate total factor productivity through innovation activities, while in developing countries R&D is more effective when used to build absorptive capacity oriented towards imitative strategies. Also at the firm level there have been some attempts to verify the relevance of the distance-to-the-frontier approach: using microdata from the Community Innovation Survey Hölz and Friesenbichler (2010) showed that R&D-based innovative strategies have a relevant role only for firms active in countries close to the technological frontier. Coad and Rao (2010), implementing quantile regressions, show that the stock of R&D has a positive impact on the economic performances of firms, but such impact increases and becomes significant only for firms closer to the frontier. Blundell, Griffith and Van Reenen (1999) find that innovative activities have a higher impact on market value for firms with a higher market share. It seems hence that R&D-based innovative behavior is a viable solution only for firms which actually are on the technological frontier, while the same is not true for less competitive firms.

Summing up the DTF literature stresses the fact that firms in the same sector in different countries will be induced to adopt different innovative strategies not only because of the different institutional setting, but because it might be more profitable for them, given their competitive environment.

Drawing on these two streams of literature presented above it is possible to put forward a set of testable hypotheses about the patterns of technological change, in which the two theories provide divergent predictions.

Hypothesis 1: the R&D intensity

According to the SSI literature the specific type of knowledge base and the features of knowledge are the main factors that determine the amount of investments in R&D in a sector (Malerba, Orsenigo, 1997). Hence I expect that the level of investments in R&D in a specific sector will be broadly the same across-countries. On the contrary the DTF literature stresses that an R&D-based type of innovation is more profitable in advanced countries, while in backward countries investment-based strategies should be adopted (Acemoglu, Aghion, Zillibotti, 2006). It is possible then to put forward two divergent hypotheses about the level of investments in R&D by firms in the same sector in different countries:

H1-SSI: Firms active in the same sector in different countries will display similar levels of investments in R&D, according to the specific type of knowledge-base used in that sector.

H1-DTF: Firms active in the same sector in different countries will display different levels of investments in R&D, according to the level of technological development of their national sector: the closer the distance to the frontier the higher will be the R&D intensity.

Hypothesis 2: the sources of innovation

According to Malerba (2002) the sources of technological opportunities differ markedly among sectors. Opportunity conditions are strictly related to the type of knowledge-base used in a sector and they define the type of inputs that are used for the development of innovations. In some sectors the main source of relevant knowledge is the university, in other sectors these are clients or suppliers. Since opportunity conditions depend on the type of knowledge used the SSI literature suggests that the main sources of information for innovative activities will be broadly the same in the same sectors across countries. On the contrary the DTF literature stresses the fact that when firms are closer to the technology frontier they will use their internal competencies (accumulated through R&D activities) to introduce brand new innovations (Kneller Stevens, 2006), while firms in backward countries will rather take advantage of external sources of innovation, such as their competitors, or their suppliers, which provide them with new machinery (Acemoglu Aghion Zilibotti, 2006; Antonelli, Fassio, 2011).

H2 SSI: Firms active in the same sector in different countries will use similar sources to introduce innovations, according to the opportunity conditions of that specific sector.

H2 SSI: Firms active in the same sector in different countries will prevalently use internal R&D-based sources of knowledge to introduce new innovations if they are in advanced sectors, while they will rely more on competitors and on suppliers if they are in backward sectors.

Hypothesis 3: the economic impact of innovation

The SSI highlights the fact that similar opportunities, appropriability conditions and types of knowledge used will lead to similar competitive structures (Schumpeter Mark I and Mark II) in different countries (Malerba, Orsenigo, 1997), hence in the same sectors the economic impact of each type of innovation should be similar. Conversely the DTF literature highlights the importance of brand new innovation only when there is the need to actually shift the frontier, while in backward countries imitation can be a suitable way to do innovation.

H3 SSI: Firms active in the same sector in different countries will benefit in the same way from the introduction of a specific type of innovation

H3 DTF: Firms active in the same sector in different countries will benefit differently from the introduction of a specific type of innovation, according to the level of technological development of the sector they are active in.

3. Empirical Strategy

In order to test empirically the different hypotheses that proceed from the SSI and DTF streams of literature the ideal way is to analyze data on innovation activities of firms active in the same sector in different countries and check which of the hypotheses explain better the observed patterns of technological change among firms. The best source of data on firm level innovation activities that allows for comparisons across countries at the European level is the Harmonized Community Innovation Survey: in this paper the fourth wave of the survey – the CIS4 – relative to the period 2002-2004, will be used.

I compare firms active in the same sectors in three large European countries such as Germany, Italy and Spain. This choice is motivated by the fact that these countries are advanced capitalistic economies, of broadly comparable size, and they are members of a highly integrated monetary union. One should hence observe very similar behaviors of German, Italian and Spanish firms within the same sectors. At the same time, as the recent European crises underlined, these countries display also a substantial degree of heterogeneity in their levels of competitiveness and technological development. While Germany is a very competitive and innovation-based economy with great export orientation, Italy and Spain, which are more specialized in low-tech activities, display lower performances in innovation activities (Innovation Union Scoreboard 2013). These differences suggest that also relevant differences might exist among these countries in the way firms do innovation, even within the same sectors. The three countries then are especially suited for the sake of my analysis, since there are reasons to suggest that both the SSI and the DTF framework could explain the observed innovation patterns.

The sectors chosen for the analysis are three mid-low tech sectors: the Rubber and Plastics Sector, Other Non-Metallic Minerals, and Fabricated Metal Products. Instead than focusing the analysis on only one sector three similar sectors were aggregated: this was done in order to have a sufficient number of observations in the CIS- data for the econometric analysis in each national sample. Indeed a typical trade-off emerges here: one can choose to limit the analysis to a very specific sector, running the risk to have less robust econometric results, or he can choose to aggregate together separated but homogenous sectors in order to obtain more reliable estimates. In this case I preferred the second strategy and I hence chose a very homogeneous set of mid-low tech sectors: indeed these three sectors are grouped together both by the OECD R&D-based classification (Hatzichronoglou, 1997) as mid–low tech sectors and by the Pavitt classification, as Scale Intensive sectors (Pavitt, 1984). They hence display a similar degree of formalization of the knowledge used (the OECD classification is based on the aggregate share of R&D expenditures on value added) and similar ways through which the innovative process is implemented.

Medium-low tech sectors are chosen because firms in these sectors are more representative of an average European firm than high-tech companies, which account for quite little shares of value added and employment in European economies. Moreover also low-tech sectors are not well-suited for the aim of this study, since innovative activity is not always a crucial element of the strategies of firms belonging to such sectors. Mid-tech sectors can better describe some sort of “average” innovative firm.

Finally in order to understand what are the determinants of innovation activity among firms in the same sectors and what are the effects of innovation on the firms’ economic performances I adapt an econometric strategy introduced by Griffith, Huergo Mairesse and Peters and (2006). The advantage of this methodology is that it allows to identify the causal links between innovation inputs, innovation outputs and economic performances by addressing the usual endogeneity problems that affect innovation surveys. Moreover it allows to easily compare CIS-based innovation data for different countries.

3.1. The mid-low tech sectors in Germany, Italy and Spain

The choice of the specific sectors is legitimate only if the three countries exhibit similar patterns of specializations in these specific sectors, otherwise I would run the risk of comparing sectors that are central in the industrial specialization of one country and of negligible importance in another country. Using OECD-STAN data at the industry level in Figures (1) and (2) I plot some aggregate statistics of the sectors under analysis in 2002 (the CIS 4 survey refers to 2002-2004). In Figure (1) the shares of the value added of each of these sectors on total manufacturing show a very homogeneous framework across countries: in 2002 the overall share of value added on total manufacturing of these sectors was bounded between 17% -in Germany- and 24% -in Italy. The results in Figure (2) with the shares of employment show the same picture. It seems clear that there are very homogenous patterns of specialization among the three countries in these three sectors and that these sectors contribute for a large part (almost one fourth) to the overall value added and employment of manufacturing. It is important to note that here I am not controlling for the level of internationalization of these sectors across countries. Even if this topic is out of the focus of this work it must be acknowledged that the innovative patterns observed among firms of each sector might be affected also by their participation to global networks of production: this should be considered as a possible limitation of this study.

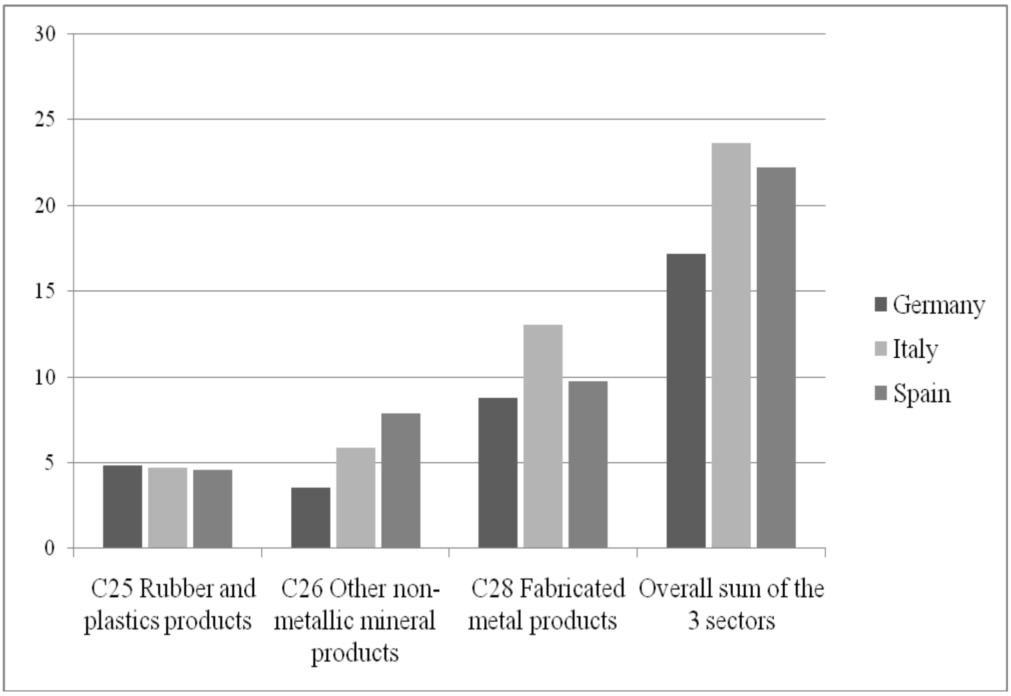
Then it is necessary to check whether substantial differences exist in the levels of productivity of the sectors across the three countries, to understand which countries are closer to the technological frontier. In Figure (3) instead I plot the time-series of the (log of) labour productivity[2] of the three sectors in the three countries, in order to provide a measure of the different levels of competitiveness and technological development. The figure highlights the lower levels of productivity of Spanish sectors, especially when compared to the German ones, while Italian productivity is broadly in the middle between the Spanish and the German one. The levels of German productivity in the time span considered are between 18% and 40% higher than Spanish levels and they are from 2% to 19% higher than the Italian levels.

These simple aggregate statistics show on the one hand that the sectors I am analyzing have roughly the same weight and importance among the three selected countries. On the other hand these sectors are also well suited for my analysis because they display a substantial heterogeneity in terms of overall efficiency and productivity: German and Italian sectors display higher levels of efficiency and are hence closer to the technological frontier with respect to Spanish sectors.

Summing up these sectors are similar enough to allow for the presence of within sector similarities across countries in innovative activity, but at the same time they show some inter-country degree of heterogeneity that might also allow for the presence of differences in the way innovation is implemented, in line with the DTF literature.

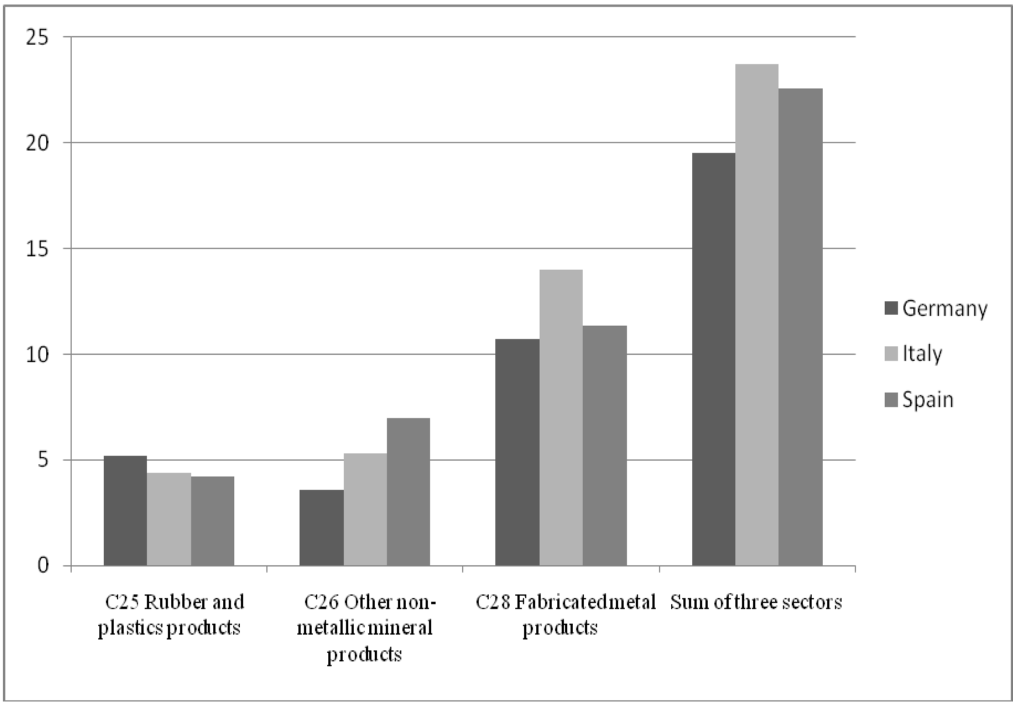
[2] For each sector labour productivity is computed taking the log of the ratio of added value in constant terms over employment (measured as the number of person engaged in a specific sector).

Figure 1. Share (%) of sectoral value added over total manufacturing in 2002



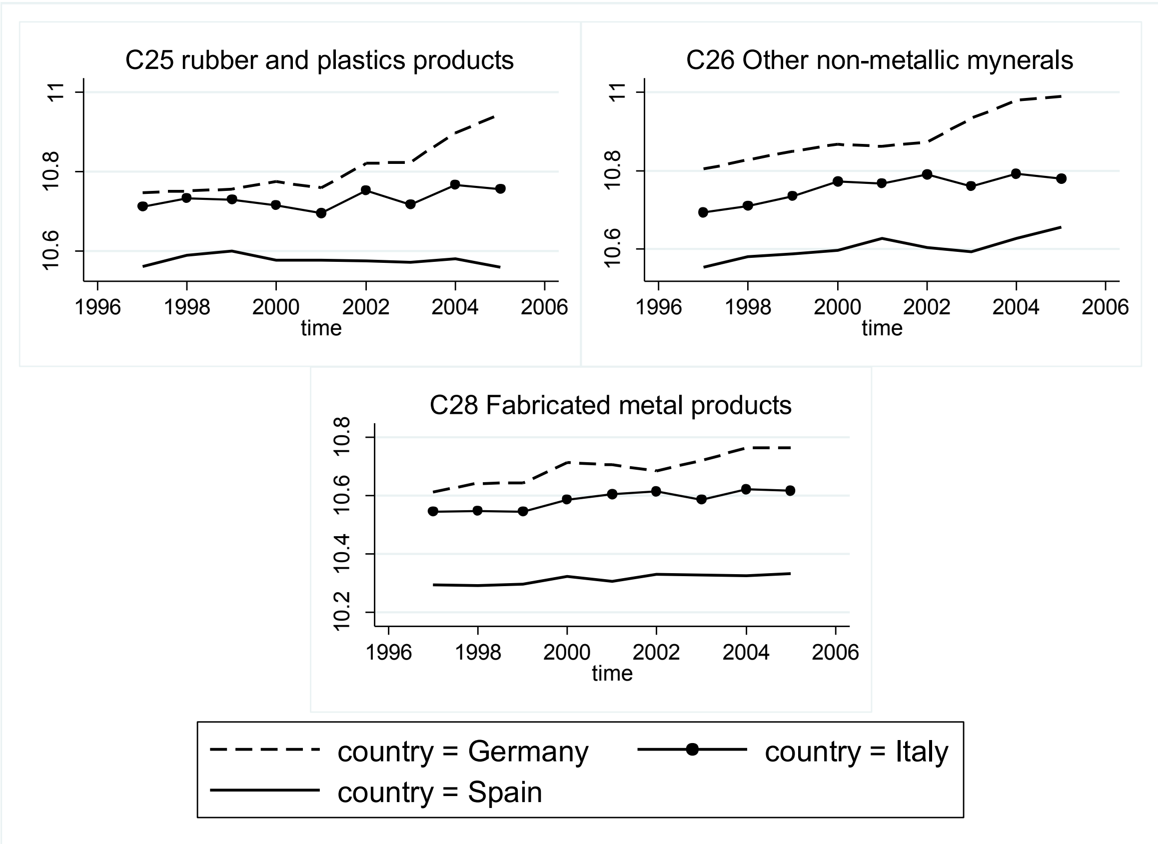
Source: OECD STAN (2013)

Figure 2. Share (%) of sectoral employment over total manufacturing in 2002



Source: OECD STAN (2013)

Figure 3. Dynamics of (log) labour productivity in the period 1998-2006



Source: OECD STAN (2013)

3.2. The model

In order to test the hypotheses presented in Section 2 I adapt the econometric strategy introduced by Griffith, Huergo, Mairesse and Peters (2006)[3], which is specifically suited for my analysis because it allows to identify the determinants of innovation activities, the sources of knowledge for innovation and the economic impact of different types of innovations. Differently from Griffith, Huergo, Mairesse and Peters (2006) here I apply this procedure to a limited set of sectors and not to all manufacturing firms. The main intuition behind the estimation procedure is to use a three stage sequential model in which three equations explain the innovative process and its effects on the output of firms. A first equation controls for the determinants of the decision to invest in innovative R&D activity. The second equation measures the effect of different innovation inputs on the introduction of heterogeneous kinds of innovative outputs. Finally the third equation measures the effect of these innovative outputs on firms' economic performances. The reason behind this sequential approach lies in the cross-sectional nature of the data: since unobserved heterogeneity is likely to affect both the decisions concerning the levels of inputs and outputs in the equations, instrumenting the endogenous regressors will allow to obtain unbiased estimates.

Hypothesis 1: the R&D intensity

The first equation is aimed at identifying the main determinants of R&D intensity, measured by the expenditure in internal and external R&D, normalized by the turnover.[4] Here I am particularly interested in the elasticity of R&D expenditures with respect to the size of firms. A higher elasticity will indicate a higher propensity to invest in R&D in the different national samples: according to the SSI this should be equal among countries, on the contrary the DTF literature suggests a higher propensity towards these kind of investments in more technologically advanced countries.

Since in the CIS4 sample firms are asked about their R&D expenditures only if they declare to have introduced product innovation, I need to control for selection bias when estimating the R&D equation. I estimate a Tobit Type II model (Anemiya, 1984) with a selection variable in

[3] The econometric strategy used by Griffith, Huergo, Mairesse and Peters (2006) on its turn builds on the seminal paper by Crepon, Duguet and Mairesse (1998).

[4] In order to have such variable (a share bounded between 0 and 1) normally distributed I take the logarithm of the ratio of R&D expenditures to sales.

which *RD* is a dichotomous variable that takes value 1 if a firm declares to have had a continuous engagement in R&D activities and 0 otherwise. I associate to *RD* a latent variable *rd** such that:

$$RD_i = \begin{cases} 1 & if \quad rd_i^* = z_i'\gamma + e_i > c \\ 0 & if \quad rd_i^* = z_i'\gamma + e_i \leq c \end{cases} \qquad (1)$$

Finally the actual R&D intensity, measured by (the log of) R&D expenditures over sales and denoted by *r*, is related to another latent variable *r** such that: [5]

$$r_i = \begin{cases} r_i^* = x_i'\beta + \varepsilon_i & if \quad RD = 1 \\ 0 & \text{otherwise} \end{cases} \qquad (2)$$

In equation (2) the main variable of interest is the elasticity of R&D with respect to size, measured by firms' sales in 2002, together with other controls such as belonging to a group, export status, the use of intellectual property rights and sector of activity.

Hypothesis 2: The sources of innovation

In the next step I model an equation for the introduction of different innovations. I consider three kinds of innovative output: product innovations new to the market, product innovations new to the firm (henceforth labeled "adoption") and process innovations. Here I am specifically interested in testing whether, according to the DTF theory, the sources of innovative outputs differ among the three country or they are broadly similar, as predicted by the SSI literature. Equation (3) identifies the determinants of the different kinds of innovation outputs. Among other control variables I use the predicted values of the latent innovative effort r_i^* that I obtained from equation (2). In this way I instrument the R&D variable, which is likely to be endogenous to the results of innovation output. The innovation equations are:

$$k_i = \hat{r}_i^*\alpha + x_i'\delta + v_i \qquad (3)$$

[5] As in Griffith Huergo, Mairesse and Peters (2006) I exploit the possibility to use the whole sample of firms, not only those engaged in R&D activities: the presence of R&D expenditures, in fact, is not considered to be the only possible outcome of an innovative effort, especially in mid-low tech sectors where knowledge is not strongly codified (Santamaria, Nieto, Barge-Gil, 2009).

In equation (3) k is a dichotomous variable which is equal to 1 if a firm introduced an innovation. I have 3 different equations in which the dependent variable is respectively brand new product innovation, product adoption and process innovation. $\hat{r}_i^*$ is the predicted level of R&D intensity from equation (1) and x_i is the set of possible sources of information for innovative activity, together with other control variables. I estimate these innovation equations as three separate probit equations by maximum likelihood.

Hypothesis 3: the economic impact of innovation

In the last step I estimate a production function in which the dependent variable is the log of turnover. Here I want to estimate the impact of the different types of innovation outputs on the economic performances of firms: specifically I am interested in the coefficients of brand new product innovation and product adoption, since, according to the DTF framework, the former should be higher in advanced countries and the latter should be more important in laggard countries. I use the predicted values of brand new product innovation, of product adoption and of process innovation, together with other controls for size and invenstment intensity. The use of the predicted values for the different kinds of innovation output allows to contrast the possible endogeneity of such variables, for the same reasons of equation (3). The production function is estimated with OLS and is the following:

$$y_i = a + \sum_j \hat{k}_{ij}^{'}\theta_{1j} + c_i^{'}\theta_2 + l_i^{'}\theta_3 + x_i^{'}\beta + u_i \qquad \text{with} \qquad j = 1,\ldots,3 \qquad (4)$$

Where y_i is the log of turnover, $\hat{k}_{ij}$ are the predicted probabilities of the realization of each of the three innovation outputs alone, c_i is (the log of) physical capital, l_i are the size dummies for employment, x_i is a set of control variables that account for country and sector effects.

3.3. The CIS data

The firm-level data used in this paper is the Harmonized Community Innovation Survey 4 (2002-2004). The CIS4 was conducted in 2004 and provides information for the period 2002–

2004. The data used have been delivered by Eurostat in micro-aggregated form for reasons of statistical confidentiality.[6]

I built three distinct databases for each of the countries: in each national database I included all the firms who responded to the survey and belonged to the three mid-low tech sectors selected: after some necessary cleaning procedure[7] the samples consisted of respectively 526, 1852 and 2126 firms. The different sizes of the national samples are due to the fact that in Germany the survey is not compulsory and hence is answered by a fewer number of firms: even if CIS surveys are designed to be representative of the population of firms of each country, the different size of the German with respect to the Italian and Spanish sample should be considered as a possible limitation of this study. In Table (1) are reported some descriptive statistics concerning the sectoral composition of the dataset and the means of each of the variables used. As can be easily seen the sectoral composition is very similar in the three datasets, with a larger number of firms belonging to the Fabricated Metal Products sector in all of the samples.

[6] As Eurostat (1999) and Mairesse and Mohnen (2001) have shown, such a procedure allows to work with error terms which, for large enough samples, are not a source of bias in the estimation of linear regression models. Moreover Mairesse and Mohnen (2001) have shown, by comparing results using raw data and micro-aggregated ones for the French CIS2 questionnaire, that also non-linear models as the ones used in this paper are not sensitive to the micro-aggregation anonymisation. In the data used in this paper the only variables which were micro-aggregated were: turnover in 2004, expenditure in Research and Development and expenditure in acquisition of machinery.

[7] The original datasets included 534 German firms, 1867 Italian firms and 2320 Spanish firms. I followed a procedure similar to that implemented by Hall and Mairesse (1995): I removed any observations for which turnover in 2002 or in 2004 was zero, I also eliminated any observations for which the growth rate of turnover was less than minus 90% or greater than 300%. Finally I erased from the dataset firms for which the ratio between total R&D expenditures and turnover was higher than 80%: the total number of erased observation was 217. In order to check whether these choices affect the overall results I also implemented a Grubb test on the intensity of R&D, on turnover in 2002 and 2004 and on the growth of turnover between 2002 and 2004. The results of the Grubb test led to a smaller number of outliers identified (93 instead than 217), leaving the overall econometric results completely unaffected. Given these results I decided to keep the more "conservative" strategy proposed by Hall and Mairesse (1995).

Table 1. Descriptive statistics of the variables in the three samples.

Variables	Germany				Italy				Spain			
Sectoral composition												
C25 Rubber and Plastic products	146				320				484			
C26 Other non Metallic Minerals	90				509				709			
C28 Fabricated Metal Products	290				1,023				933			
	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max
Innovation variables												
Number of firms with no R&D	249				1463				1400			
R&D intensity	0.013	0.030	0	0.352	0.004	0.015	0	0.347	0.008	0.032	0	0.689
Product innovation new to the market	0.319	0.467	0	1	0.117	0.322	0	1	0.154	0.361	0	1
Product innovation new to the firm	0.481	0.500	0	1	0.134	0.341	0	1	0.238	0.426	0	1
Process innovation	0.356	0.479	0	1	0.271	0.444	0	1	0.325	0.468	0	1
Important sources of information												
Internal sources within the enterprise or group	0.418	0.494	0	1	0.133	0.340	0	1	0.251	0.434	0	1
Suppliers	0.169	0.375	0	1	0.098	0.297	0	1	0.124	0.329	0	1
Clients	0.319	0.467	0	1	0.062	0.241	0	1	0.115	0.319	0	1
Competitors	0.122	0.327	0	1	0.024	0.152	0	1	0.055	0.227	0	1
University	0.044	0.205	0	1	0.006	0.080	0	1	0.033	0.178	0	1
Trade fair and conferences	0.110	0.314	0	1	0.041	0.198	0	1	0.055	0.227	0	1
Other firms' controls												
Turnover in 2004 (in logs)	16.100	1.769	11.871	21.370	15.233	1.410	11.794	20.793	15.417	1.443	11.419	21.411
Investment Intensity	0.015	0.037	0	0.375	0.016	0.055	0	0.780	0.009	0.042	0	0.640
Belonging to a group	0.606	0.489	0	1	0.187	0.390	0	1	0.231	0.422	0	1
International markets	0.625	0.484	0	1	0.490	0.500	0	1	0.563	0.496	0	1
Formal protection	0.312	0.464	0	1	0.110	0.312	0	1	0.124	0.329	0	1
Local funding	0.118	0.323	0	1	0.111	0.315	0	1	0.163	0.369	0	1
National funding	0.093	0.291	0	1	0.075	0.264	0	1	0.103	0.304	0	1
European funding	0.084	0.386	0	1	0.022	0.183	0	1	0.033	0.232	0	1
Employment size												
less than 50	0.399	0.490	0	1	0.674	0.469	0	1	0.579	0.494	0	1
50 -249	0.365	0.482	0	1	0.262	0.440	0	1	0.348	0.476	0	1
more than 250	0.236	0.425	0	1	0.063	0.243	0	1	0.073	0.261	0	1
Total observations	526				1852				2126			

Source: Eurostat's CIS 4 data (2002-2004)

In Table (1) I also report the mean value of the variables used in our estimations. I hence introduce the three kinds of innovative strategies that I decided to analyze: new to the market product innovation (brand new innovation), new to the firm product innovation (adoption/imitation) and process innovation. Among Italian and Spanish firms the main type of innovation is process innovation, while in Germany product innovation (of both kind: new to the firm and new to the market) is more central in firms' strategies. The average size of the firms in the three databases is comparatively larger in Germany than in Spain and Italy. Italy in particular has the higher percentage of small firms (less than 50 employees), in line with the well-known prevalence of small and medium enterprises in the Italian productive system.

As for the important sources of information for innovation while in Germany clients are the second most important source of information for firms after the firm itself, in Spain and Italy suppliers appear to be more important than clients for the purpose of innovation activities. Moreover professional conferences, trade fairs and meetings are more important than universities and other higher education institutes. More than 60% of the surveyed German firms belong to a group, while in Italy and Spain the percentage is much lower. Finally Germany displays a higher propensity to export, as shown by the high share (more than 60%) of firms which consider the international markets as the most important.

4. Results

Hypothesis 1: the R&D intensity

In Table (2) are presented the results for equations (1) and (2), concerning the decision to engage continuously on R&D and on the actual amount of resources invested in it. The main variable of interest here is the elasticity of R&D with respect to size in equation (2), since this is an indication of the general propensity of firms to invest in R&D.

The results from the tobit specification show a very similar picture in the three samples for what concerns the decision to engage or not continuously in R&D: competing in international markets and issuing patents is positively associated with R&D activities, in line with previous contributions (Brouwer, Kleinknecht, 1999). Also size is positively related with the continuous engagement in R&D activities (Cohen, Klepper, 1996; Cohen, Levin, Mowery, 1987).

Table 2. Tobit estimates of R&D equations: R&D selection and R&D intensity

Dependent variable	Engagement in R&D (marginal effects)			(log of) R&D to sales ratio		
Sample	*Germany*	*Italy*	*Spain*	*Germany*	*Italy*	*Spain*
	(1)	(2)	(3)	(4)	(5)	(6)
Turnover in 2004 (in logs)	0.067***	0.051***	0.054***	-0.086	-0.190**	-0.546***
	(0.015)	(0.006)	(0.007)	(0.072)	(0.084)	(0.055)
Belonging to a group	0.011	0.014	0.034	0.058	0.440**	0.447***
	(0.046)	(0.020)	(0.022)	(0.209)	(0.171)	(0.117)
International markets	0.155***	0.066***	0.136***	-0.276	0.249	0.525***
	(0.045)	(0.016)	(0.018)	(0.313)	(0.204)	(0.176)
Patenting activity	0.338***	0.224***	0.246***	0.382	0.556**	0.334**
	(0.052)	(0.036)	(0.033)	(0.292)	(0.232)	(0.150)
Local funding	-	-	-	0.568**	0.090	0.380***
	-	-	-	(0.239)	(0.123)	(0.104)
National funding	-	-	-	0.346	0.218	0.750***
	-	-	-	(0.247)	(0.138)	(0.125)
European funding	-	-	-	0.192	0.049	0.162*
				(0.161)	(0.173)	(0.083)
Constant	-	-	-	-3.531***	-3.256*	2.894***
	-	-	-	(1.309)	-1.807	(1.097)
rho	-	-	-	0.471**	0.695***	0.373**
	-	-	-	(0.186)	(0.164)	(0.165)
Wald test of indep. eqns.(rho = 0)	-	-	-	4.58	7.26	4.17
p-value	-	-	-	0.032	0.007	0.041
Log-pseudolikelihood	-	-	-	-452.7683	-960.418	-1445.595
Number of censored firms				249	1463	1400
Total Observations	526	1852	2126	526	1852	2126
Rubber and Plastic products	146	320	484	146	320	484
Other non Metallic Minerals	90	509	709	90	509	709
Fabricated Metal Products	290	1,023	933	290	1,023	933

The dependent variable in columns (1), (2) and (3) is the probability to invest continuously in R&D expenditures. The dependent variable in columns (4), (5) and (6) is the intensity of R&D expenditures (the log of R&D expenditures to sales ratio). The Tobit type II model (Anemyia, 1984) is estimated through maximum likelihood. In columns (1), (2) and (3) marginal effects are reported. All models include sector dummies. Heteroskedasticity robust standard errors in parentheses, * significant at 10%; ** significant at 5%; *** significant at 1%

In columns (4), (5) and (6) of Table (2) are reported the coefficient of the elasticitiy to size (measured by sales) for equation (2): since in the equation R&D is divided by sales, the actual elasticity of R&D to sales will be equal to β (the estimated coefficient) minus one.[8] Differently from Cohen and Klepper (1996) and Crepon, Duguet and Kabla, (1996), who found an elasticity not significantly different from one, in the estimates these findings are confirmed only for Germany, where the elasticity amounts to 1, while among Italian and Spanish firms the elasticity to size is respectively 0.8 and 0.45. In other words while in Germany a 1% increase in size (as measured by sales) brings a corresponding 1% increase in R&D expenditures, in Italy it brings a 0.8% increase and in Spain it leads only to a 0.45% increase. These findings confirm that the growth of Italian and especially Spanish firms is not always supported by corresponding investments in formalized knowledge. This evidence supports the DTF version of Hypothesis 1 (H1-DTF): firms in national sectors that are far from the technological frontier will rely less on R&D-based innovative strategies, with respect to firms in advanced sectors.

Hypothesis 2: the sources of innovation

In Table (3) and (4) the results from the probit estimations of equations (4) are presented: here I am interested in testing whether similarities or differences emerge in the use of different sources of information for innovation activities, following hypotheses H2-SSI and H2-DTF. Since I expect that innovative outputs and R&D activities might be correlated I use the predicted values of R&D intensity from the Tobit equations.[9]

[8] The equation for the elasticity of R&D to sales is: $\ln(R\&D_i) = \ln(sales_i)\beta + x_i^{'}\delta + \varepsilon_i$
where ε is the elasticity of sales to R&D, while in columns (4), (5) and (6) we have:
$\ln(R\&D_i / sales_i) = \ln(sales_i)(\beta - 1) + x_i^{'}\delta + \varepsilon_i$

[9] I hence have a measure of innovation input (effort) also for those firms who actually have zero or missing values for R&D expenditures, assuming that these firms may still make innovative efforts even if not through formalized R&D activity.

Table 3. Probit: product adoption and brand new product innovation

Dependent variable	Product adoption			Brand new product innovation		
sample	*Germany*	*Italy*	*Spain*	*Germany*	*Italy*	*Spain*
	(1)	(2)	(3)	(4)	(5)	(6)
Sources of information						
Internal to the firm	0.087	0.050***	0.187***	0.169***	0.071***	0.157***
	(0.056)	(0.019)	(0.027)	(0.049)	(0.023)	(0.023)
Suppliers	-0.063	0.014	0.035	-0.047	0.012	0.024
	(0.071)	(0.017)	(0.032)	(0.056)	(0.017)	(0.024)
Clients	0.160***	0.072***	0.184***	0.052	0.067***	0.122***
	(0.057)	(0.031)	(0.040)	(0.051)	(0.032)	(0.032)
Competitors	-0.049	0.079**	0.107**	-0.013	-0.003	0.028
	(0.080)	(0.054)	(0.051)	(0.068)	(0.029)	(0.034)
University	-0.104	0.046	0.056	-0.056	0.194*	0.051
	(0.135)	(0.090)	(0.063)	(0.101)	(0.149)	(0.046)
Trade fairs	0.177**	0.038*	0.146***	0.109	-0.004	0.071*
	(0.080)	(0.027)	(0.054)	(0.078)	(0.019)	(0.039)
Investments						
predicted R&D intensity	0.073	0.046*	0.006	0.116	0.010	0.042***
	(0.094)	(0.025)	(0.018)	(0.077)	(0.026)	(0.014)
Investment Intensity	0.045***	0.018***	0.020***	0.012*	0.013***	0.001
	(0.007)	(0.002)	(0.003)	(0.007)	(0.002)	(0.002)
Other controls						
International markets	0.138**	0.013	0.068***	0.142***	0.008	0.027
	(0.060)	(0.013)	(0.021)	(0.050)	(0.013)	(0.017)
Patenting activity	0.122*	0.038	0.199***	0.176***	0.188***	0.233***
	(0.073)	(0.027)	(0.037)	(0.064)	(0.049)	(0.034)
Size 50 -249	-0.084	0.061***	0.019	0.041	0.034**	0.056***
	(0.061)	(0.017)	(0.026)	(0.057)	(0.017)	(0.021)
Size >250	0.117	0.114***	0.108**	0.141*	0.088***	0.173***
	(0.080)	(0.045)	(0.054)	(0.076)	(0.039)	(0.055)
Pseudo R_squared	0.219	0.349	0.207	0.213	0.300	0.260
Log-likelihood	-284.406	-474.670	-925.176	-259.189	-380.613	-674.759
Total Observations	526	1852	2126	526	1852	2126
Rubber and Plastic products	146	320	484	146	320	484
Other non Metallic Minerals	90	509	709	90	509	709
Fabricated Metal Products	290	1,023	933	290	1,023	933

The dependent variable in columns (1), (2) and (3) is the probability to introduce a product innovation new only to the firm. The dependent variable in columns (4), (5) and (6) is the probability to introduce a product innovation that is new also for the market. R&D intensity corresponds to the predicted values obtained from the Tobit type II estimation of equation (3). Marginal effects are reported. All models include sector dummies. Heteroskedasticity robust standard errors in parentheses, * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 4. Probit: process innovation

Dependent variable	Process innovation		
sample	*Germany*	*Italy*	*Spain*
	(1)	(2)	(3)
Sources of information			
Internal to the firm	0.106**	0.112***	0.323***
	(0.052)	(0.040)	(0.030)
Suppliers	0.209***	0.106***	0.177***
	(0.068)	(0.044)	(0.044)
Clients	0.021	0.065	0.167***
	(0.054)	(0.050)	(0.048)
Competitors	0.016	-0.099***	0.045
	(0.071)	(0.025)	(0.064)
University	-0.118	-0.041	0.023
	(0.096)	(0.083)	(0.079)
Trade fairs	0.119	-0.001	0.182***
	(0.075)	(0.043)	(0.066)
Investments			
predicted R&D intensity	0.288***	0.066	0.054**
	(0.086)	(0.053)	(0.022)
Investment Intensity	0.047***	0.071***	0.038***
	(0.007)	(0.004)	(0.004)
Other controls			
International markets	0.216***	0.032	0.127***
	(0.052)	(0.024)	(0.025)
Patenting activity	-0.092	-0.060	0.166***
	(0.064)	(0.035)	(0.041)
Size			
50 -249	0.093	0.059**	0.039
	(0.057)	(0.030)	(0.031)
>250	0.046	0.125**	0.219***
	(0.076)	(0.064)	(0.060)
Pseudo R_squared	0.237	0.553	0.296
Log-likelihood	-261.095	-482.772	-943.77
Total Observations	526	1852	2126
Rubber and Plastic products	146	320	484
Other non Metallic Minerals	90	509	709
Fabricated Metal Products	290	1,023	933

The dependent variable in columns (1), (2) and (3) is the probability to introduce a process innovation. R&D intensity corresponds to the predicted values obtained from the Tobit type II estimation of equation (3). Marginal effects are reported. All models include sector dummies. Heteroskedasticity robust standard errors in parentheses, * significant at 10%; ** significant at 5%; *** significant at 1%

The results about the sources of information display a high degree of similarity among the three national samples: for each type of innovation in the three countries I find that firms indicate the same preferred sources of information. Internal capabilities are extremely important for the development of brand-new product innovation in all countries. On the contrary clients and trade fairs are very important for product adoption/imitation, highlighting the role of user-producers linkages in these specific sectors (Von Hippel, 1988). Suppliers, as well as internal capabilities, are always positive and significant for process innovation in all the three countries. University laboratories instead almost never have positive or significant coefficients, confirming the different patterns of innovation in mid-low tech sectors as compared with high tech sectors (Von Tunzelmann, Acha, 2005). These findings confirm the validity of the SSI version of Hypothesis 2 (H2–SSI): opportunity conditions, that are strictly related to the type of knowledge-base used in a sector, define the type of inputs that are used for the development of innovations and lead to similarities in the types of innovation sources across the three national samples. As regards the effect of R&D-based investments on the different types of innovations I do not find clear evidence in favor or against the two versions of Hypothesis 2: R&D is rarely significant for both types of product innovation, while it is positive and significant for process innovation, but only in Germany and Spain. This mixed results could be due to the fact that I am using the predicted values of R&D from equation (2) also for firms who did not actually make them: hence I am not precisely measuring R&D investments but rather a general innovative effort of each firm.

Hypothesis 3: the economic impact of innovation

Finally in Table (5) are presented the results of the instrumental variable estimation of the output function. I regress the log of turnover on the predicted values of the probit estimations for each kind of innovative output, on the employment dummies, used as proxies for labour, on the log of machinery acquisition (investment in physical capital) and on a set of sector dummies.

Table 5. Estimates of the production function equation

Dependent variable	Log of turnover	Log of turnover	Log of turnover
sample	*Germany*	*Italy*	*Spain*
	(1)	(2)	(3)
Product innovation (brand new)	2.585***	1.517***	-2.777***
	(0.420)	(0.261)	(0.332)
Product innovation (adoption)	-0.729	-1.794***	4.353***
	(0.512)	(0.304)	(0.455)
Process innovation	-1.528***	-2.136***	-0.932***
	(0.275)	(0.186)	(0.246)
Size			
50 -249	1.598***	1.892***	1.868***
	(0.093)	(0.044)	(0.04)
>250	3.174***	3.390***	3.427***
	(0.113)	(0.078)	(0.078)
(log of) Investment	0.055***	0.168***	-0.038***
	(0.014)	(0.012)	(0.007)
Constant	14.330***	14.595***	14.409***
	(0.144)	(0.039)	(0.042)
R-squared	0.802	0.705	0.665
Total Observations	526	1852	2126
Rubber and Plastic products	146	320	484
Other non Metallic Minerals	90	509	709
Fabricated Metal Products	290	1,023	933

The dependent variable in columns (1), (2) and (3) is the log of turnover. Product innovation (brand new), Product innovation (adoption), and Process innovation corresponds to the predicted probability of introducing respectively a product innovation new to the market, a product innovation new only to the firm and a process innovation, as predicted by the probit estimations of equation (4). All models include sector dummies. Heteroskedasticity robust standard errors in parentheses, * significant at 10%; ** significant at 5%; *** significant at 1%

This section allows to test Hypothesis 3 about the economic effects of different types of innovation. According to the SSI literature the knowledge-base used in a sector will strongly determine also the competitive environment in which firms are embedded: hence I expect that the same type of innovation will have broadly the same effect on the economic performances of firms. According to the DTF theory instead in backward national sectors adoption and imitation will be the most effective way to innovate, while in advanced sectors brand new innovation will provide a competitive advantage to firms and will produce an effect on their performances.

In Table (5) are presented the semi-elasticities of the different kinds of innovation output with respect to turnover. The coefficients of the two types of product innovation are very different across countries. While in Germany and Italy only brand new product innovation has a positive and significant coefficient, among Spanish firms product adoption is the only positive and large coefficient, while the introduction of a product which is new also for the market has a negative and significant coefficient. Process innovation instead has a negative and significant coefficient in all countries, meaning that firms that rely only on process innovation have on average lower levels of sales. However it must be taken into account that such negative effect might be worsened by the fact that sales are used as a dependent variable: as a consequence in this model it is possible to identify only the demand shift effect and the temporary monopoly rent of innovators, which is clearly associated with product innovation, while efficiency increases, which are more associated with process innovation, are not accounted for.

In Table (5), for what concerns Italian and German firms, the coefficients of capital are positive and significant, in line with the related literature (Polder *et al.*,2009). On the contrary the coefficient becomes negative and significant among Spanish firms. This is probably due to the fact that, since the CIS4 doesn't provide a measure of the stock of capital, but only of the investments in fixed capital in the years between 2002 and 2004, I am using a flow measure of capital (investments) instead than a stock, which might affect the estimates.[10] I hence consider this variable as an additional control of the propensity of firms to invest.

Overall the results from the production function estimates confirm the validity of the DTF version of Hypothesis 3 (H3–DTF): different innovative output have differentiated economic effects on the basis of the technological development of a national sectors. More specifically brand new product innovation is extremely important in countries which have a higher degree of technological competitiveness (Germany and, to a lower extent, Italy), while in countries which have not completed the catch up process (Spain) product imitation can be a more effective strategy.

[10] Also Griffith, Huergo, Mairesse and Peters (2006) found a lower elasticity of investments to labour productivity for Spain, with respect to Germany and France. A possible explanation could be due to the high number of zero values in the firms' distribution of the expenditures in machinery. As a robustness check I ran the same production function estimations only for firms which had positive expenses in machinery. The results show that the coefficient of "capital" increases proportionally in each of the three countries, leading to positive and significant values also for Spain (about 0.10). The coefficients of the innovative variables are instead left unchanged.

6. Conclusions and Policy Implications

This paper has analyzed the patterns of innovative activities among three mid-low tech sectors (the Rubber and Plastics Sector, Other Non-Metallic Minerals, and Fabricated Metal Products) in Germany, Italy and Spain. The aim of the paper has been to test in a specific empirical context the different predictions of the Sectoral Systems of Innovation framework and those of the Distance-to-the-Frontier literature. While the SSI stresses the fact that similar knowledge-bases and opportunity conditions should also lead to similarities in innovative strategies in the same sectors across countries (Malerba and Orsenigo, 1997; Malerba 2004), the DTF highlights the incentives for firms to behave in different ways according to the distance to the technological frontier of the sector they are active in (Acemoglu, Aghion, Zillibotti, 2006). Firms in national sectors that are close to the frontier should invest in R&D-based innovative activities and introduce radically new products, while for firms in backward sectors it will be more profitable to adopt investment-based strategies of imitation from more advanced countries. The three countries are very appropriate for this type of analysis: indeed German sectors show the highest level of labor productivity at the aggregate level, Spanish sectors display the lowest level of productivity and Italian sector are broadly in the middle between the other two countries.

The paper tests empirically a set of hypotheses that originate from the two theoretical frameworks outlined above. The results of the empirical analysis show that both frameworks are able to explain some of the observed innovative patterns. More specifically I find significant cross-countries differences in the propensity to invest in R&D activities, as measured by the elasticity of R&D to turnover. In Germany the elasticity turns out to be higher than in Italy and especially than in Spain. I interpret these findings as a confirmation of the DTF framework against the SSI one: firms in more advanced national sectors rely more on R&D-based strategies for their innovation activities than firms in technologically backward sectors.

On the contrary the results indicate that the SSI framework is more appropriate than the DTF one to identify the sources of firms' innovative outputs. According to the SSI literature opportunity conditions and knowledge-related features of the technology used determine the type of actors that provide firms with useful knowledge for the development of new innovations: since these features are strongly sector-specific they will be similar in the same sector across countries. Indeed in the empirical analysis of this paper strong regularities emerge in the types of sources used for innovation across the three countries. Internal sources are important for brand new product innovation in all countries, clients and trade fairs are important for product imitation, while suppliers and internal resources are important for process innovation.

The DTF framework instead is better able to explain the effects of innovation on the economic performances of firms: while in Germany and Italy only brand new innovation has a positive impact on sales, in Spain instead imitation has the largest effect. Again these findings confirm the appropriateness of the DTF theory, contrary to the SSI which predicts the existence of similar competitive framework (Schumpeter Mark I or II), according to the nature of the technology used.

The results show that both approaches need to be considered when sectoral analyses on innovative activities are performed: the SSI literature is extremely relevant for the identification of the main determinants of the innovative activity *per se*. The DTF literature becomes relevant instead for the decisions concerning the investment in R&D activities and the success of specific types of innovations, showing that firms within the same sectors follow different strategies according to the competitive environment in which they are embedded. Summing up these results show that, although broad technology-driven sectoral similarities exist across countries, however even among European developed countries the differences in the overall competitiveness of a sector can still influence the way in which innovations are generated and exploited.

From the perspective of a European innovation policy these results are particularly interesting: they suggest that sector-specific industrial policies should include both homogeneous and heterogeneous elements across the different countries. The existence of sectoral invariances in innovative activity should be acknowledged and it should induce to apply similar technology-policies in the same sectors across countries for certain specific elements of innovative activity (for example in the access to the sources of knowledge). However the differences related to the distance-to-the-frontier should also suggest to fine-tune each national policy in order to understand which type of innovation is better suited for the specific economic context in which it is introduced.

Finally an important warning for policy-makers must be pointed out: policies that are appropriate for the level of development of a national sector but that are not able to bring it closer to the frontier can introduce a typical "development trap" effect, in which backward sectors fail to converge towards the frontier (Acemoglu, Aghion, Zillibotti, 2006). The recent European crises have shown how in the next years less competitive member states such as Spain and Italy will have to invest resources precisely in the attempt to catch up and approach the technological frontier.

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