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Do External Sources of Information Matter for the Innovation Performance of Companies Operating in Portuguese Metal Industry?

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Bio

Pedro Jorge Martins Santos Silva, born on 6 of September 1981, in Porto. He studied Economics in the Catholica University of Porto were, after going through an international experience in the University of Economics of Warsaw (Poland), He graduated in 2007. His international experience, allied with his interest in economics and different cultures were his main motivations for his next step. He started to work in the international area of Mota Engil and went aboard to Luanda, Angola where he have worked in the financial department of one of Mota Engil's owned companies in that country. After that experience he came back to Portugal and worked for 6 years in a metal working company, Capa Engenharia e Construção S.A., where he was responsible for the international project management during the first three years, and in the last three years he was the commercial responsible for that company in Luanda.

With the objective of restructure a family company that was facing some issues due to the economic environment e decided to return to Portugal and enroll his efforts in that project. Aligned with that propose he started the Master in Innovation and Technological Entrepreneurship at Faculty of Engineering at University of Porto having as main motivation the opportunity to use the scientific knowledge as an fostering factor in the professional strategy that he is enrolled with.

He still working on that professional project as he is starting to see some of the results he was aiming at.

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Abstract

The relevance of sources of information that are useful for companies enrolled in innovative activities has been object of many empirical studies, but it's diversity of results shows that the impact that sources of information have in companies is not the same and sometimes has different direction dependant on the economic environment and sector in which companies operate.

This paper adds to the existing literature the case of the Metal and Metalworking industries operating at a periphery country as Portugal.

Based on a sample of 6593 Portuguese companies including 1309 operating in the MI sector that answered the Community Innovation Survey, we used an econometrical model to assess the impact of sources of information in the innovative performance of the companies.

We were able to found that in terms of external sources of information, "Other Sources" like conferences, trade fairs, exhibitions, scientific journals and/or technical publications, and, professional and industry associations impact positively and significantly innovation in MI companies. Regarding to cooperation activities we obtained that companies in the MI sector that cooperate with foreign partners have that asset as one key activity in fostering innovation. We were also able to find that in the same line as the rest of the manufacturing companies in Portugal, MI Company's innovation is affected positively by their human capital, (specifically employees with a master's degree), by their investment in continuous R&D and by their training in innovation activities. The results also show that the acquisition of machinery and equipment, and again in line with the rest of the manufacturing sector, has positive and strong impact in innovation. Companies that resort to external R&D activities also see a positive impact in their innovation activities performance. On the opposite side we obtained that the increase of size of a company has a negative impact in innovation.

Keywords: International Technology Transfer; Developing Countries; Regional Development

JEL-Codes: O33; O19; R11.

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1. Introduction

Extant literature have for long demonstrated that companies seldom innovate in isolation. Quite the opposite, they need to intermingle and collaborate with other economic agents both to explore new sources of knowledge and to exploit current ones (Gómez et al., 2016).

Open innovation has generated an increase of interest during the last decade (West et al., 2014). Such concept, launched by Chesbrough (2003), observed increasing acceptance among academics and specialists. It states that companies, besides relying on ideas and knowledge developed internally, they should also draw on ideas and knowledge developed outside (Chesbrough et al., 2006).

In this context, several studies were undertaken with the objective of exploring the effects of the use of external sources of information in the innovative activities of companies. Those studies use different geographical and/or sectoral samples (e,g. Lööf and Heshmati, 2002; Laursen and Salter 2004; Caraça et al., 2009; Cesário et al., 2015), mostly focusing on highly developed countries and manufacturing industry as a whole (see Vivas et al. 2015). Very few addressed single sectors within manufacturing, and none addressed the metal industry.

The study of single sectors is important as the literature strongly suggests that the impact of the use of external sources of information for innovation is highly sensitive to the sector characteristics (Pavitt, 1984; Heidenreich, 2009). Metal industry is an interesting case study as it is a sector characterized by low/medium technology which usually presents less favorable conditions for open innovation (Maietta 2015).

A seminal earlier study by Mansfield and Lee (1996: 1057), analyzing US companies from seven industrial sectors, including the metal industry, evidenced that universities, an external institutional source of information for companies' innovation activities, "contributed most significantly to [companies'] product and process development" and "have had a major impact on industrial innovation in the short term, as well as over the long run".

In Portugal, metal industry is a rather important sector. Most recent data available (Banco de Portugal, 2015), shows that in 2013, the metal industry (including Basic Metallurgic, Metal and Electrical Products, and Transport Equipment) accounted for about a quarter of the number of companies, turnover and number of persons employed of manufacturing

industries. In average terms, companies in the metal industry generated 2.6 times more turnover and 2.5 times more employees than the average company in Portugal. The industry is mostly made up of micro-enterprises (73%) (99% of small and medium companies, according to ANEME, 2015) and it is characterized by high external trade openness, being responsible for about almost one third of the Portuguese total exports (ANEME, 2015).

Given that extant studies demonstrate that even in technological laggard contexts (see Gomez et al., 2014), higher innovation performance is associated with firm's technological capabilities (namely internal R&D and human capital), complemented and interacted with external innovation sources of information for innovation, most notably with universities, and collaborative agreements, it would be illuminating to bring new and fresh evidence on these issues by studying the companies operating in the Portuguese metal industry.

For such endeavor, we resort to data from the Community Innovation Survey, which includes 6593 companies, 3681 operating in the manufacturing industry, out of which 1309 are from the metal industry.

Using logistic regressions, we assess the direct and indirect (through companies' internal knowledge basis) impact of external sources of information for innovation (market – clients, suppliers and competitors, institutional – universities and R&D labs, and others – trade fairs, professional and sectoral associations) on companies' innovation performance.

The dissertation is organized as follows. Next section overviews the literature in the area. Section 3 presents the methodological underpins. The empirical results are detailed in Section 4. Finally, Conclusions summarize the main contributions and limitations of the present research.

2. Theoretical framework

2.1. Innovation and specificities of the metal industry

Innovation is about the markets and organizations (Caraça et al., 2009). Most of the innovation generated by companies is the result of the capacity that managers and employees have to find solutions to existing problems (Fitjar and Rodríguez-Pose, 2013). This capacity affects directly firm's competence to respond to the challenges made by suppliers, customers and the market (Yu, 2001).

The existence of a relation between the type of innovation search strategies used by companies and their innovative performance has been discussed by a large number of empirical studies (e.g., Katila and Ahuja 2002; Laursen and Salter 2006; West et al. 2014).

The literature suggests that knowledge spillovers that result from the interaction between sources and companies can only occur when agents share 'languages', face the same problems, and use similar technologies (Tavassoli and Karlsson, 2015). The use of different languages may imply that it is not possible to transform shared knowledge into innovations (Tracey and Clark, 2003). Therefore, information flows are more likely to occur inside the same sector of activity (Fitjar and Rodríguez-Pose, 2013). Indeed, as argued by (Freel, 2003: 762) "certain types of cooperation are associated with specific types of innovation, involving certain companies, in certain sectors".

Although recognizing that the effect of external sources of information in the innovative performance of companies is influenced by sector of activity in which they operate, most of the empirical studies test those impacts by focusing on the manufacturing sector as a whole (see Santamaría et al., 2009; Corredor et al., 2015), neglecting sectors' heterogeneity. The present study seek to overcome such gap by analyzing the relevance of externals sources of information for innovation in the context of a given sector, the metallurgical and metalworking sector.

The metal industry (MI) is part of the manufacturing industry, being considered (according to the OECD's technology intensity definition) as a medium-high/ medium-low-technology (LMT) (OECD, 2011). The interest in studying the innovative behavior of this type of industry has been secondary when compared to high-tech industries (Hirsch-Kreinsen et al., 2005; Maietta, 2015; Galati et al., 2016). Yet, medium-high and medium-low technology industries constitute the largest part of the manufacturing

employment (Sandven et al., 2005; Hirsch-Kreinsen, 2015). Innovation in these industries is more often result of the transformation of stock knowledge into economic useful knowledge, rather than result of the latest scientific or technological knowledge (Bender and Laestadius, 2005).

In Portugal, the MI is characterized by a strong export intensity and is responsible for a very significant share of international trade (Banco de Portugal, 2015), which exposes the sector to very demanding global challenges. Empirical studies show that innovation is strongly influenced by the export intensity of companies (Tavassoli and Karlsson 2015). Competing at the world market demands a continuous flow of new and improved products. Innovation is therefore presented as a sustained response to the challenges of globalization by developing innovative solutions that can gear competitiveness, differentiation, and value to the companies (Vieira et al., 2011). Indeed, the study by Hansen (2010: 65), focused on Danish fabricated metal industry, found that "the ability to create tailor-made solutions is central to the competitiveness of these medium-low-tech firms" and that "[k]nowledge is … highly important, yet in different ways than for high-tech industries".

2.2. Main hypothesis to be tested

2.2.1. External sources of knowledge as sources of information and cooperation for innovation

In the last years and following the trend of 'open innovation', companies started to give more importance to the use of external sources for new ideas, information, knowledge and technologies including different kinds of market sources (suppliers, clients, competitors, etc.), consultants, outsourcing of R&D to universities and specialized R&D companies (Lungeanu et al., 2015).

Companies which engage in collaboration with external agents tend to be more innovative than companies that only rely on their own resources for innovation (Fitjar and Rodríguez-Pose, 2013). In fact, accessing knowledge across a wide range of external actors and sources allows companies to access advanced technologies and processes which has proven to help them achieve and sustain innovation (Laursen and Salter 2006). As the interaction between different parts fosters learning processes through the sharing of knowledge and information (Tracey and Clark 2003), it is expectable a positive effect of external sources of information on the innovative performance of companies.

The studies that relate the use of external sources of information with the innovative performance of companies are already extensive. Table 1 presents a selection of those studies which explicitly address the impact by type of external source, most notably market sources, comprising customers, suppliers and competitors, scientific sources, including universities and R&D Labs, and other sources, such as trade fairs and sectorial associations.

Vega Jurado et al. (2009) studying a sample of 1329 Spanish companies concluded that an external knowledge search strategy is a very important source of ideas and resources that helps companies to improve their innovative performance. According this study, the source that has more impact on innovation is the acquisition of machinery. Suppliers, and customers also produced a positive impact on companies' innovation performance. An important result that was obtained in this study is that external R&D has no impact on the companies' innovative performance.

Table 1: External sources of information and impact - synthesis of some studies

Authors (year)	Country (# companies)	Tech. Intensity	Market			Scientific			Others		
			Customers	Suppliers	Competitors	Universities	R&D labs	Others	Fairs	Sector associations	Others
(Lööf and Heshmati 2002)	Sweden (619)	High, Medium and Low Intensity	-	+	+	0	N/A	N/A	N/A	+	N/A
(Santamaría, Nieto, and Barge-Gil 2009)	Spain (4580)	High, Medium and Low Intensity	0	-	0	0	+	+	0	0	0
(Vega-Jurado, Gutiérrez-Garcia, and Fernández-de-Lucio 2009)	Spain (1329)	High, Medium and Low Intensity	+	+	+	+	0	+	0	0	+
(Fitjar and Rodríguez-Pose 2013)	Norway (1602)	High, Medium and Low Intensity	+	+	-	+	N/A	N/A	N/A	+	N/A
(Corredor, Forero, and Somaya 2015)	Colombia (4820)	High, Medium and Low Intensity	++	++	+	++	N/A	++	NA	+	0

A study undertaken in Colombia by Corredor et al. (2015), using 4820 manufacturing companies, the authors demonstrated that the use of external sources has always a positive impact in the innovation performance of the companies.

Some studies, however, reached different results. For instance, Lööf and Heshmati (2002) show that in case of Swedish manufacturing industries, customers have a negative impact on the innovative performance of the companies. Also Santamaria et al. (2009), using a

different and wider sample than Vega Jurado et al. (2009), concluded that the impact of a supplier based search strategy is negative. The same negative impact was observed by Fitjar and Rodriguez (2013) in what concerned the information search strategy based on competitors.

This diversity of results shows that despite a general positive trend, the impact of the external sources of information for innovation might differ according to sector of activity, but also characteristics of the firms and their search strategies. Despite of this latter claim, we conjecture that

H1: *The use of external sources of information and cooperation for innovation by companies operating in Portuguese metal industry directly and significantly impacts on their innovative performance*.

2.2.2. Internal capacities

Low and medium tech (LMT) companies have the major part of their innovative activities done inside their doors (Nelson, 2000). It is their in-house capacity that allows them to recognize the needs, evaluate, negotiate and adapt technology in order to make it available for their customers (Cohen and Levinthal, 1990).

Literature allows us to identify as internal capacities, the human capital, usually measured by the level of the education of the employees and the accumulated internal knowledge that is result of internal R&D activities, in-house training and the acquisition of machinery, equipment or software(Freel, 2005).

Regarding to the level of education, studies focusing on the manufacturing industries show that the higher is the level of education of the employees, the stronger is the capacity of the firm to absorb new knowledge and therefore to innovate (Pires et al, 2008; Frenz and Ietto-Gillies, 2009).

In line with the human capital, training activities inside the firm tend also to improve substantially the absorptive capacity of the company and increase the probability of innovation (Cesário et al., 2015).

Investment made by companies in in-house R&D is commonly associated as having a positive effect in their innovative performance. For instance, Köhler et al. (2012) analysed the impact of the variable "R&D intensity" among some other strategies of innovative knowledge search, on the sales of companies. Their results show that internal R&D activities have a strong and positive effect on companies' sales performance.

Being metal industry a low-medium tech (LMT) business activity, it shares some of other (LMT) manufacturing industry characteristics. Thus, we expect that the internal capacities of the companies in metal industry have a positive effect in their innovative performance. There for we test the following hypothesis:

H2: *Internal capacities of the companies operating in Portuguese metal industry are positively and significantly related to their innovative performance*.

2.2.3. Interaction between external sources of information for innovation and companies' internal capacities

According to the studies shown in Table 1, results regarding the impact of external sources of information for innovation on companies' innovation performance are not totally conclusive. Albeit all of them show a positive pattern towards the influence of external sources on the innovative activities of the companies, such influence is not uniform. This may be explained by the fact that even having a positive effect, the influence of external sources of information on the innovative performance of the company is constrained by the capacity of the company to absorb that external knowledge (Cohen and Levinthal, 1990). Indeed, such interaction is highly dependent on the human capital available in the companies and on the level of training of the employees (Jensen et al., 2007). Indeed, external actors and sources do not impact equally across different sectors of activity and levels of technology involved (Köhler, Sofka, and Grimpe 2012).

In the case of LMT companies, innovation is not usually result of scientific novelty but instead of the adaptation of general stock knowledge into economically useful knowledge. In that way, companies with best creative and innovation-enabling capacities tend to gather better results when translating and fitting the existent knowledge in the specific conditions of the firm (Hirsch-Kreinsen, 2008).

The ability to improve innovation activities using external sources is also dependent upon the continuously performed in-house R&D, that is, the possession of a proper internal absorptive capacity (Tavassoli and Karlsson, 2015).

In that way, it is critically to test the impact of the combination of the internal capacities of the company with their external information search strategy:

H3: *The combination between the use of external sources of information and the internal capacities (human capital and internal knowledge - continuous R&D and training for innovation) of the companies operating in Portuguese metal industry is positively and significantly related to their innovative performance.*

2.2.4 Interaction between external sources of information for innovation and companies' external capacities

Company's knowledge basis is not only composed by their internal capacities but also by technological spillovers that result from the acquisition of machinery and from cooperation with external R&D labs. As seen for the internal capacities, external capacities also influence the absorptive capacity of firms and therefore are very important to the way that external sources of information are understood and potentially adopted by firms.

The influence of external knowledge basis takes an even more important role in the case of SME's as those companies overcome their lack of resources by cooperation with external entities as R&D Labs (Pinto et al 2015). Santamaria et al. (2009) showed empirical evidence that in the case of LMT firms, as the scenario in this study, the acquisition of advanced machinery and software together with external "design" activities have a significant impact on innovation outputs of firms. In the case of advanced machinery, most of the impact happens in process innovation. This may be explained by the standard and more artisanal processes that are commonly used in LMT industries and which can be easily improved in terms of quality and efficiency by the acquisition of new and more technological equipment. This is not only important in terms of process innovation but also on the improvement that this new processes add in the way that firms are able to adopt and adapt information from external sources.

As seen for the internal capacities, external R&D and the acquisition of new machinery and software are very important components of the absorptive capacity of a company and therefore it is mandatory to understand the extant of the impact of external capacities of a firm in the adoption of information from external sources and how this combination impact the innovative performance of Portuguese MI firms.

H4: *The combination between the use of external sources of information and the external capacities (i.e., acquisition of machinery and software and external R&D) of the companies operating in Portuguese metal industry is positively and significantly related with their innovative performance*

2.2.5. Control Variables

It is important to look at some other variables as they are considered by literature as being influent for the innovative performance of companies. This set includes variables such as geographical location, size of the company or cooperative environment (Pires et al., 2008).

Large companies usually have more resources to be allocated to innovation activities (Maietta, 2015), yet they are less flexible and more bureaucratic than smaller companies (Hirsch-Kreinsen, 2008). Thus, the influence of the company's size is not clear-cut. Despite these ambiguous perspectives, overall analysis shows us that size tend to be positively related to innovation performance of companies (see Garriga et al., 2013).

Innovative performance is also highly related to the multinational characteristics of a company. The greater learning and knowledge base available inside a multinational group is pointed as being a catalyst to the efficiency of the innovative process (Pinto et al., 2013). This influence is dependent on the type of activity that a company is involved in. Pires et al. (2008) found that for a given R&D investment and a certain size typology, being part of a multinational group produces a positive effect in process innovation but a negative effect in product innovation.

2.3 The theoretical model

At this point and summarizing the literature that we have seen so far, we can say that innovative performance of companies is affected directly and indirectly (though companies' knowledge basis) by the use of external sources of knowledge and the internal ability to exploit them (Cohen and Levinthal, 1990).

The theoretical framework can be illustrated by Figure 1, where the innovative performance of a company is a function of its internal capacities and its use of external sources of knowledge for innovation.

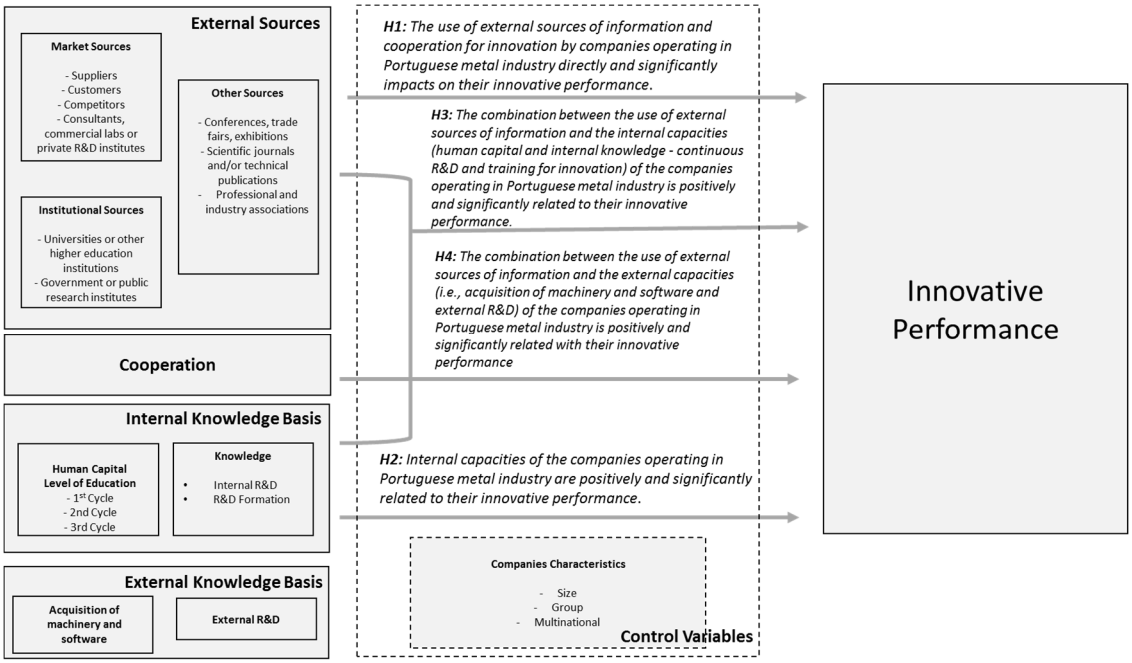

Figure 1: The conceptual framework of analysis

Source: Own elaboration

3. Methodology

3.1. Briefly detailing the database

This study uses the Community Innovation Survey 2008 (CIS) as source for the data. CIS is designed to provide information about the innovative activities of companies in different sectors and provides us statistics broken down by countries, type of innovators, economic activities and size classes. We selected the 2008 data instead of the latest data available because the periods from 2008 to 2012 were largely affected by the global economic crisis. During that period many adjustments have been imposed due to decrease of turnovers, therefore, and as the CIS statistics measure innovative performance related to the increase of turnover, we think that the use of data from that period may be fallacious.

CIS 2008 provides us a database of 6593 Portuguese companies. In the present study we filtered this database in two: manufacturing companies and metal industries. This enables to compare the results and to understand whether the companies operating in the metal industry follows the same pattern as the rest of the manufacturing companies.

In order to fit the characterization of the sector with its real environment inside the Portuguese economy, we use the ANEME's classification (see Table 2). With this procedure we have 1309 companies.

Table 2: Industries included in metalworking sector (CAE Rev. 3)

24 - Base Metallurgic	**29 - Motor Vehicles, Trailers and Components**
241 - Steel Mill, Iron and Alloy manufacturing	291 - Manufacture of motor vehicles
242 - Manufacturing of tubes, pipes hollow profiles and other steel accessories	292 - coachwork, trailers and semi-trailers manufacture
243 - Other activities of the 1st transf. of Iron and Steel	293 - Manufacture of parts and accessories for motor vehicles
245 - Ferrous and Non-Ferrous metal casting	
	30 - Other Transportation Equipment
25 - Metal Products, except Machinery and Equipment	301 - Shipbuilding
251 - Metal building materials	302 - Railways material manufacturing
252 - Tanks, vessels, boilers and central heating metal radiators	303 - Manufacture of air and spacecraft
253 - Steam generators (except boilers)	304 - Manufacture of military fighting vehicles
254 - Manufacture of weapons and ammunition	309 - Manufacture of transport equipment
255 - Forged, stamped and rolled products; Powder metallizing	
256 - Treatment and coating of metals; general mechanics activities	**Other CAEs**
257 - Cutlery, tools and ironmongery	265 - Instruments and appliances for measuring, testing and navigation; watches and clocks
259 - Manufacture of other metal products	266 - Radiation and electro medical equipment
	325 - Manufacture of medical instruments and surgical equipment
28 - Machines and equipment	331 - Repair and maintenance of metal products, machinery& equip.
281 - Machinery and equipment for general use	332 - Installation of industrial machinery and equipment
282 - Other general purpose machinery	383 - Material recovery
283 - Machines and tractors from agriculture, livestock and forestry	
284 - Machine tools, other than portable	
289 - Other machines and equipment for specific use	

Source: Own elaboration

3.2. Proxies for the relevant variables

As we have introduced before, and according to our framework of analysis, companies' innovative performance is dependent on five major determinants: 1) External sources of information for innovation; 2) Cooperation; 3) Internal knowledge resources; 4) External knowledge resources; and 5) Control variables.

3.2.1. Innovative performance

CIS provides us data about 12 distinct types of innovation, associated to product, process, market and organizational innovation. We first compute a variable that adds up all the innovation types performed by each company - this indicator goes from 0 to 12, meaning that 0 is when a company did not have any type of innovation during the period in analysis (2006-2008), and, 12 meaning that the company performed all the types of innovation included in the survey. Then, we compute a dummy variable which assumes the value 1 in case the company performs more than 6 distinct types of innovation and o otherwise. Thus, we called the first companies the top innovation performers.

3.2.2. External sources of information for innovation and cooperation

We studied external sources in two different ways as we think it is the best way to use the information provided by CIS. In the case of external R&D and machinery, equipment and software acquisition, we choose to use the direct information from the CIS through those specific questions. In the case of market sources (suppliers, customers, competitors), institutional sources (universities or higher education institutions and government or public research institutes) and other sources (conferences, scientific journals, professional associations) we created dummy variables for each case where the value 1 occurs when the company uses and attributes high importance to that specific source as of "High Importance".

Being part of a very export oriented sector we think that we can best measure its cooperation intensity if we give higher weight to the cooperative activities with foreign entities. Therefore and as it has been done before by Laursen & Salter, 2004 we used an index obtained from the responses of companies that claimed to have been enrolled in cooperative innovation activities during the period CIS 2008 uses. This index codifies the answers given by companies as a binary variable (excluding intra group cooperation and cooperation with partners located in Portugal). The sum of the results of this binary

variable will allow us to have a ranking of companies by its cooperation in innovation activities intensity.

3.2.3. Internal and external knowledge bases

In our model we have two major blocks of internal sources, human capital and knowledge derived from continuous internal R&D. We measured the human capital using the level of education of the employees.

According to the survey this indicator was measured as the percentage of employees that are graduates, master or PhD. Internal knowledge was measured directly from the answers that companies have given to specific questions to whether they perform continuous internal R&D activities in the period under analysis (2006-2008).

External knowledge basis encompasses two variables, the external R&D and the acquisition of machinery or software.

3.2.4. Interaction variables

The concept of absorptive capacity suggests that the impact of external sources of information I distinct depending on the internal capabilities of companies. In order to capture such distinct impact, we created two interaction variables. One that combines the internal knowledge basis with the external sources of information (internal knowledge basis * external sources of information), and another that combines the external sources of information with the external knowledge basis (external knowledge basis * external sources of information). The internal knowledge basis variable consists in the product two variables: 1) training for innovation (a dummy variable that assumes the value 1 in case the company had training activities for innovation and 0 otherwise; and 2) human capital stock - the proportion of employees with the degree equal or higher than graduation/licensee. The external knowledge basis variable results from the sum of two dummy variables, the external R&D and the acquisition of machinery or software.

3.2.5. Control variables

Three control variables were considered: company's size ('Size'), whether the company belongs to a group ('Group') and whether the company is a multinational ('Multinational').

The size was measured by the number of employees working in the company in 2008. Group was obtained directly from the survey, by companies' answer to the question whether they were or not part of a group. Multinationality was measured by the response to the question whether the company's headquarters was located outside Portugal.

3.3. Econometric specification

Following the line of some other quantitative studies regarding this subject and using similar databases (e.g., Pires et al., 2008; Varis and Littunen, 2010), we resort in the present study to logistic regressions estimations. Logistics econometric models allow us to estimate the impact that the independent variables have on the likelihood of a company to be a top innovator (having, in the three year period 2006-2009, performed more than 6 types of innovation).

In order to have an easier reading of the model, we use the original equation in terms of the probability ratio between the occurrence and non-occurrence of the event, the log odds of the event:

$$\log\left(\frac{Prob\ (Top\ innovator)}{Prob(non\ Top\ innovator)}\right) = \beta 0 + \underbrace{\beta 1 Market + \beta 2 Institutional + \beta 3 Other_{Sources}}_{External\ Sources} + \underbrace{\beta 4 I_{Coop_{Foreign}}}_{Cooperation} + \underbrace{\beta 5 Licensee + \beta 6 Master + \beta 7 PhD}_{Human\ Capital} + \underbrace{\beta 8 RDcontinuous + \beta 9 Training\_inov}_{Internal\ Knowledge\ Basis} + \underbrace{\beta 10 Machine_{aquisit} + \beta 11 RDexternal}_{External\ Knowledge\ Basis} + \underbrace{\beta 12 IKI * Market + \beta 13 IKI * Institutional + \beta 14 IKI * Other\_sources}_{Internal\ Interaction\ Variable} + \underbrace{\beta 15 EKI * Market + \beta 16 EKI * Institutional + \beta 17 * Other\_sources}_{External\ Interaction\ Variable} + \underbrace{\underbrace{\beta 18 Size}_{size} + \underbrace{\beta 19 Group}_{group} + \underbrace{\beta 20 Multinational}_{multinationality}}_{control\ variables} + \varepsilon i$$

The interpretation of the logistic coefficient can be made as a variation of the logarithmic probability associated with a unit variation in the dependent variable. Thus, the value of *e* raised to β_i is the factor by which the odds change when the i-th independent variable increases one unit. If β_i is positive, the factor will be greater than 1, which means that the odds have increased; if β_i is negative, the factor will be less than 1, which means that the odds have decreased; finally, when β_i is 0, the factor equals 1, leaving the odds unchanged.

4. Empirical Results

4.1. Descriptive results

The percentage of top innovators is higher for the whole set of business activities and lower in metal industry, where only 14% of the companies can be classified as top innovators, that is, which have performed, from 2006 to 2008, more than six distinct types of innovation(see Table 3).

Regardless the industry about 13% of companies uses and considers market sources as very importance external sources of information for innovation, whereas scientific sources are only used and highly relevant for less than 4% of the companies in each industry. The corresponding figure for other external sources is about 6%.

Table 3: Means and standard deviation of the relevant variables by industry

			All activities (# 6593)		Manufacturing (# 3681)		Metal Industries (# 1309)	
			Mean	***St. dev.***	**Mean**	***St. dev.***	**Mean**	***St. dev.***
Top innovator (% companies that performed more than six types of innovation)			**18.2%**	0.386	15.0%	0.357	14.1%	0.348
Oppeness	**External Sources of information for Innovation** (% companies that attribute high importance to…)	**Market**	12.7%	0.244	12.5%	0.244	**12.9%**	0.242
		Scientific	**3.8%**	0.131	3.3%	0.122	3.2%	0.119
		Others	5.9%	0.188	**6.3%**	0.190	6.2%	0.187
	Cooperation (% companies that cooperates with foreign entities…)	**Cooperation**	24.1%	0.950	**25.1%**	0.896	23.4%	0.857
Internal knowledge basis	**Human Capital** (average % of … in total employees)	**Graduate/Licencees**	**14.7%**	0.206	6.8%	0.092	7.8%	0.095
		Master	**0.6%**	0.027	0.2%	0.010	0.2%	0.010
		PhD	**0.2%**	0.024	0.1%	0.008	0.1%	0.006
	Internal knowledge (% companies that performs continuous R&D/have training for innovation)	**Continuous R&D**	**12.4%**	0.330	**12.4%**	0.329	11.7%	0.321
		Tranining for innovation	**34.5%**	0.475	30.9%	0.462	34.3%	0.475
External knowledge basis	**External knowledge** (% companies that acquired machinery and equipment/ performed external R&D)	**Acquisition of machinery and software**	43.2%	0.495	42.5%	0.494	**44.8%**	0.498
		External R&D	**16.4%**	0.370	14.0%	0.347	14.1%	0.348
Control	**Context**	**Size** (average no. employees)	**119**	538.678	79	170.852	70	178.0
		Group (% companies)	**27.2%**	0.445	18.6%	0.389	18.7%	0.390
		Multinational (% companies)	**7.6%**	0.265	5.9%	0.237	6.5%	0.247

Human capital, most notably the percentage of graduate employees is smaller in manufacturing (6.8%) than in metal industry (7.8%), and much smaller than for the whole set of activities (14.7%). The percentage of master and PhD workers is negligible in all

industries, including metals where about 0.3% of employees possess these academic degrees.

Approximately 13% of the companies claimed to have performed continuous internal R&D activities over the period 2006-2008, whereas about one third stated that they have undertaken training activities for innovation.

The acquisition of machinery and software is quite common within the companies surveyed, particularly in metal industry (around 45% of the companies admitted to have acquired machinery and software over the period 2006-2008). A reasonable percentage of companies stated to outsource R&D activities: 16.4% for all activities and 14% in manufacturing and metal industries.

Companies are larger for the group of all activities and smaller for metal industry with an average number of employees in 2008 of 70 individuals. Only 19% of the metal industry companies belong to a group and 6.5% are multinationals.

4.2. Causality analysis

Our main hypotheses are tested for the total of the Portuguese business activities (Models A) as well as the manufacturing industry (Models B) and the Metal industry (Models C). We further consider two situations: one without interaction variables (Models 1) and the other where we included the interaction variables (Models 2). To overcome potential multicollinearity issues arising we estimates one additional set of regressions (Models 3).

4.2.1. Estimated models without interaction variables

The models estimated (see Table 4) present a reasonable goodness of fit, albeit the test of Hosmer and Lemeshow rejects the null hypothesis that the models represent the reality well, the percentage of observations estimated correctly is very high (84%).

Results evidence that in metal industry companies that use and attribute high importance to other external sources of information for innovation (e.g., conferences, trade fairs, exhibitions, scientific journals and/or technical publications professional and industry associations) and that cooperate with foreign entities tend, on average, to outperform the remaining in terms of innovation (see Model C1). However, the importance attributed to market and scientific sources fail to emerge statistically significant. Thus, the first hypothesis (***H1:*** *The use of external sources of information and cooperation for innovation by companies operating in Portuguese metal industry directly and*

significantly impacts on their innovative performance.) is partially corroborated. It is interesting to note that in the case of manufacturing (Model 1B) and all business activities (Model 1A), market related sources matter for companies' innovative performance.

Table 4: Determinants of innovative performance of Portuguese companies, 2006-2008 [dependent variable: the company is a top innovator], excluding interaction variables as determinants

			All		Manufacturing		Metal Industries	
			Model 1A		Model 1B		Model 1C	
			beta	*p-value*	beta	*p-value*	beta	*p-value*
Oppeness	External Sources of information for Innovation	Market	1.107	0.000	0.762	0.005	0.570	0.225
		Scientific	-0.351	0.294	-0.501	0.313	-0.897	0.275
		Others	1.231	0.000	1.686	0.000	2.183	0.000
	Cooperation	Cooperation	0.380	0.000	0.548	0.000	0.365	0.094
Internal knowledge basis	Human Capital	Licencees	0.199	0.000	0.026	0.756	0.019	0.908
		Master	0.243	0.001	0.318	0.032	0.482	0.086
		PhD	-0.211	0.112	-0.166	0.545	0.498	0.496
	Internal knowledge	Continuous R&D	0.454	0.000	0.632	0.000	0.661	0.006
		Tranining for innovation	1.165	0.000	1.098	0.000	1.145	0.000
External knowledge basis	External knowledge	Acquisition of machinery and software	1.231	0.000	1.328	0.000	1.288	0.000
		External R&D	0.632	0.000	0.659	0.000	0.536	0.015
Control	Context	Size	-0.215	0.000	-0.120	0.134	-0.392	0.014
		Part of a Group	-0.196	0.055	-0.493	0.005	-0.002	0.993
		Multinationality	0.371	0.009	0.362	0.123	0.358	0.374
		N	**6593**		**3681**		**1309**	
		Top innovators	5396		3130		1125	
		Others	1197		551		184	
Goodness of fit		**Nagelkerke R^2**	0.391		0.369		0.331	
		Hosmer and Lameshow Test (p-value)	57,718	*0,000*	34,775	0,000	23,086	0,003
		% correct	84,1		86,1		87,9	

Note: Grey cells identify statistically significant estimates.
Source: Own elaboration.

The internal and external knowledge bases, that is, companies' capabilities, emerge as significantly related to innovation performance in all industries. This means that the second hypothesis (***H2:*** *Internal capacities of the companies operating in Portuguese metal industry are positively and significantly related to their innovative performance.*) is strongly validated. For companies operating in metal industries the weight of master employees is the only human capital component that discriminates top innovators from the remaining companies.

4.2.2. Estimated models with interaction variables

As the previous estimate models, the ones with interaction terms (see Table 5) present a reasonable goodness of fit. Albeit the test of Hosmer and Lemeshow rejects the null hypothesis that the models represent the reality well, the percentage of observations estimated correctly is very high (above 81%) and the Nagelkerke R^2 is similar to the models estimated without interaction terms.

Table 5: Determinants of innovative performance of Portuguese companies, 2006-2008 [dependent variable: the company is a top innovator], including interaction variables as determinants

			All		Manufacturing		Metal Industries	
			Model 2A		Model 2B		Model 2C	
			beta	*p-value*	beta	*p-value*	beta	*p-value*
Oppeness	External Sources of information for Innovation	Market	2.644	0.000	1.821	0.004	0.901	0.448
		Scientific	0.885	0.296	-0.348	0.787	-2.834	0.308
		Others	1.498	0.010	2.349	0.003	2.324	0.122
	Cooperation	Cooperation	0.417	0.000	0.568	0.000	0.379	0.085
Internal knowledge basis	Human Capital	Licencees	0.226	0.000	0.019	0.820	0.049	0.770
		Master	0.268	0.000	0.337	0.022	0.480	0.090
		PhD	-0.216	0.103	-0.176	0.518	0.500	0.496
	Internal knowledge	Continuous R&D	0.562	0.000	0.653	0.000	0.723	0.011
		Tranining for innovation	1.187	0.000	1.078	0.000	1.203	0.000
External knowledge basis	External knowledge	Acquisition of machinery and software	1.341	0.000	1.449	0.000	1.245	0.000
		External R&D	0.854	0.000	0.873	0.000	0.465	0.090
Interaction variables	Externals Sources and Internal Knowledge	Market*IKI	-1.730	0.035	-0.702	0.606	-1.270	0.612
		Scientific*IKI	0.024	0.986	-1.286	0.575	1.139	0.814
		Others*IKI	-0.779	0.452	0.484	0.767	-0.235	0.936
	Externals Sources and External Knowledge	Market*EKI	-1.684	0.004	-1.503	0.084	0.087	0.956
		Scientific*EKI	-1.646	0.079	0.676	0.659	2.048	0.483
		Others*EKI	-0.179	0.802	-1.458	0.145	-0.052	0.977
Control	Context	Size	-0.246	0.000	-0.125	0.124	-0.420	0.011
		Part of a Group	-0.190	0.061	-0.479	0.006	-0.030	0.914
		Multinationality	0.336	0.017	0.328	0.161	0.377	0,351
		N	**6593**		**3681**		1309	
		Top innovators	5396		3130		1125	
		Others	1197		551		184	
Goodness of fit		Nagelkerke R^2	0,397		0.372		0.332	
		Hosmer and Lameshow Test (p-value)	35.133	*0.000*	25.599	0.001	21.027	0.007
		% correct	81.8		85.0		88.0	

Note: Grey cells identify statistically significant estimates.
Source: Own elaboration.

These models allow testing the third and fourth hypotheses of our theoretical framework. Results for the metal industry (Model 2C) fail to provide support for the third and four

hypotheses (***H3:*** *The combination between the use of external sources of information and the internal capacities (human capital and internal knowledge - continuous R&D and training for innovation) of the companies operating in Portuguese metal industry is positively and significantly related to their innovative performance./* ***H4:*** *The combination between the use of external sources of information and the external capacities (i.e., acquisition of machinery and software and external R&D) of the companies operating in Portuguese metal industry is positively and significantly related with their innovative performance*). Indeed, the estimate coefficients do not present statistical significant at the standard levels.

A significant and direct impact of external knowledge sources on innovation performance is observed in the case of manufacturing (Model 2B) and all business activities (Model 2A).

4.2.3. Overcoming potential multicollinearity problems

Given the high correlations existing between the external sources and the interaction variables, it is likely that models estimated in Table 5 might suffer from multicollinearity. As such, we estimated two additional models (Models 3C and 4C) in which we removed some independent variables that were correlated with the interaction independent variables (see Table 6).

We removed the external sources as independent variables and used instead their interaction with the internal (see Model 3C in Table 6) and external (see Model 4C in Table 6) knowledge basis of the companies.

There was no evidence of an indirect impact neither of the market sources nor the scientific sources on the innovative performance of the companies. However, the other sources (conferences, trade fairs, exhibitions, professional and industry associations) have an indirect positive impact on companies' innovative performance.

Thus, H3 and H4 are partially corroborated.

The remaining estimates maintained their signs and statistical significance.

Table 6: Determinants of innovative performance of Portuguese companies operating in metal industry, 2006-2008 [dependent variable: the company is a top innovator] - overcoming multicollinearity problems

			Model 1C		Model 2C		Model 3C		Model 4C	
			beta	*p-value*	beta	*p-value*	beta	*p-value*	beta	*p-value*
Oppeness	External Sources of information for Innovation	Market	0.570	0.225	0.901	0.448				
		Scientific	-0.897	0.275	-2.834	0.308				
		Others	2.183	0.000	2.324	0.122				
	Cooperation	Cooperation	0.365	0.094	0.379	0.085	0.400	0.069	0.393	0.074
Internal knowledge basis	Human Capital	Licencees	0.019	0.908	0.049	0.770	-0.056	0.728	0.023	0.888
		Master	0.482	0.086	0.480	0.090	0.454	0.112	0.467	0.098
		PhD	0.498	0.496	0.500	0.496	0.428	0.562	0.511	0.491
	Internal knowledge	Continuous R&D	0.661	0.006	0.723	0.011	0.471	0.065	0.710	0.004
		Tranining for innovation	1.145	0.000	1.203	0.000	1.093	0.000	1.244	0.000
External knowledge basis	External knowledge	Acquisition of machinery and software	1.288	0.000	1.245	0.000	0.575	0.010	0.310	0.190
		External R&D	0.536	0.015	0.465	0.090	1.394	0.000	1.176	0.000
Interaction variables	Externals Sources and Internal Knowledge	Market*IKI	-	-	-1.270	0.612	1.110	0.406		
		Scientific*IKI	-	-	1.139	0.814	-2.034	0.319		
		Others*IKI	-	-	-0.235	0.936	4.973	0.001		
	Externals Sources and External Knowledge	Market*EKI	-	-	0.087	0.956			0.758	0.296
		Scientific*EKI	-	-	2.048	0.483			-0.955	0.374
		Others*EKI	-	-	-0.052	0.977			2.914	0.000
Control	Context	Size	-0.392	0.014	-0.420	0.011	-0.315	0.048	-0.386	0.015
		Part of a Group	-0.002	0.993	-0.030	0.914	0.019	0.945	-0.021	0.940
		Multinationality	0.358	0.374	0.377	0.351	0.320	0.429	0.357	0.380
		N	1309		1309		1309		1309	
		Top innovators	1125		1125		1125		1125	
		Others	184		184		184		184	
Goodness of fit		Nagelkerke R^2	0.331		0.332		0.324		0.326	
		Hosmer and Lameshow Test (p-value)	23.086	0.003	21.027	0.007	17.905	0.022	14.657	0.066
		% correct	87.9		88.0		87.7		88.1	

Note: Grey cells identify statistically significant estimates.
Source: Own elaboration

5. Conclusion

The discussion around which sources of information are more benefic to companies when it comes to their innovation strategies, has received substantial attention in the last years. The diversity of studies targeted mainly the so called high tech industries (Bala Subrahmanya, M.H. 2013), low and medium tech industries (Heidenreich, 2009), manufacturing industries (Castellacci, 2008), and services industries (Pires et al., 2008). All those studies identify that the characteristics of a certain sector in a certain economic environment strongly affect the impact that the sources of information used by companies have in their innovative performance. Thus, the analysis of single industries is on demand. The main goal of the present study is to analyze the metal industry in a peripheral country, Portugal.

Results pointed that companies operating in metal industry which use and attribute high importance to 'other sources' of information for innovation (such as conferences, trade fairs, exhibitions, scientific journals and/or technical publications,and, professional and industry associations) are the ones that have better innovative performance. This result is common to manufacturing and all business activities, but, the strength of the coefficient is higher in the metal industry. Our results are in line with Vega-Jurado et al. (2009) and Corredor et al. (2015).

Another important conclusion that it was possible to reach was that companies that performed training for innovation and continuous R&D activities were able to have the impact of 'other sources' in innovative performance, rise to the double. This conveys that companies that invest in their internal knowledge basis are more prepared to understand and adopt the information that result from those external sources and are able to transform that knowledge into innovations, which then is reflected in the results of the companies, being on sales or even in costs and/or productivity.

Regarding other components of 'Openness', the estimations did not permit to reach any solid conclusions about the relevance of market or the scientific sources of information for innovation in companies' innovative performance. However, and in line with Wassmann et al.'s (2016) study, companies that cooperate with foreign entities are more likely to be a top innovator.

Internal knowledge basis (composed by employees' human capital, training for innovation activities, and continuous R&D) emerged as a positive determinant of the

innovation performance of the companies operating in the Portuguese metal industry. A study done for the UK manufacturing companies undertaken by Frenz & Ietto-Gillies (2009) reached similar results.

Regarding to the education level of employees, licensees and PhD do not evidence to influence the innovation performance of the companies operating in the Portuguese metal industry. In contrast, employees with master degree are significantly and positively associated with innovation performance.

In terms of external knowledge basis, the strongest source of impact in innovation was the acquisition of machinery and software. External R&D activities also have a positive impact but without the strength that the acquisition of machinery and software had. Our results about external R&D are in the same line as Santamaría et al.'s (2009) study focusing the Spanish manufacturing companies.

The results of this dissertation provide decision makers operating in the Portuguese metal industry (or in other industries with similar characteristics) an understanding that the investment in conferences, trade fairs, exhibitions, scientific journals and/or technical publications,and, professional and industry associations, might constitute an effective and efficient way of searching for information usable in their innovative activities. It further demonstrate that the combination of companies' internal and external knowledge bases creates an enhancer context to the use of those sources of information for innovation.

Due to the size of the sample (small) the model that the study uses shows that some interaction variables are correlated, therefore it is not possible to have an accurate measure of the impact that the absorptive capacity really has in the innovative performance that external sources of information may induce into companies.

Future research should address on what are the most adequate investments that companies should do in their knowledge basis structure in order to obtain the most out of external sources of information as well as be more prepared to take better advantage of opportunities in an uncertain and fast changing environment.

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