

DIFFERENTIAL EMPIRICAL INNOVATION FACTORS FOR SPAIN AND THE UK

Authors:

Dr. Mariluz Mate-Sanchez-Val*
Technical University of Cartagena
mluz.mate@upct.es

Professor Richard Harris
Durham University Business School

* Corresponding author

1. Introduction

There is considerable support for the view that innovation (leading to technological progress) is one of the main driving forces of economic growth (Romer, 1990). Increases in R&D investments produce greater knowledge and overall capabilities, which allow different regions to improve the range and quality of their products and processes, leading to higher economic growth (Bilbao-Osorio and Rodríguez-Pose, 2004; Harris, 2011; Nunes et al., 2012). Innovation is a complex process which cannot be fully understood independently of the social and institutional conditions of every country (Asheim, 1999). Therefore, the understanding about the specific national factors influencing the innovation process is a fundamental topic to be considered in order to improve the competitiveness and development in certain areas (Almeida et al., 2011). Based on this result, the European Commission (2002) has designed regional policies to reduce the gap between European countries differentiating between advanced (core) and backward (periphery) countries (e.g. Cabrer-Borras and Serrano-Domingo, 2007). These measures have not seen any major narrowing in performance as was hoped. Thus there is a need for further research to clarify how national differences impact on innovation.

Despite the importance of this topic, empirical studies in this area are scarce and most of them take a macroeconomic perspective when analysing regional differences in what determines innovation (Navarro et al., 2009). For example, the studies by

Castellacci and Archibugi (2008) and Castellacci (2011) look at the role of innovation in growth models, distinguishing between technological clubs in Europe. Regarding the studies which differentiate across countries, there are a wide variety of examples that focus on different variables, such as companies' technological intensity (Heindereich, 2009; Nunes et al., 2012); spillovers (Faria and Lima, 2011); external linkages (Laursen and Salted, 2006; Faria and Schmidz, 2012); and institutional characteristics (Barbosa and Faria, 2011; Ganter and Hecker, 2013). In this context, interregional comparative studies dealing with the effects of the 'region' on innovation activities are mostly absent (Edquist, 2005). The aim of this study is to consider the role of these national differences, derived from structural characteristics in each country, and analyse how they impact on companies' innovation. Our empirical approach is to analyse the effects of the traditional factors impacting on innovation, and measure any differences between two countries: the UK and Spain. We select these countries because they have different structural characteristics. The UK is composed of more advanced regions with better economic development and stronger industrial specialization based on medium-high and high-tech manufactures (Navarro et al., 2009). Spain belongs to the "follower" group of countries in Europe. It is characterised by lower economic and technologically development regions, with lower per capita income than the EU average. Its productive system is based on service (mainly tourism) or agriculture sectors where industry is more 'light weight' in this type of structure. The important gap between these countries, and the political efforts directed to promote innovation in less development European areas, highlights the importance of this study. Our empirical application allows us to identify the particular mechanisms which promote innovation activities in each country and establish the differences between them. For each country, we have access to the European Community Innovation Survey (CIS4). These databases were made available from the National Institute of Statistics (in Spain) and the Office for National Statistics (in the UK). These surveys provide detailed information about innovation activities over the period 2002-2004 of a representative group of companies in each country. Based on this information, we select two samples comprising private manufacturing firms. With the aim of identifying the particular driving factors which characterise the activities of innovation, using a two-step Heckman model of the determinants of R&D expenditure.

Our findings indicate that although the role of traditional explanatory variables is comparable to previous contributions in this area (Rogers, 2004; Arbussa and Coenders, 2007 or Hauge, 2009, among others), the extent to which they affect innovative activities is dissimilar between the two countries, which is associated with the specific characteristics of each country (Fagerberg and Srholec, 2008). Particularly in Spain, public support is more important in promoting innovation activities; whereas linkages with international markets are more important for companies in the UK. Based on these results, we would argue that regional policies to promote innovation in Spain should concentrate more on the promotion of market relationships between co-located firms. Since our results suggest that Spanish firms (and the development of Spanish industries) are at a different stage, with Spain lagging behind the UK in terms of being able to benefit from R&D, greater exposure to internationalisation is also necessary for Spanish firms as well as UK based firms.

This paper is organised into four sections. The next section presents the literature review and our hypotheses to be tested; the third section presents general descriptive characteristics of innovation activity in the UK and Spain. Section 4 presents our empirical application, while the main conclusions are summarised in section 5.

2. Innovation and regional effects.

There is an extensive literature which considers ‘territory’ as an important element in the explanation of firms’ innovation outcomes (Porter, 1998). According to these studies, the specific characteristics of a country result in differences in firms’ capacity to assimilate innovation (Barbosa and Faria, 2011). In this sense, company innovation is not only determined by internal factors but it is also defined by external elements which vary by country (Cooke, 2001). Understanding the mechanisms which generate innovation represents a significant contribution in the design of regional policies to promote economic growth (Rodriguez-Pose, 1999). Despite their importance, studies examining national differences in innovation systems are scarce, and those that exist mostly focus on specific areas and/or take an aggregate approach (Sternberg and Arndt, 2001). Regarding empirical studies focused on European countries, both advanced and backward areas have been observed (Castellacci and Archibugi, 2008; Castellacci, 2011). This division has not only been examined in research papers but it

has also been applied by the European Commission (2002) in policy terms. According to this typology, advanced regions are characterised by productive systems based on medium-high and high tech industrial sectors with high levels of development in innovation activities. Backward regions present low levels of economic and technological development. Their productive systems are usually based on the service sector (mainly tourism) and on agriculture (Navarro et al., 2009), with overall economic performance levels lower than European averages. Dissimilarities between advanced and backward regions may therefore result in differences in the manner in which the factors that determine innovation operate in these different areas, thus influencing firm innovation rates. This leads to our first overall, and more general, hypothesis:

H1: The determinants of innovation are influenced by differences in regional characteristics; the strength of these determinants therefore varies between more advanced and backward regions.

2.1 Factors hampering innovation and regional development

The importance of innovation to enterprise success has provoked an interest in identifying the specific barriers and obstacles that limit the development of these activities. Some of the key factors hampering innovation are derived from environmental characteristics (financial costs, institutional constraints, government policies, lack of finance, lack of customer responsiveness or government regulations) and cannot be controlled by managers (Silva *et al.*, 2008; Barbosa and Faria, 2011). Distinguishing between advanced and backward regions, the former is characterized by companies which take greater advantage of internal resources to increase innovation outcomes, and thus cost factors and the availability of technological information are relatively more important. For example, (Frenz and Ietto-Gillies, 2009) found that information asymmetries were important barriers to innovation for advanced regions. In contrast, companies located in backward regions are affected more by economic deficiencies derived from the characteristics of the external environment (such as lack of qualified personnel, and inefficiencies in market structures) (Navarro et al., 2009). These characteristics impose a more fundamental set of external barriers which have to be overcome in order to improve innovation rates and thus promote economic growth in these less favored areas. It is also likely

that public policies to overcome ‘market failures’, and thus encourage more firms to engage in (and spend more on) innovation, will be different; in advanced regions receiving public support is more likely to mitigate against the initial cost barriers and result in more firms engaging in innovation; in disadvantaged areas public support is less likely to overcome more ‘systemic’ external barriers, and instead encourage firms that do spend on innovation to invest more resources (Dachs and Peters, 2013).

H2a: Barriers identified by enterprises in advanced and backward regions are quantitatively different. Companies in advanced regions are more affected by a lack of internal resources (link to the cost of innovating) whereas restrictions to innovation in more backward regions are dominated by the external structural deficiencies of the economy.

H2b Public support for innovation will impact different on firms in advanced and backward regions.

2.2 Absorptive capacity in different environments

‘Absorptive capacity’ concerns the ability of firms to recognise, internalise and make effective use of (i.e., assimilate) external knowledge (Cohen and Levinthal, 1989); that is, the mere exposure to such knowledge does not guarantee an increase in innovation (Escribano et al., 2009). Following Arbussa and Coenders’ (2007), we recognize two types of absorptive capacity: the use of external knowledge related to new technology, and the capability to integrate this knowledge into a firm’s innovation process. We expect that both internal and external absorptive capacities differ in advanced and backward regions. Companies in advanced regions start with more developed innovation processes; they are more likely to have assimilated external knowledge in the past and their main concern is to integrate and transform this knowledge into their innovation structure (Castellacci, 2011). Higher absorptive capacity allows such firms to profit from external knowledge acquisition, and thus is likely to have a significant impact on innovation activities (Veugelers, 1997). Firms located in backward environments have a less evolved innovation process and are less likely to have invested in raising absorptive capacity in the past; their main objective is to understand external information in order to increase their basic knowledge (Ganter and Hecker, 2013). In this case, the firm’s internal resources to innovation are

scarce and their innovation activities are based on other external flows received from links with other agents (see next sub-section).

H3. Absorptive capacity differs between advanced and backward regions. In advanced regions, absorptive capacity will be more relevant while for backward absorptive capacity plays a much smaller role.

2.3 The intensity of the spill over effects in different regions

Another aspect to be considered in the innovation process is the more general knowledge flows among different agents in a particular location or 'system'. Previous researchers in this area have emphasised the public nature of knowledge that flows freely across agents (Coe and Helpman, 1995). At a micro level, companies interact with other economic agents as well as with their external environments and this result in knowledge transmission. These spillovers may be generated by internal specific characteristics or by external elements related with regional characteristics. The diffusion of knowledge is conditioned upon these elements which determine the intensity of interactions among agents for different regions (Audretsch and Feldman, 2004). Following Rodríguez-Pose and Crescenzi's study (2007), two kinds of factors delimit spillovers among economic agents. The first group is associated with companies' internal characteristics and their internal innovation efforts. In this sense, firms with less innovative capacity tend to search for additional external information, to incorporate it in their innovation process. These companies intensify links with their neighbours who are also involved in innovation (Faria and Lima, 2011). The second group is linked with regional social factors. The relevant variables for this group are related with educational achievement, efficient employment and demographic configuration (Rodríguez-Pose, 1999). We expect to find more intense spillovers effects, based on specific socio economic characteristics, in firms located in regions with more developed social structures. In these areas, links among companies are based on non-market interactions involving the sharing of a general pool of knowledge and expertise within spatial boundaries.

H4: The intensity and type of spillover effects will differ between advanced and backward areas. In advanced areas, interconnections among companies will be based

more on how well-developed is the socio-economic structure of the region. For backward regions, links among companies involved in R&D are more important.

3. Innovation activity in the UK and Spain

Innovation is a complex concept: there is no generally accepted means of quantifying innovation activity. The extant literature has considered input and output measures to evaluate the innovation activities of companies. Input indicators (the focus of this paper) mainly measure resources applied to the innovation process (Carayannis and M. Provan, 2008). These inputs include intellectual, human and technological capital (e.g. Leenders and Wierenga, 2002; Parthasarthy and Hammond, 2002; Carayannis et al., 2006). They also take into account the design of a firm's innovation strategy. Based on this perspective, the OECD (2005) has established a specific classification of innovative activities, which we outline in Table 1 when presenting some basic data for the UK and Spain. This shows the number of companies involved in any kind of R&D activity in the UK is higher than in Spain. The main differences are in intramural, external know-how and training activities.

Insert Table 1

The idea of taking into account these input variables to measure innovation is supported by the fact that high investment in input activities is related to high innovation outputs. Hence, we define input innovative activities in terms of R&D expenditure. In this paper, R&D is limited to only including intra and extra mural spending, plus the acquisition of other external knowledge (i.e., the usual 'Frascati' definition). We base our use of such a narrow definition on the study by Harris and Li (2009), which provides evidence that other kinds of R&D activities are less important in discriminating between high-level outcomes (e.g., innovation and exporting activities).

Table 2 shows the level of R&D expenditure in Spain and the UK, by whether firms innovated or not. According to these results, firms that innovated spent considerably more on R&D on average and have higher R&D intensity levels (i.e. R&D spending

per unit of sales). In addition, Table 2 finds important gaps between the UK and Spain: R&D expenditure in the UK is about twice the Spanish value. In the case of R&D intensity values the difference is even greater.

Insert Table 2

Lastly, we looked at the evolution of innovative activity (measured in terms of R&D expenditure) for the UK and Spain as well as the EU-27 average between 1993 and 2008. Figure 1 shows an upward trend for R&D expenditure in both countries, as well as in the EU-27 average. Nevertheless, the diagram confirms the existence of a considerable technological gap between the UK and Spain.

Insert Figure 1

In summary, our analysis coincides with the previous literature looking at innovative differences among European countries (Griffith et al., 2006). These disparities are more noticeable between Northern and Southern European countries like Spain and the UK. Therefore, it would be useful to understand more fully the causes of such differences in order to intensify efforts to decrease such regional disparities.

4. Empirical analysis

4.1 Data

Information is obtained from the 2005 European Community Innovation Survey (CIS4) administered by the respective governments of the UK and Spain. The purpose of this survey was to collect detailed information from establishments with more than 10 employees about their innovation activities, innovation capacities and innovation outputs for 2002-2004. The survey collected the data using a stratified sample based on employment and sector. Because of legal obligations to complete the questionnaire, the response rate of the Spanish survey was very high (around 94%); in the UK the survey was voluntary and a 55% response rate was achieved.¹ From these

surveys, we have selected private manufacturing firms for Spain and the UK. The importance of analysing the manufacturing sector is explained by its strong relationship with economic growth (Mate et al., 2009). Some authors (e.g., Arbussa and Coenders, 2007; Harris and Li, 2009) have also shown that there generally is a higher probability to undertake R&D activities in the manufacturing sector than in other market-based sectors of the economy. Our representative samples include 5,059 firms from the UK and 10,776 from Spain².

4.2 Variable definitions

Table 3 shows the set of variables we apply in our analysis, along with the source of the data.

Insert Table 3

4.2.1 R&D activities

We use two dependent variables to represent companies' innovation activity: R&D UNDERTAKEN OR NOT and R&D intensity. R&D UNDERTAKEN is a dummy variable which takes the value of one if the enterprise undertakes R&D activities or zero otherwise. R&D INTENSITY is defined as R&D spending per unit of sales in thousands of Euros. R&D spending is defined as intramural R&D, acquired external R&D or acquired other external knowledge. Other spending categories included in CIS4 (such as acquisition of machinery and equipment) have not been included in the analysis, for the reasons set out above.³

4.2.2 Absorptive capacity

There is no direct information on absorptive capacity; nevertheless, the CIS4 databases contain information on sources of information of external and internal knowledge, and the extent to which firms cooperated on innovation, which can be used to measure absorptive capacity (see Table A.1 in the unpublished appendix, available on request). Using this information, we have taken exactly the same approach as presented in Harris and Li (2009), using factor analysis to build different

indicators of internal and external absorptive capacity⁴. Four principal components were obtained based on both the Spanish and UK CIS4 data. In line with previous literature (e.g., Cassiman et al., 2002), these elements are representative of the (1) internal absorptive capacity, related to changes in the business structure of the company and (2) external absorptive measures, consisting of three components (the first one relates to the external knowledge links of the company, and the other two measuring national and international cooperation). In order to test the adequacy for the factors, we compute the overall Kaiser-Meyer-Olkin (KMO) (Kaiser, 1960) criterion for the UK and Spain. KMO values are 88.2% and 87% respectively. Thus, the factors do indeed represent different dimensions of absorptive capacities.

4.2.3 Factors hampering innovation

The CIS4 questionnaire (see Table A.2 in the unpublished appendix) allows us to classify innovation barriers into different categories, as shown in Table 4.

Insert Table 4

Using the questions asked in CIS4, we compute one Likert-type variable for each type of innovation barrier. Respondents were asked to rank the importance of each barrier using on a four-point scale⁵. To ensure the internal consistency of our measures, we compute Cronbach's Alpha (Cronbach, 1951) values for the Spanish and English CIS samples. Both were sufficiently high (0.928 and 0.918, respectively) to conclude that we have adequate measures to evaluate innovation barriers.

4.2.4 Regional effects

We have three measures of interregional effects. Firstly, we have included a dummy variable for each NUT II⁶ region in which firms are located (specifically, the UK consists of twelve NUT II regions, and Spain has seventeen). These take into account regional heterogeneity by accounting for any specific characteristics of the region at a subnational level, which are likely to influence the innovation outcomes of companies located in each area.

Next, we consider *interactions effects* between the firms and their environments from an internal and external perspective (Rodríguez-Pose and Crescenzi, 2006). Internal elements are directly related to innovation activities in the company while the external determinants are associated with socio-economic characteristics.

In order to build a variable representative of *internal spillovers* related to R&D activities in companies, the *standardised index of accessibility to innovation* is applied. This index uses the R&D of neighbour regions to measure the accessibility of extra-regional innovative activities (see equation 1).

$$A_i = \sum_j g(r_j) f(c_{ij}) \quad (1)$$

where A_i is the accessibility of region i , r_j is the activity R to be reached in region j , c_{ij} is the generalised cost of reaching region j from region i , and $g(\cdot)$ and $f(\cdot)$ represent *functions of activity* (activities/resources to be reached) and *impedance* (cost/opportunity to reach the specific activity). In our case, the activity to be reached is defined in terms of R&D expenditure (in thousands of Euros) while the definition of the impedance function is based on bilateral distance:

$$f(c_{ij}) = \frac{1}{d_{ij}} \quad (2)$$

$$\sum_j \frac{1}{d_{ij}}$$

In this case d_{ij} is the metric distance (in kilometres) between the centroids of regions i and j . To compute the distance variable we obtained the coordinates of the centroids of each NUT II region (using European Commission data), basing distance on the Euclidean distance between two points⁷. The accessibility index was then standardised.

Lastly, external spillovers linked to social economic characteristics in neighbour regions were computed using the concepts of a *social filter* and an *accessibility index*. This is a composite index which includes a set of variables describing the socio-economic characteristics of a region. According to Malecki (1997), Fagerberg et al. (1997) and Rodríguez-Pose (1999), the most relevant variables to include are

educational achievement, productive employment of human resources, and demographic structure. To quantify educational achievement we used the percentage of the population having completed higher education. Productive employment of human resources was measured by the percentage of employees in the agriculture sector and the unemployment rate. Finally, to take into account demographic structure, we used the percentage of the population aged between eighteen and sixty years.⁸ In order to obtain the social index for each country we undertook a Principal Component Analysis for each sample. In both cases, the first principal component represented around a 50% of the total variance. Therefore, the social indexes were computed and standardised taking into account the scores of this first principal component. Finally, a second variable representative of the external influence of socio-economic conditions was computed, using an *accessibility index* (i.e., equations (1) and (2)) but with the *social index* just outlined used to define the *activity function*, $g(r)$.

4.2.5 Control variables

The *size* of the company is defined in terms of the number of employees recorded in the CIS4 questionnaire. Based on this information, we compute five dummy variables which take the value of one if the company belongs to the corresponding size category (and zero otherwise). We control for size because previous studies have concluded that innovation performance might depend on economies of scale (Cockburn and Henderson, 1994). Industrial sector is controlled to capture inter-industry differences in opportunities. In particular, firms located in technologically advanced subsectors usually report the highest rates of innovation (Arbussa and Coenders, 2007). We converted the Spanish CNAE (National Classification of Economic Activities) code into the more general SIC (Standard Industrial Classification) codes so as to get a homogeneous classification in both countries. Using this harmonised classification, we built a set of seventeen dummy variables⁹ representing each sector.

Based on Veugelers (1997) and Cassiman and Veuglers (1998), we control for the complementarity of R&D activities adopted by each company. Companies have the option to choose various approaches to undertaking R&D, akin to ‘make’ and/or ‘buy’ decisions, where they can undertake R&D themselves and develop their own

technology (intramural R&D) and/or source externally (extramural R&D and/or licence know-how). To acquire a technology they can also choose to cooperate in joint-R&D activities with other firms. Hence, we have classified establishments in the CIS datasets into those that undertake ‘make’, ‘buy’ or ‘cooperate’ decisions (or any combination of these three options).¹⁰ These variables take the value of one if the firm has undertaken the specific type of complementary R&D activity, or zero otherwise.

We also control for the internationalization of the company, using two dummy variables (NATIONAL and INTERNATIONAL) based on the CIS question about the geographical market in which the enterprise sells its product. Finally, we consider whether the company received public support to promote innovation activities (Acs et al., 1994; David et al., 2000).

4.3. Econometric analysis

In order to determine the influence of the different factors affecting innovation activities for Spain and UK, we use the Heckman (1979) approach. This methodology is based on a two step procedure: the first regression has R&D UNDERTAKEN OR NOT as the dependent dummy variable, and the second estimation has R&D INTENSITY as the dependent variable and introduces a correction bias to account for potential sample selection issues. This approach recognises that those companies that innovate are not a random sub-set of the entire sample; rather, modelling R&D intensity needs to consider that those with non-zero innovation levels have certain characteristics that are also linked to a company’s ability to innovate. Failure to take into account this self selection element would lead to results that suffer from selection bias.¹¹

The unit of observation in our study is the firm. To select the relevant variables to be retained in each equation, we used the ‘from-general-to-specific’ methodology proposed by Hendry (1993). Thus, non-significant variables are dropped, with the final model tested against the most general to ensure that the null hypothesis (that dropped variables are statistically unimportant) is accepted.

Insert Table 6

Insert Table 7

Our results (see Table 6 and 7 for details) generally corroborate the hypotheses as set out in Section 2. Firstly, the parameter estimates of the coefficients obtained are generally different when comparing the regression results for the UK and Spain.¹²

Secondly, *factors hampering innovation* are different for Spain and the UK. In the UK, these factors are more strongly related to financial costs and the lack of technological information, while in Spain there is a closer association with institutional and market-based factors. The support received from government exerts a positive effect on R&D activities in both countries (Bilbao-Osorio and Rodríguez-Pose, 2004), but with different impacts in terms of the effect on whether to engage in R&D and how much to spend on R&D. Public sector support is more prevalent in Spain (Table 5) and its effect is much more influential in terms of increasing the amount invested in R&D activities. For the UK, this variable is relatively more important in overcoming the initial barriers to undertaking innovation.

The *Absorptive capacity* coefficients confirm that higher values have a positive effect on R&D activities, but that this differs between countries (Castellacci, 2011). In the UK, absorptive capacity is associated with international (and to a lesser extent national) cooperation and knowledge links (Ianmarino et al., 2013); whereas, in Spain, the role of absorptive capacity is much smaller.

Spatial variables (location and spillover effects) are relevant in both countries (Faria and Lima, 2011), but again with interesting differences that support the hypotheses set out in Section 2. In the UK, firms in Northern Ireland are (8.4%) less likely to undertake R&D activities motivated by the lack of development in this area (Harris, Li and Trainor, 2009). In Spain, firms in Catalonia or the Basque Country have (cet. par.) a (2-2.5%) higher probability of engaging in R&D. These areas correspond to the most productive Spanish regions (Mate et al., 2009). Spillover effects are positive and significant although their relative importance are different between the two countries. For the UK, firms' innovation is positively influenced by the socio-economic characteristics of surrounding regions (Frenz and Ietto-Gilles, 2009). According to Rodríguez Pose and Crescenzi (2008) this kind of interaction is only significant if the internal socio-economic characteristics of the analysed region are

also good. For the Spanish case, socio-economic characteristics are not the main mechanism for transmitting knowledge to generate higher innovation; rather, it is directly driven by the amount of R&D undertaken in neighbouring firms. Thus, innovation spillovers in the Spanish case are more likely to be pecuniary and based on market (i.e., buyer-seller) transactions, while those in the UK appear to be linked more with non-pecuniary spillovers which are based on non-market interactions usually involving the sharing of a general pool of knowledge and expertise across spatial boundaries.

Regarding our control variables, our results are generally as expected. In accordance with Cohen and Kleper (1996) we obtain a positive and significant relationship between *size* of the firm and the probability of undertaking R&D activities. Such size effects are more noticeable for Spanish than for UK firms with over two hundred employees. This result is explained by the productive characteristics of the different countries; for example, Spain has generally smaller size firms than the UK (see Table 5). Regarding the importance of *industrial subsector*, we find that, in both countries, firms located in more technological subsectors have a higher probability of undertaking R&D activities (Arbussa and Coenders, 2007; Nunes et al., 2012).

The variable *destination of sales* indicates that firms involved in exporting activities are more likely to undertake R&D in both countries. This result coincides with previous contributions (Wakelin, 2001; Laursen and Salted, 2006). Finally, concerning the *complementary of R&D activities*, firms that only “buy R&D” (i.e. firms that only acquire R&D from external sources) have lower innovation rates than companies that combine these activities. This is in contrast with firms that both undertake intra-mural R&D (i.e., carry out their own R&D) and extra-mural R&D; it can be argued (Veugelers, 1997) that simply buying-in R&D is indicative of lower levels of absorptive capacity leading overall to less R&D being undertaken. For Spain, the negative relation between the “buy only” variable and R&D intensity is much greater. Moreover, we also found that the combination of different innovative activities (own, acquired and/or cooperational R&D) in Spain exerts a *negative* influence on firms’ R&D intensity which is not an expected outcome. It would seem that in Spanish firms the use of extra-mural R&D acts as a substitute for internal R&D; this could help to explain why absorptive capacity is of less importance in

Spain, as well as its lower level of R&D overall (cf. Table 1 which confirms that Spain has much lower intra-mural R&D; and Figure 1).

5. Conclusions

The aim of this paper has been to consider which factors explain differences between Spanish and British innovation activities at the firm-level. To achieve this purpose we used a two-step Heckman model in each country, based on homogeneous information taken from the European Community Innovation Survey. Initially we determined which factors exert an influence on the probability of undertaking R&D activities. Conditional on this, and thus taking into account the possible selection bias generated by a firm's decision to engage in R&D, we analysed the factors that foster R&D intensity.

Although this study is a contribution to previous research that focuses on the determinant of innovation at the firm level, it goes further to draw attention to the role of location as an additional factor to be emphasised in explaining differences between technologically advanced and backward regions. Previous studies that look at the importance of location are mostly based on aggregate information, or simply include the spatial factor as an additional control variable (Navarro et al., 2009). Our contribution to filling the gap in the literature involves us in examining and thus confirming that the innovation process depends also on the country in which a company operates. In general, we find that the *signs* of the common variables used in our analysis are in accordance with previous studies for Spain and the UK (Rogers, 2004, Arbussa and Coenders, 2007, Hauge 2009; Ianmarino et al., 2013) but, in addition, we find that the strength of the impact of different determinants is not the same. In the UK, the level of absorptive capacity has a much stronger impact on innovation (especially international cooperation and external knowledge links). Because the UK is more advanced in terms of R&D and innovation, companies rely more on external information as an additional resource to improve their innovation processes (Frenz and Ietto-Gillies, 2009). Another factor leading to better innovation results in the UK relates to the socio-economic characteristics of surrounding areas (Rodríguez Pose and Crescenzi, 2008). In this way, advanced regions dependent more

on absorptive capacity also require thriving environments with good economic conditions to strengthen innovation (Castellacci, 2011).

In contrast, Spain is a country with a less developed infrastructure; pro-innovation factors are more strongly associated with institutional and market advances (Fagerberg and Srholec, 2008). Fewer Spanish firms engage in undertaking any R&D, and those that do are more likely to specialise in particular (traditional) industrial sectors. The importance of absorptive capacity is also much weaker in determining which firms in Spain engage in R&D, compared to the UK. Once firms have overcome R&D barriers, the R&D intensity of Spanish companies is much more likely to be driven by the availability of public support (the latter is more important in helping firms overcome R&D entry barriers in the UK than in Spain). Spillover effects are more likely to depend on links with other innovative firms in nearby regions, rather than the overall socio-economic characteristics of surrounding areas.

Our findings provide some suggestions for politicians and managers in order to increase innovation rates in each country. In the UK, politicians may direct more of their efforts to support the economic and social structures in their relatively less advanced areas. This measure helps to ensure that there is an adequate environment for companies which undertake R&D activities. Managers need to recognise the importance of internationalization in order to promote new innovation activities (Harris and Li, 2009). Our results point to external information imported from other regions and countries as a key factor that improves innovation in advanced regions. In Spain, reforms to promote innovation should be orientated towards improving the internal capabilities of firms. Public support should be focused on helping companies to modernize their productive systems including, current technological tools, and not in providing them with substitute resources for buying-in external R&D. Links with near-by companies are also important to strength internal knowledge and encourage innovation. Therefore, managers should establish more relationships with companies characterised by high innovation outcomes.

This study also faced some limitations which could be considered for future research. First, the CIS 4 database provides information for the period 2002-2004. Further studies are needed using current information to confirm our results. Second, our research confirms differences in firms' innovation only between Spain and the UK.

Following European Commission (2002) classification (core-periphery European countries), the next step in our research will be to compare our findings against more European countries, answering the question: Are there general behaviours in the firms' innovation processes in core European countries in comparison with periphery countries?.

References

- Acs, Z. Audretsch, D.B. and Feldman, M., 1994. R&D spillovers and recipient firm size. *Review of Economics and Statistics*, 76 (2), 336–340.
- Almeida, A., Figueiredo, A. and Rui-Silva, M., 2011. From concept to policy: Building regional innovation systems in follower regions. *European Planning Studies*, 19(7), 1331-1356.
- Arbussa, A. and Coenders, G., 2007. Innovation activities, use of appropriation instruments and absorptive capacity: Evidence from Spanish firms. *Research Policy*, 36(10), 1545-1558.
- Artz, K.W; Norman, P., Hatfield, D. and Cardinal, L., 2010. A Longitudinal Study of the Impact of R&D, Patents, and Product Innovation on Firm Performance. *Journal of Product Innovation Management*, 27,725–740.
- Asheim, B. and Gertler, M., 2005. The geography of innovation. Regional Innovation Systems. *The Oxford Handbook of Innovation*, 291-317. Oxford University Press
- Audretsch D.B. and Feldman M., 2004. Knowledge Spillovers and the Geography of Innovation, in Henderson J.V. and J.F. Thisse. *Handbook of Urban and Regional Economics*, 4, 2713-2739. Elsevier, Amsterdam.
- Barbosa, N.; Faria, A.P., 2011. Innovation across Europe: How important are institutional differences?. *Research Policy*, 40(9), 1157-1169.
- Bilbao-Osorio, B. and Rodríguez-Pose, A., 2004. From R&D to innovation and economic growth in the EU. *Growth and Change*, 35(4), 434-455.
- Cabrer-Borras, B. and Serrano-Domingo, G., 2007. Innovation and R&D spillover effects in Spanish regions: A spatial approach. *Research Policy*, 36 (9), 1357-1371.
- Carayannis, E., Popescu, D, Sipp, C. and Stewart, M., 2006. Technological learning for entrepreneurial development (TL4ED) in the knowledge economy (KE): case studies and lessons learned. *Technovation*, 26, 419–443.

- Carayannis, E. and Province, M., 2008. Measuring firm innovativeness: towards a composite innovation index built on firm innovative posture, propensity and performance attributes. *International Journal of Innovation and Regional Development*, 1(1), 90-107.
- Cassiman, B., Perez-Castrillo, D and Veugelers, R., 2002. Endogenizing know-how flows through the nature of R&D investments. *International Journal of Industrial Organization*, 20(6), 775-799.
- Castellacci, F., 2011. Closing the Technology Gap?. *Review of Development Economics*, 15(1), 180-197.
- Castellacci, F. and Archibugi, D., 2008. The technology clubs: The distribution of knowledge across nations. *Research Policy*, 37(10), 1659-1673.
- Cockburn .M, and Henderson, M., 1994. Racing to Invest? The Dynamics of Competition in Ethical Drug Discovery. *Journal of Economics and Management Strategy*, 3, 481-519.
- Coe, D. and Helpman, E., 1995. International R&D spillovers. *European Economic Review*, 39(5), 859-887.
- Cohen, W. and Levinthal, D., 1990. Absorptive Capacity: A new perspective on learning and innovation. *Administrative Science Quarterly*, 35, 128-152.
- Cohen, W. and Klepper, S., 1996. A Reprise of Size and R&D. *Economic Journal*, 106(437), 925-51.
- Cooke, P., 2001. Knowledge Economies: Clusters, Learning and Co-operative Advantage. *London, Routledge*.
- Cronbach, L. J., 1951. Coefficient alpha and the internal structure of tests. *Psychometrika*, 16, 297-334.
- Dachs, B. and Peters, B., 2013: Innovation, employment growth, and foreign ownership of firm. *Research Policy*, Online publication.
- David, P., Hall B. and Toole, A., 2000. Is public R&D a complement or substitute for private R&D?. A review of the econometric evidence. *Research Policy*, 29, 497-529.
- Edquist, C., 2005. Systems of innovation. Perspectives and challenges, 181-208. *The Oxford Handbook of Innovation*. Oxford University Press.
- Escribano, A., Fosfuri, A. and Tribo, J., 2009. Managing external knowledge flows: the moderating role of absorptive capacity, *Research Policy*, 38, 96–105.
- European Commission, 2002. Towards a European Research Area. Key Figures 2002. *Luxembourg: Office for Official Publications of the European Communities*.

- Fagerberg, J., Verspagen, B., and Caniels, M., 1997. Technology, growth and unemployment across European Regions. *Regional Studies*, 31 (5), 457-466.
- Fagerberg, J. and Srholec, M., 2008. National Innovation Systems, Capabilities and Economic Development. *Research Policy*, 37, 1417-1435.
- Faria, P. and Lima, F., 2012. Interdependence and spillovers: is firm performance affected by others' innovation activities?. *Applied Economics*, 44, 4765-4775.
- Faria, P. and Schmidt, T., 2012. International cooperation on innovation: firm-level evidence from two European countries. *Innovation: Management, Policy and Practice*, 14(3), 2120-2162.
- Frenz, M. and Ietto-Gillies, G., 2009. The impact on innovation performance of different sources of knowledge: Evidence from the UK Community Innovation Survey. *Research Policy*, 38(7), 1125-1135.
- Ganter, A. and Hecker, A., 2013. Persistence of innovation: Discriminating between types of innovation and sources of state dependence. *Research Policy*, 42(8), 1431-1445
- Gil-Canaleta, C., Pascual-Arzo, P. and Rapún-Gárate, M., 2002. Structural change, infrastructure, and convergence in the regions of the European Union. *European Urban and Regional Studies*, 9, 115-135.
- Griffith, R.; Huergo, E.; Mairesse, J. and Peters, B., 2006. Innovation and Productivity Across Four European Countries. *Oxford Review of Economic Policy*, 22(4), 483-498.
- Harris, R. and Li, Q., 2009. Exporting, R&D and Absorptive Capacity in the UK Establishments. *Oxford Economic Papers*, 61, 74-103.
- Harris, R., Li, Q. and Trainor, M., 2009. Is a higher rate of R&D tax credit a panacea for low levels of R&D in disadvantaged regions?. *Research Policy*, 38 (1). 192-205.
- Harris, R., 2011. Models of Regional Growth: Past, Present and Future. *Journal of Economic Surveys*, 25(5), 913-951.
- Iammarino, S., Piva, M., Vivarelli, M. and Tunzelmann, N., 2012. Technological Capabilities and Patterns of Innovative Cooperation of Firms in the UK Regions. *Regional Studies*, 46(10), 1283-1301.
- Hauge, A., 2009. Knowledge economies: innovation, organization and location. *Journal of Economic Geography*, 9(2), 285-287.
- Heckman, J., 1979. Sample selection bias as a specification error. *Econometrica*, 47, 153-61.

- Heidenreich, M., 2009. Innovation patterns and location of European low- and medium-technology industries. *Research Policy*, 38, (3), 483-494.
- Hendry, D., 1993. *Econometrics: Alchemy or Science? Essays in Econometric Methodology*. Oxford, UK and Cambridge, USA.
- Kaiser, H. F., 1960. The Application of Electronic Computers to Factor Analysis. *Educational and Psychological Measurement*, 20, 141-51.
- Laursen, K., and Salter, A., 2006. Open for Innovation: The role of openness in explaining innovation performance among UK manufacturing firms. *Strategic Management Journal*, 27(2), 131-150.
- Leenders, M. and Wierenga, B., 2002. The effectiveness of different mechanisms for integrating marketing and R&D. *Journal of Product Innovation Management*, 19, 305-17.
- Malecki, E., 1997. Technology and Economic Development: The Dynamics of Local, Regional and National Competitiveness. *Addison Wesley Longman: London*.
- Mate, ML; García-Pérez-Lema D and López-Hernández F., 2009. Spatial effects in the productivity convergence of Spanish industrial SME's. *Spanish Journal of Finance and Accounting*, 141, 13-36.
- Navarro, M., Gibaja, J., Bilbao-Osorio, B. and Aguado, R., 2009. Patterns of innovation in EU-25 regions: a typology and policy recommendations. *Environment and Planning C: Government and Policy* (27): 815-840.
- Nunes, P., Serrasquero, Z. and Leitao, J., 2012. Is there a linear relationship between R&D intensity and growth?: Empirical evidence on non-high-tech vs high-tech SMEs. *Research Policy*, 41(1), 36-53.
- OECD, 2005. *The Measurement of Scientific and Technological Activities: Guidelines for Collecting and Interpreting Innovation Data: Oslo Manual, Third Edition*. Prepared by the Working Party of National Experts on Scientific and Technology Indicators, *OECD, Paris*.
- Parthasarthy, R., and Hammond, J., 2002. Product innovation input and outcome: Moderating effects of the innovation process. *Journal of Engineering and Technology Management*, 19(1), 75-91.
- Porter, M.E., 1998. *On competition*. Boston: *Harvard Business School*.
- Rodriguez-Pose, A., 1999. Innovation prone and innovation averse societies. Economic performance in Europe. *Growth and Change*, 30, 75-105.
- Rodriguez-Pose, A. and Crescenzi, R., 2006. R&D, spillovers, innovation systems and the genesis of regional growth in Europe. *Regional Studies*, 42(1), 51-67.
- Rogers, M., 2004. Networks, Firm Size and Innovation. *Small Business Economics*, 22(2), 141-153.

- Romer, P., 1990. Endogenous technological change. *Journal of political economy*, 98(II), 71-102.
- Silva, M.; Leitao, J. and Raposo, M., 2008. Barriers to innovation faced by manufacturing firms in Portugal: how to overcome it for fostering business excellence?. *International Journal of Business Excellence*, 1, 92-105.
- Sternberg, R., and Arndt, O., 2001. The Firm or the Region: What Determines the Innovation Behaviour of European Firms?. *Economic Geography*, 77(4) 364-382.
- Vance, C. 2009. Marginal effects and significance testing with Heckman's sample selection model: a methodological note. *Applied Economic Letters*, 16(14), 1415-1419.
- Veugelers, R., 1997. Internal R&D expenditures and external technology sourcing. *Research Policy*, 26, 303-315.
- Wakelin, K., 2001. Productivity growth and R&D expenditure in the UK manufacturing firms. *Research Policy*, 30(7), 1079-1090.

¹ Population weights are calculated for both datasets so ensure that the results from the surveyed firms who responded are representative of the respective populations of firms operating in each country.

² See http://www.ine.es/daco/daco42/daco4221/ite_cues04.pdf and <http://www.bis.gov.uk/assets/biscore/corporate/migratedd/publications/f/file9688.pdf> for a copy of CIS4 questionnaires for Spain and UK respectively.

³ Note, we find that they do not substantively alter the results

⁴ Detailed results for the factor analysis are available from the authors; as stated, our approach follows closely that given in Harris and Li (2009) p.10.

⁵ (1) Factor not experienced, (2) factor experienced at a low level, (3) experienced at a medium level and (4) experienced at a high level.

⁶ NUT II follows the EUROSTAT regional classification (2008).

⁷ We also computed the Harvesine expression developed to calculate the distance between two points in a sphere, but there were no differences between the results obtained because we are considering short distances.

⁸ These variables were obtained from the corresponding National Institutes of Statistics for Spain and the Office for National Statistics for the UK.

⁹ Fosfuri and Tribo, (2008) show the correspondence between CNAE and SIC codes. We have seventeen dummy variables representing: ind1 'mining and quarrying'; ind2 'food and drink'; ind3 'textiles'; ind4 'clothing, leather and footwear'; ind5 'wood products'; ind6 'paper'; ind7 'publishing & printing'; ind8 'chemicals'; ind9 'rubber and plastics'; ind10 'non-metallic minerals'; ind11 'basic metals'; ind12 'fabricated metals'; ind13 'machinery and equipment'; ind14 'electrical machinery'; ind15 'medical etc instruments'; ind16 'motor and transport'; ind17 'furniture and other manufacturing'.

¹⁰ The 'make' sub-group engaged in intramural R&D spending; the 'buy' sub-group either acquired external R&D and/or acquired other external knowledge. These categories have been discussed in Table 1. The 'cooperation' sub-group comprised those that they had co-operative arrangements on innovation activities with another (i.e. not their own) enterprise or institution during 2002-2004.

¹¹ Note, the use of the Heckman sample selectivity approach is not about separating out the R&D decision into two stages; the two parts of the Heckman model are estimated simultaneously using a FIML approach.

¹² We tested whether the estimates were statistically significantly different by pooling the two datasets and introducing a common set of regressions plus composite variables where each regressor was multiplied by a dummy variable (coded 1 for Spain and 0 for the UK). We were only unable to reject the null at the 5% level for the following variables: both employment size variables and destination of sales in Table 6, and the food & drinks and wood products dummies, plus national cooperation absorptive capacity in Table 7.