Quantity or quality? What do academic R&D funds promote?

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Abstract

Despite the high amount of public funds allocated to academic research and development (R&D), only a few studies have provided systematic evidence on the effects of such investment. This paper aims to contribute to this literature with an analysis of the effects of academic R&D funds on the scientific production at regional scale. Our research questions
are divided in two groups. The first group encompasses some questions related to the spatial pattern of regional scientific production and R&D funds. The second group aims to analyse the role of Higher Education R&D (HERD) expenditures on the quantity and quality of scientific output. The dataset used in our analysis consists of a regionalized sample of 994,938 scientific papers by authors affiliated with European universities from 1998 to 2004. The data were obtained from the Thomson ISI (Information Sciences Institute) database and include papers in collaboration from all scientific fields (except the social sciences and humanities) for over 500 European universities at the NUTS II level of regional aggregation. The quality is proxied by the number of citations a paper receives in subsequent papers: this data was aggregated at regional level. The methodology involves a descriptive analysis and several econometric models. The empirical model is based on a regional knowledge production function estimated with an unbalanced sample of European regions for the period 1998 to 2004.

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Quality or quantity? What do academic R&D funds promote?

Abstract: Despite the high amount of public funds allocated to academic research and development (R&D), only a few studies have provided systematic evidence on the effects of such investment. This paper aims to contribute to this literature with an analysis of the effects of academic R&D funds on the scientific production at regional scale. Our research questions are divided into two groups. The first group encompasses some questions related to the spatial pattern of regional scientific production and R&D funds. The second group aims to analyse the role of Higher Education R&D (HERD) expenditures on the quantity and quality of scientific output. The dataset used in our analysis consists of a regionalized sample of 994,938 scientific papers by authors affiliated with European universities from 1998 to 2004. The data were obtained from the Thomson ISI (Information Sciences Institute) database and include papers in collaboration from all scientific fields (except the social sciences and humanities) for over 500 European universities at the NUTS II level of regional aggregation. The quality of academic papers is proxied by the number of citations they receive in subsequent papers: this data was aggregated at regional level. The methodology involves a descriptive analysis and several econometric models. The empirical model is based on a regional knowledge production function estimated with an unbalanced sample of European regions for the period 1998 to 2004. The paper is organized as follows. In Section 1, we stress the relevance of the topic and outline the objectives. In Section 2, we review the literature on this topic. Section 3 establishes the methodology. Section 4, describes the data collection process. Section 5 provides the results. The main conclusions and policy implications are obtained at the end of the paper.

1. Introduction

The identification of academic scientific capabilities is important for regional and supranational governments that must decide scientific priorities and the allocation of funds. This issue is particularly relevant in Europe, where there is an intense debate about how the current situation and trends in research could have a negative influence on competitiveness and employment in the years ahead (ECE, 2000, 2007). Moreover, from a political view, the publication of the Commission’s paper on the European Research Area-ERA in (2000) has stressed the importance of regions in the development of research and innovation capacity within Europe.

The ERA initiative specifically identifies a role for the regional scale in achieving its objectives (see ECE, 2001) and, among others, funding mechanisms are considered relevant instruments in shaping quantity and quality of research (Dominics, 2011). However, while there is some evidence of the short-term usefulness of R&D incentives at country level to promote scientific research (Griliches.. Geuna), regional-specific information seems to be largely missing in the literature. In this paper we fill this gap by providing some insight on the scientific production across European regions. Additionally we particularly focus on the role of financial funds in promoting academic scientific production at regional level.
The methodology involves a descriptive analysis and several econometric models to estimate the impact of university funds in encouraging the production of science in European regions.

This paper contributes to the literature in several ways. First, despite the relevance of some economic aspects involving research activities in universities (see the surveys by Dasgupta and David, 1994; Stephan, 1996), the empirical literature concerning the production of science in universities at regional scale is very scarce and this paper gives new evidences on this topic. Second, we use new data; we address our research question by using an original database of regionalised academic published papers retrieved from the ISI Web of Knowledge. The data contains about one million papers for the period 1998-2004 classified by regions in Europe 15 (NUTS II level of aggregation, see the Appendix for details of the type of regions). Third, from a political view, it provides to policy makers a direct contribution to mapping science and the role of academic R&D funds, and thus some clues for a better knowledge of the European Research Area.

The paper is organized as follows. Section 2 summarizes the literature relevant to this paper. Section 3 describes the data and provides an overview of the patterns of university scientific production at regional level across Europe 15. Section 4 presents a regional version of a knowledge production function and the estimations of several models explaining the effects of R&D expenditures on the production of scientific knowledge are provided. Section 5 summarizes the main findings. Section 6 concludes with a brief discussion of policy implications.

2. The role of university R&D funds in encouraging research performance

This literature review is organized around two relevant questions for this paper: (i) why university research in regions is important? (ii) what is the role of R&D expenditure in explaining the production of science?

The positive effects of universities in regions may occur through a variety of university outputs that potentially have important impacts on regional economic development. In this paper we focus on one of these outputs: the production of scientific knowledge. University scientific knowledge may have an influence on innovation in regions in different ways. On the one hand, there is a potential direct contribution when a university produces useful new scientific knowledge with applications to the industrial processes. The papers by Mansfield (1991; 1998), Mansfield and Lee, (1996), Cohen et al., (1998), Beise and Stahl, (1999), among others, have emphasized that knowing the characteristics of science production in universities and their underlying mechanisms is useful for their direct implications in the development of industrial innovations. On the other hand, the production of university knowledge may have an indirect contribution to regional innovation due to the flow of knowledge between universities and firms. This knowledge interactions can take place through a variety of channels between academics and firms (when reading scientific papers, or via direct conversation or informal meetings with the inventors, etc.) The flow of knowledge has important potential benefits for regions because of spillovers from university to industry affecting not only technology, but other relevant variables for the economic system (see for instance, Agrawal (Jaffe, 1989; Jaffe et al., 1993; Anselin et al., 1997; Anselin et al., 2000;
Verspagen and Schoenmakers, 2000; Maurseth and Verspagen, 2002; Acosta and Coronado, 2003; Agrawal and Cockburn, 2003; Fischer and Varga, 2003; Audretsch et al., 2005; Calderini and Scellato, 2005; Abramovsky et al., 2007; Acosta et al., 2011b). The proliferation of a consistent literature illustrating the importance of physical proximity for knowledge flows and for the promotion and development of innovation and new firm formation, along with the high degree of self-government enjoyed by many European regions, makes it clear that the study of university knowledge is relevant not only in national or supranational contexts but also at the regional level.

This literature has addressed the production of knowledge in universities from the perspective of their consequences, and overall it stress that the production of academic knowledge in general, and scientific knowledge in particular, is important for the economic system. We assume then, that the stronger the capacities for production of knowledge, the more beneficial their effect should be. However, little is known about the causes leading to strengthen these scientific capacities and particularly, the effects of the amount of R&D that universities receive. In the following paragraphs we summarize the main results obtained so far about the effects of funds on the production of science.

Only a few papers have addressed this issue from an empirical economic view.¹ In this brief review we summarize previous results relevant to our research; particularly our focus of attention on the role of university R&D expenditures in promoting the production of science in universities.

A couple of papers by Adams and Griliches (1996; 1998) were one of the early attempts to measure the relation between inputs (R&D expenditure) and outputs (scientific publications and citations) from an economic view. Their point of departure was the evidence of a discrepancy between the growth of R&D expenses (5.5% per year in real terms) and the total number of scientific articles (1% per year) for the United States during 1981-1991. Several regressions using different lags for R&D provided average elasticity of 0.6 for papers and 0.7 for citations at the university and field level, suggesting the possibility of diminishing returns to scale. However, the results were possibly biased because, as the author remarked, spillover effects among universities and fields were not taken into account and the difference in elasticities with more aggregated models was possible there. Therefore, serious data limitations and difficulties hindered the authors from drawing firm conclusions.

In subsequent research, Adams et al.(2005) studied the size of scientific teams and institutional collaboration with data derived form 2.4 million scientific papers written in 110 top U.S. research universities that had at least one author form this set of leading US universities. Their analysis was carried out over the period 1981-1999. The source of their data was the Institute for Scientific Information (ISI). They found positive and highly significant coefficients of the logarithm of the lagged stock of R&D (with values around 0.45 for the equation of log (papers) as dependent variable, and 0.55 for the

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¹ A stream of literature focussed on the individual productivity of researchers has sometimes considered R&D funding as an “environmental attribute”, along with other personal characteristics (researcher sex, age, education, etc.) and institutional attributes of the institutions for which those researchers work (see for instance, Arora et al., 1998; Cesaroni and Gambardella, 2003; Carayol and Matt, 2006); however, this growing literature is far from the view follows in our paper.
equation of log (citations) as dependent variable), suggesting diminishing returns to the stock of R&D applied at the university-field level.

Following a similar methodology to Adams and Griliches (1998), Crespi and Geuna (2008) examined the determinants of scientific production at cross-country level. Their data contained a sample for 14 countries and 21 years (1981-2002) for which the authors had information on higher education research and development (HERD). The outputs were taken from the Thomson ISI national science indicators database on published papers and citations. This research differs from Griliches and Adams (1998) in several points (different structure of data, context, etc.), but mainly in considering spillover effects of higher education R&D in the original knowledge production function. Assuming the difficulties for obtaining robust results for elasticities of the outputs (number of papers and citations), given the poor quality of the data and modelling problems, their models suggested decreasing returns to the domestic component of R&D. The analysis of international spillovers indicated evidence of a significant impact from the weighted investment in HERD in other countries.

Payne and Siow (2003) estimated the effects of federal research funding on research outcomes in the U.S. at university level using publications as the measures for research outcomes from Institute for Scientific Information (ISI) data on articles published and citations to articles published. Their analysis of these outputs measure covers 57 universities and 1,017 observations, representing about 18 years of data for each university. For scientific articles as dependent variable, all their estimations for federal research funding were significant and showed diminishing returns. They also used citations per article but obtained a negative and very small effect. The authors concluded that increasing federal research funding results in more, but not necessarily higher quality, research output.

In his study on European Universities, Aghion et al. (2007) used a survey questionnaire sent to the European universities in the 2006 Top 500 Shanghai ranking. Using regression analysis they found a significant and positive relationship between budget per student and research performance at country level. Their analysis also indicates that the research performance of universities is positively associated with their size and their age.

The main lesson from this empirical literature is that money helps to achieve a better research performance. However, difficulties in obtaining accurate data prevent from estimating reliable university R&D effects (elasticities), although most of the analyses found decreasing returns to university R&D expenditure. Moreover, as pointed at the beginning of the paper, despite the role of regions in the research policies framed into the ERA strategy, there is no previous research on the effects of R&D funds on research at regional scale. In order to contribute to this empirical literature, we address a number of related empirical questions in the following Sections:

1. How is the production of scientific research distributed across European regions? What regions lead the generation of science and in what fields?

2. What are the effects of academic R&D funding in promoting the quantity and quality of scientific research at regional scale? Is there any difference according to the level of regional development?
3. University scientific production across European regions

In order to cope with the first group of empirical questions, in this Section we explain how the data was obtained and present an overview of the distribution of university research for 1998 to 2004 in EU-15 using an original dataset. Some findings at the more detailed level of individual regions and fields over the same period are also presented.

3.1 Data description

The data used in this study consists of a set of university research articles published in scientific journals indexed by the Science Citation Index Expanded (SCI). As is well known, the SCI is a bibliographical database produced by the Information Sciences Institute (ISI), which is in turn a part of Thomson Reuters’ Web of Science. The main advantage of ISI citation indexes is that they provide a complete list of all authors and their affiliations. There are also some well known limitations of this database. For example, it does not include all journals, and the ISI journal list is strongly biased towards journals published in English (see for details Bordons et al., 2002; van Raan, 2005; Weingart, 2005).

The procedure to account for university scientific papers at NUTS II level in the EU-15 followed the following steps:

(i) Data on academic publications containing at least one author affiliated with a university from a EU-15 country for 1998–2004 were retrieved from the SCI. It is worth emphasizing that the lack of normalization in the way in which academic institutions are named hinders the finding of academic publications. For this reason, we included several search terms to help identify Higher Education institutions in both English and other languages. This search resulted in 994,938 publications.

(ii) Regionalization at the NUTS II level of aggregation of the academic publications obtained in Step 1 for 213 European regions (see Appendix for the list of NUTs by countries). We first identified the NUTS II associated with each university using the list provided by the members of the European Indicators, Cyberspace and the Science-Technology-Economy System (EICSTES). For those universities not included in the EICSTES list, we searched for the address on each university’s website. We then applied the full-count method involving the crediting of each co-author with one publication. Following the full-counting procedure, the total number of academic papers distributed among regions during 1998–2004 was 1,206,644.

(iii) Classification of academic publications by scientific field. In a first stage, we classified the 7,155 journals in our sample according to the categories defined by the Journal Citations Report (JCR) database for the ISI. However, this classification is generally too specific, because it includes more than two hundred individual categories. For this reason, in a second stage we grouped the ISI categories into 12 broad scientific disciplines using the Third European Report on S&T indicators. In this classification, each ISI category is assigned to only one scientific discipline, but each journal is

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2 This dataset was first use in Acosta et al. Acosta, M., Coronado, D., Ferrándiz, E., & León, M. 2011a. Factors affecting inter-regional academic scientific collaboration within Europe the role of economic distance. *Scientometrics*, 87(1): 63-74.. See this paper for more details about it.
assigned to several categories by the ISI. If a journal was assigned to more than one scientific discipline, we applied the full-count method so that we considered a full publication for each discipline.

3.2 Regional distribution of science across European regions

The spatial distribution of publications is mapped in Figure 1. As shown, of the 213 regions in total, 24 do not have any scientific publications, 34 have between one and 1,000 publications, 73 have from 1,000 to 6,000 publications, 43 have from 6,000 to 12,000 publications, 16 have from 12,000 to 18,000 publications and 23 have more than 18,000 publications.

The indexes in Table 1 reveal that the production of scientific knowledge is highly concentrated in a few regions. As shown in Table 1, the Gini coefficient takes a value of 0.61 for the initial year (1998) and 0.59 for the latest year (2004) in the sample. Moreover, the trend—as shown in the Gini coefficients— is slightly downward over the period 1998 to 2004. The remaining concentration indexes in Table 1 lead to the same conclusion; the value of the C5 index takes a value of about 13, suggesting that just five regions account for 13% of papers. Similarly, the value of the C10 index is 22, indicating that 10 regions provide almost 22% of publications.

Table 1. Descriptive statistics and regional concentration indexes of academic scientific publications

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<tbody>
<tr>
<td>N</td>
<td>157,446</td>
<td>164,492</td>
<td>166,66</td>
<td>170,603</td>
<td>174,266</td>
<td>179,770</td>
<td>193,398</td>
<td>1,206,644</td>
</tr>
<tr>
<td>Mean</td>
<td>739.19</td>
<td>772.27</td>
<td>782.49</td>
<td>800.96</td>
<td>818.16</td>
<td>844.00</td>
<td>907.98</td>
<td>5,664.99</td>
</tr>
</tbody>
</table>
In order to provide some descriptive details of how the production of scientific knowledge is distributed according to the level of regional development, we include in Table 2 information about the concentration of scientific production separating Objective 1 (regions where the GDP per capita is less than 75% of the European average) from the rest. Several facts emerge from this Table:

- The distinction between regions according to the level of economic development (GDP per capita) shows that less-developed NUTS regions generated 13.3% of all EU-15 academic papers in 1998. This percentage increased to 15.7% in 2004.
- On average, an Objective 1 region produced 339 papers in 1998, while a developed NUT region generated 904 papers in the same year. Therefore, the number of academic papers in a less-developed region was 37% of those generated in a developed NUTS region. This figure increased to 45% in 2004.

Several regions may be included in the group of developed regions, but having a low level of scientific capacity (e.g. those regions with a strong tourism sector). To present a complete picture we also divided the regions according to the level of HERD per capita (right-hand of Table 2). These data show that regions with less than 75% of the EU-15 average HERD per capita (42% of all regions in the sample) contributed to 12% of all publications in 1998, increasing to 13.4% in 2004. On average, a region in this group produced 79% fewer papers than a region in the group with HERD per capita higher than 75% of the EU-15 average.

Table 2. Regional production of academic papers by type of NUTs region (*)

<table>
<thead>
<tr>
<th>Groups of regions according to their level of development</th>
<th>Groups of regions according to their level of HERD</th>
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<tbody>
<tr>
<td>----------------------------------------------------------</td>
<td>------</td>
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<tr>
<td>Regions below 75% of the EU-15 average G.D.P.</td>
<td>No. Papers</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td>Std. Dev</td>
</tr>
<tr>
<td>Regions above 75% of the EU-15 average G.D.P.</td>
<td>No. Papers</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
</tr>
</tbody>
</table>
This analysis shows an unbalanced picture of the generation of academic papers since
the average capacity for publication of a less developed region is about 45% of the
capacity of a developed region in the core group. The disparities are rather stronger
when we consider a classification of regions based on Higher Education R&D
expenditures.

4. The role of academic R&D funds in promoting the quantity of regional scientific
production
In order to address the second group of questions related to the impact of R&D
expenditures on science production, we estimate a regional version of the knowledge
production function (KPF). The following subsections present the model, variables, the
method of estimation and results.

4.1 Model and variables

In order to evaluate the impact of R&D expenditures on science production, we estimate
a regional version of the knowledge production function suggested by Adams and
Griliches (1996) in terms of inputs and outputs. The inputs are academic R&D funds;
The outputs are research publications. The empirical panel model takes the form:

\[
\ln SP_{it} = \beta \ln RD(r)_{it} \delta RS_{it} + \alpha_i + \eta_i + u_{it}
\]

Where the dependent variable \( SP_{it} \) is the quantity of scientific knowledge production
captured by the number of papers or citations received by papers of the region \( i \) in the
year \( t \). The explanatory variables are as follows:

- \( \ln RD(r) \) is the logarithm of past R&D expenditure (since it takes time for R&D
to be reflected in new papers).
- RS. We use aggregate data (production of papers) and it is expected that
regions with a large participation in fields with high propensity to publish
produce more outputs. Therefore, this variable controls for the weight that each
scientific field has in the production of outputs in forms of scientific papers.
- \( \alpha \) represents regional specific effects; it was included because research activity
might be affected by several others contextual elements such as cultural
practices, regional demand of research or particular regional innovation policies.
- \( \eta \) captures time effects.
- \( u \) is a disturbance term, representing all other unaccounted forces determining
this particular measure of output.

Our primary interest focuses on the significance of parameters \( \beta \) and \( \alpha \). The first
coefficient measures the returns to the scale of the region research effort level while the
second indicates the changing level of regional efficiency to transforms resources into
results, if everything else were correctly specified in this equation.
It is worth noting that measurement problems arise when the academic R&D expenditure is included as an explanatory factor. This variable is captured using R&D expenditure in the Higher Education Sector (HERD) from Eurostat (in Million of Purchasing Power Standard (PPS) at 2000 prices). The variable includes all universities, colleges of technology, institutions of post-secondary education, and centres operating under the control or associated to higher education institutions, whatever their source of finance or legal status. It should be bear in mind that on the one hand, academic R&D may underestimate the total value of R&D resources if there are other financial sources; and on the other hand, R&D expenditures overstates the total value of resources devoted to research because some of the R&D is assigned to the production of other outputs (for instance, university patents). Furthermore, the statistics present also a problem of missing observations for many European regions. Similar restrictions in data to those for the European regions have been stressed in the scarce research on this topic in other contexts; for example, Adams and Griliches (1996, 1998) reported comparable problems for the USA; Crespi and Geuna (2008) pointed out related difficulties at country level. We assume this imperfection of academic R&D expenditure as we do not have a better inputs indicator.

4.2 Estimation method and results

As it is known, the standard methods for estimation the suggested panel model are fixed effects or random effects. The major difference between these two techniques is the information for obtaining the coefficients. The fixed effects estimates are calculated from differences within each region across time; the random effects estimates are usually more efficient, since they include information across individual regions as well as across periods. The major drawback with random effects is that it is consistent only if the regional-specific effects are uncorrelated with the other explanatory variables. A Hausman specification test is frequently apply to pick up the more efficient estimates.

This standard procedure can hardly be applied in this case. First, we count on an unbalanced panel in which HERD present very little variance year by year; second, the dependent variable (nº of publications by regions) presents unsteady fluctuations year by year (some regions present high values for one year and a dramatic drop for the following year). Given these characteristics of our sample, panel fixed effects procedure doesn’t make sense in this context for the nature of the dependent variable; the application of a within estimator would produce misleading results because a differentiation of HERD is required to obtain the within estimates, and this produces imprecise estimates. In these cases, we are forced to use random effects estimation in order to learn anything about the population parameters (Wooldridge, 2003 p. 286). This is our starting point (Table 6). We subsequently applied other procedures and compare the results with the base models.

In order to know how reliable our results are, we carried out two robustness analysis. The first analysis consisted of using alternative estimation methods (Table 7). In the second proposal we used a three or a five-year’s lag and applied typical U-shaped function to R&D expenditures (Adams and Griliches, 1996, Crespi and Geuna, 2008) (Table 8)

<table>
<thead>
<tr>
<th>Table 7. Effects of HERD on the number of scientific papers published by regions (1998-2004). Alternative estimates</th>
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<tbody>
<tr>
<td><strong>Objective 1 Regions</strong></td>
</tr>
<tr>
<td>(1)</td>
</tr>
<tr>
<td>t-4</td>
</tr>
<tr>
<td>VI(ef)</td>
</tr>
<tr>
<td>(0.0902)</td>
</tr>
<tr>
<td>VI(re)</td>
</tr>
<tr>
<td>(0.0972)</td>
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</table>

<table>
<thead>
<tr>
<th>Region</th>
<th>Objective 1 Regions</th>
<th>Non Objective 1 Regions</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td></td>
<td>Weight 3t</td>
<td>Weight 5t</td>
</tr>
<tr>
<td>VI (ef)</td>
<td>0.7245*** (0.0735)</td>
<td>0.8811 *** (0.0528)</td>
</tr>
<tr>
<td>VI (re)</td>
<td>0.7917*** (0.0806)</td>
<td>0.8829 *** (0.0577)</td>
</tr>
<tr>
<td>BE (wls)</td>
<td>0.9169*** (0.1018)</td>
<td>0.9838 *** (0.1452)</td>
</tr>
<tr>
<td>POOLED</td>
<td>0.7489*** (0.0901)</td>
<td>0.8890 *** (0.0682)</td>
</tr>
</tbody>
</table>

Notes: Weight 3t: Is the inverted U-lag with weights 0.25, 0.5, and 0.25, respectively for R&D lagged one, two, and three years. Weight 5t: Is the inverted U-lag with weights 0.111, 0.222, 0.333, 0.222, 0.111 respectively, for R&D lagged from one to five years.

4. The role of academic R&D funds in promoting the quantity of regional scientific production

The analysis of the effects of academic R&D expenditures on quality is still in progress, thus the results are not presented in this draft.

5. Conclusions

This paper attempts to identify the spatial distribution of academic scientific production patterns across European regions, and is mainly aimed at evaluating the role of higher education R&D expenditures in encouraging scientific production. A preliminary descriptive analysis suggests a growing trend in the number of publications, increasing from 157,446 in 1998 to 193,398 in 2004. The data also displays a high level of concentration of publications in a few regions, with little change over the period 1998–2004. For example, just five regions account for 13% of all publications, and this figure remains relatively unchanged over the period under examination.

The separation of regions according to different levels of economic development indicates that an Objective 1 region (one with a GDP per capita less than 75% of the EU-15 mean) produced on average less than half (45%) the papers of a more economically advanced region. However, both groups of regions display a similar rate of publications involving collaboration with other regions. After dividing the NUTS regions into two groups according to higher education R&D expenditure, the results show that a region in the less-favoured group (one with R&D per capita less than 75% of the EU-15 mean) produces on average 21% of the publications of a region in the group with R&D per capita expenditures greater than 75% of the EU-15 mean. Therefore, the descriptive statistics suggest that the level of development and the resources devoted to higher education R&D affect the capacity to generate research outputs.
In order to address the second group of research questions, related to the role of university R&D funds on regional scientific production, we estimated a knowledge production function using random effect models. The base models were complemented with alternative estimates and lag structures for R&D expenditure. As previous research on this topic, the available data on university R&D funds prevent us from obtaining accurate effects. Nevertheless, we have identified some regularities.

- Money matters to produce scientific knowledge in universities across European regions. The coefficient capturing the effects of R&D is significant in all models and the values were always below 1. Therefore, as in previous research at other spatial scale, decreasing returns to scale were obtained.

- The effects are different according to the level of development in regions. Estimates for the coefficient of university R&D present larger values for Objective 1 regions than for developed regions. This means that an increase of for example 10% in university R&D expenditure has a large impact (on average) on outputs (scientific papers) in Objectives 1 regions than in developed regions. The explanation for this result might stem from several facts: first, the starting point in terms of production of scientific papers is higher in developed regions than in Objective 1 regions (note that elasticities give the impact in relative terms). Second, the specialization patterns and the weight of each field are different in the two types of regions. Third, developed regions might not have to rely as much on money as Objective 1 regions do because the formers count on more experienced, better and more efficient scientific infrastructure, and in general more suitable conditions for research.

- Higher education R&D expenditures take more time in producing scientific output in Objective 1 regions than in developed regions. In all our models we found that for Objective 1 regions the elasticities take the largest value for the five year-lag; they increase from the third year-lag to the five year-lag. While for developed regions elasticities take the larger value for the third lag and usually decrease to a minimum for a five year-lag. This was confirmed using different lag structure and combinations.

- Regional specialization has a significant effect for the production of scientific papers in regions; however, we obtained significant coefficients for fields in Objective 1 regions that are different from those obtained in more developed regions. This result suggests that scientific specialization matters for producing scientific outputs in both types of regions, but not necessarily has to be in the same fields.

References


