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THE INNOVATION PROCESS OF EUROPEAN REGIONS

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RÉSUMÉ

Le processus d'innovation n'est ni linéaire, ni additif mais complexe, caractérisé par des influences croisées entre les acteurs impliqués. Dans cette perspective, la présente contribution vise à examiner, pour les régions européennes, le processus d'innovation en modélisant explicitement les influences réciproques entre la recherche et le développement (R&D) du secteur privé, des universités et du gouvernement à l'aide d'un système à équations simultanées basé sur une fonction de production de connaissances. Testé sur un échantillon étendu de 153 régions européennes, les résultats suggèrent que la création de connaissances dépend fortement des investissements R&D réalisés par le secteur privé et par les universités mais également de leurs fertilisations croisées. La capacité de création de connaissances n'est pas uniformément distribuée au sein de l'Europe. Elle est particulièrement faible dans les régions « d'objectif 1 ». Pour ces dernières, les principaux leviers sur lesquels une politique de S&T adéquate devrait s'appuyer sont identifiés.

ABSTRACT

This paper aims at investigating the innovation process of European regions in taking into account potential feedback relations between university and private business research and development (R&D). After a review of the related literature, we construct a simultaneous equation model based on a knowledge production function framework. The model is tested onto an extended sample of 153 European regions and highlights that the European region's knowledge creation heavily depends on private business and university R&D efforts which, in turn, influence each other. However, the European landscape is characterised by important disparities in terms of knowledge creation capacities. Since the innovative capacity of "objective 1" regions is extremely weak, we attempt to identify by means of dummy variable estimations the specific components of the innovation process that should be fostered by an adequate S&T policy.

MOTS CLÉS: Régions européennes, processus d'innovation, interactions R&D public-privée.

KEYWORDS: European regions, innovation process, public-private R&D interactions.

JEL CLASSIFICATION: R10, O18, O31.

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INTRODUCTION

It is not a new history that the wealth of nations and regions depends on their capacity to transform ideas and inventions into new products and processes. Schumpeter (1954) in his seminal contribution already argues that economic growth requires innovation – the generation of higher quality products at lower unit costs than had previously been obtainable. The endogenous growth literature (Romer, 1986, 1990, 1994; Lucas, 1988; Grossman and Helpman, 1994) adds to this requirement that technological change is mainly a result of consciously planned, market motivated industrial R&D. If this is the case, then the regional capacity to sustain innovation is embodied in institutions and resources – the region's underlying technological infrastructure. This infrastructure is composed of three main elements namely universities which develop new technologies, innovative firms that transform these technologies into industrial innovation and the government which provides R&D support. However, as has become clear by the numerous unsuccessful policy making attempts to imitate Sillicons Valley's success story, infrastructure alone is not sufficient. The productivity and efficiency of this infrastructure heavily depends on the region's characteristics in terms of the qualification level of human capital, the willingness to cooperate and the openness and degree of insertion into the world economy. Moreover, contrary to a conventional wisdom of the "linear model" that, for a long time, viewed innovation as a straightforward path from the laboratory directly to the marketplace, the innovative process is circular rather than sequential. Schematically, university research feeds private business research. And private business research which is also fuelled by diverse types of expertises coming from customers and supplies, feeds back university research (Kline and Rosenberg, 1987).

As far as the first two components of the region's technological infrastructure are concerned, university and private business sector R&D, Mansfield (1991) note that university R&D enhances the stock of basic knowledge, generates increasing technological opportunities across a wide range of industrial fields, and increases the potential productivity of private industrial R&D. However, these opportunities and potentialities do not automatically turn into real effects. While knowledge is clearly a crucial element, in *itself* it does not contribute to economic growth. It has to be incorporated into the production of goods and services. Advances in technological and organisational knowledge have to be absorbed by firms and applied to the production process and organisation of work. Therefore the economic contribution of academic institutions depends on the effectiveness of technology transfer and diffusion to the private business sector. Varga (1989) identifies several ways of university – private business knowledge transfers: formal co-operations and agreements on R&D, industry financed university research centres, faculty consulting in industry, scholarly journal publications and industrial associates programs. It is worth noting, that most formal and informal mechanisms of technology transfer and diffusion heavily depend on spatial proximity. This is even more the case for spillovers of tacit knowledge. A form of technology transfer that requires a high degree of spatial proximity is channelled through the labour marked. Local labour markets of scientists and engineers promote local technology transfer since they are more likely to move to nearby firms when changing jobs (Bania et al., 1992) and trained graduates may look for their first jobs in an area of the university (Jaffe, 1989). Other forms of knowledge transfers are industrial incubators and industrial parks mainly aimed at providing facilities to start-up firms as well as university spin-offs.

Besides universities and the private business sector, the third component of a region's technological infrastructure is the government. Government R&D is partly realised in universities but also in national laboratories. The rationale behind government research is not only to satisfy public needs but also to counterplay marked failures in the field of R&D investment. Imperfect appropriability of research results is the most important one. While this characteristic of R&D activity constitutes a positive externality and contributes to economic development, imperfect appropriability discourages the private business sector to perform R&D for which it can not capture the entire return. Since the private rate of return is smaller than the social one, government intervention in this field is fully justified, especially when the associated risk is high[2]. Independently from the appropriability problem, government may simply want to stimulate private business and / or university R&D. The economic rationales behind these interventions are manifold: reducing the private cost of R&D, strengthening the capacity of knowledge creation of universities in a given strategic field, helping the private business sector to increase its absorptive capacity, encouraging universities and / or businesses to actively join global international research networks or stimulating cooperation between industry and university.

As stated previously, technological infrastructure alone is not sufficient. The productivity of this infrastructure heavily depends on the efficiency of technology transfer and diffusion mechanisms and on the region's absorptive capacity. In order to benefit from existing knowledge sources outside and inside the region, the private business sector must be able to understand and to integrate this knowledge which is only possible if a minimum level of R&D is performed within the firm (Cohen and Levinthal 1989). Cockburn and Henderson (1998) show that the absorptive capacity is dependent on the intensity of R&D performed by the firm, the level of qualification and competence of the workforce, the remuneration of the latter and the capacity to tie close links with the public sector. These factors ensure a high quality internal research but also access to public research performed by universities and the government. Moreover, the higher the quality of human capital, the higher the productivity of internal research provided that strong links are established with public research. The openness of a region may also provide important innovative inputs. Not only geographically mediated knowledge spillovers are shown to significantly contribute the region's knowledge creation (Acs et al., 2002, Anselin et al., 1997, Autant-Bernard, 2002) but also technologically mediated knowledge spillovers (Greunz, 2002a, 2002b). Putting it differently, provided that the absorptive capacity of a region is sufficiently developed, it can benefit from research efforts realised in surrounding regions and regions with which a common technological profile is shared.

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[2] For an overview of the effects of different government policy instruments on private R&D see Guellec and van Pottelsberghe (2001) and David et al. (2000).

Finally it is worth noting that an environnement characterized by an efficient, interdependent technological infrastructure, an important absorptive capacity and a high degree of international integration may be an attractive location choice for high technology companies and start-up activities. Even if this aspect is somewhat external to the endogenous growth literature, it can not be denied that these factors influence high technology location (Engel and Fier, 2001). Among the determinants of location choice, availability of qualified labour is generally listed as the most important determinant (Malecki, 1985, Galbraith and De Noble, 1988). Provided that these attracted firms source locally and are tightly integrated in the region's productive system, they contribute to the region's knowledge creation and growth potential.

From the above consideration it should be quite clear that the innovation process is complex, characterised by various looping and feedback relations between the components of the technological infrastructure which require spatial proximity, and that the innovative productivity heavily depends on the region's absorptive capacity. While there exists a wide range of literature focusing on particular aspects of this innovation process[3], relatively little attempts have been undertaken to explicitly investigate the reciprocal influence of university research and private business research as well as their impact on knowledge creation. Table 1 provides an overview of the most important analysis in this field. All of them are carried out either for the US state level or for US metropolitan statistical areas (MSA).

Jaffe (1989) was the first who considered a simultaneous model of influence. He was also the first to use the Griliches (1979) production function framework for a sample of 29 US states over a disconnected period of 8 years. Although Jaffe's analysis distinguishes between different technological areas, only the overall results are presented in Table 1. In his system, corporate patents are the outcome of university and private business R&D expenditures. University R&D depends on a set of structural variables and on private business R&D. The latter in turn is a function of university R&D. Jaffe's findings suggest that both industry and university research are an important source of innovation for the private business sector. Furthermore, universities induce the location of industry R&D spending nearby. However, neither for his global model nor for the different technical areas, he finds evidence of a significant impact of industrial R&D on university R&D.

Inspired by the work of Jaffe (1989), Feldman and Florida (1994) investigate a very similar model but instead of corporate patents, they consider commercial product-innovation citations as a measure of innovative output. Moreover, they include the concentration of firms active in related manufacturing industries as well as specialised business services among their independent variables. As reported in Table 1, they find evidence that both, industrial and university R&D, positively and significantly influence private business innovation. University R&D fuels industrial R&D and contrary to the findings of Jaffe (1989),

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[3] Varga (1998) provides a detailed overview of the literature with regards to university research and regional innovation. Massard (2001) offers a summary of recent empirical analysis focusing on knowledge externalities and the geography of innovation.

their estimates indicate that the reverse also occurs, private business R&D positively and significantly influence university R&D. Anselin et al. (1997) broaden the cross-section database used by the former authors and test the system for a sample of 125 MSA[4]. A major innovation with respect to other studies in this field is the introduction of spatially lagged explanatory variables.

Although the estimated elasticities vary importantly according to the specifications, as Jaffe (1989) and Feldman and Florida (1994) they find a positive impact of university R&D and industrial R&D on innovative output. Moreover, university R&D significantly influences private business R&D. As Jaffe (1989) but contrary to Feldman and Florida (1994) they find no evidence of a significant contribution of private business R&D to university research.

TABLE 1. SELECTED STUDIES FOCUSING ON RECIPROCAL INFLUENCE OF UNIVERSITY AND PRIVATE BUSINESS R&D IN A KNOWLEDGE PRODUCTION FUNCTION FRAMEWORK

	Jaffe (1989)	Feldman and Florida (1994)	Anselin et al. (1997)
dependent variable: innovative output			
private business R&D	0.94 (18.08)	0.24 (4.44)	0.50 (9.16)
university R&D	0.10 (3.18)	0.16 (3.60)	0.13 (3.67)
other variables	• geographical coincidence index • population	• geographical coincidence index • concentration of firms in related manufacturing industries • business service value added (SIC 7397) • population • sales	• spatially lagged university and industry R&D
R^2_a	-	-	0.61
dependent variable: private business R&D			
university R&D	0.70 (5.46)	0.57 (7.65)	0.26 (3.29)
other variables	• manufacturing value added • population	• concentration of firms in related manufacturing industries • presence of at headquarters of Fortune 500 • population	• spatially lagged university and industry R&D • high tech employment • dummy for high tech university department • dummy for presence of at least 10 headquarters of Fortune 500 in MSA
R^2_a	-	-	0.65

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[4] The authors also investigate the system for 43 US states in using different measures for the "geographic coincidence index" that aims at correcting for the relative inappropriateness of states for this kind of analysis. Table 1 only reports the results for their sample of 125 MSA.

TABLE 1. CONTINUED

dependent variable: university R&D			
private business R&D	0.14 (0.96)	0.26 (6.56)	0.05 (0.32)
other variables	• nb. of public universities • nb. of private universities • nb. of federally founded R&D centres	• concentration of firms in related manufacturing industries • nb. of federally founded R&D centres • population	• spatially lagged university and industry R&D • dummy for high tech university department • size of universities • education expenditures
R^2_a	-	-	0.63
proxies:			
innovative output	• corporate patents	• product innovation citations of the 13 most innovative three-digit SIC: number of innovations for an industry i in state s	• product innovation citations in aggregated high tech sectors (SIC 28, 35-38) in MSAs
private business R&D	• expenditures	• average annual expenditures ten years prior to 1982 in industry i and state s	• employment high tech research labs
university R&D	• expenditures	• average annual expenditures ten years prior to 1982 in industry i and state s	• expenditures
other information:			
observations	29 US states	29 US states	125 metropolitan statistical areas (MSA)
years	1972-77, 79, 81	1982	1982
method	3SLS	3SLS	2SLS

Notes: t-statistics in brackets, 2SLS = two stages least squares, 3SLS = three stage least squares.

Inspired by the above mentioned analysis, this paper focuses on the European regional landscape for which this kind of investigation has never been undertaken. A particular attention is accorded to the qualification level of human capital since the latter has been shown to largely determine a region's absorptive capacity (Cockburn and Henderson, 1998) and the location choice of companies (Malecki, 1985, Galbraith and De Noble, 1988).

Our investigation should enable us to:

- highlight the respective contributions of university R&D and private business R&D to the knowledge creation at the European regional level;
- ascertain whether the innovative process in European regions is characterised by feedback relations between university R&D and private business R&D;
- achieve a better understanding regarding the role of qualification within the process of knowledge creation;
- identify for the European less favoured regions, the leverages that should be stimulated by adequate policy measures in order to enhance their innovation process.

The remainder of the paper is organised as follows. In the next section we explain our knowledge production function, present the data and discuss the role of variables taken into consideration. Section three presents some striking facts and figures that characterise the European regional landscape in terms of innovation in- and outputs. The estimation results are explained in section four. Section five highlights some specific aspects that underlie the innovation process of less developed regions and the resulting policy implications. The conclusion summarises the most important findings, and suggests some exciting topics for further research.

1. FRAMEWORK AND MODEL

A powerful approach to empirically model the characteristics of localised knowledge flows and their influence on regional innovation is the knowledge production function framework initiated by Griliches (1979) and first implemented at the aggregate level by Jaffe (1989). The conceptual framework of our paper is precisely based on the "Griliches (1979)–Jaffe (1989) knowledge production function" which has been largely investigated in recent empirical literature for the US (Jaffe, 1989; Acs et al., 1991, 2002; Anselin et al., 1997; Varga, 2000), Italy (Capello, 2001), France (Autant-Bernard, 2001, 2002), Austria (Fischer and Varga, 2001b), Germany (Fritsch, 2002) and at the European regional level (Greunz, 2002).

According to Griliches, innovative input is best reflected by new knowledge, which is primarily embodied in R&D efforts:

$$R\&D\ output = f\,(R\&D\ input) \qquad (1)$$

In essence, this knowledge production function can be modelled using a Cobb-Douglas type production function as given by equation (2). Following the above-mentioned stream of literature, we adopt a general version of the Cobb-Douglas production function, which does not impose any restriction regarding returns to scale:

$$R\&D\ output = a\ (R\&D\ input)^{b} + exp^{\varepsilon} \qquad (2)$$

Under this formulation, the term *a* is a constant while *b* measures the elasticity of R&D output with respect to R&D input. Taking the natural logarithm of each side of (2) leads to:

$$ln\ (R\&D\ output) = ln\ a + b\ ln\ (R\&D\ input) + \varepsilon \qquad (3)$$

Since we wish to analyse the effects of university R&D and private business R&D on the regional innovative capacity we distinguish in (4) between these two different kinds of R&D inputs:

$$ln\ (P) = ln\ a_1 + a_2\ ln\ (BR\&D) + a_3\ ln\ (UR\&D) + a_4\ ln\ (HQ) + a_5\ ln\ (MQ) + \varepsilon_1 \qquad (4)$$

where[5]:

P	is the number of patents for 1000 inhabitants and proxies R&D output. Patent data refer to patent applications to the European Patent Office (EPO) and are attributed to the living place of the inventor.
BR&D	stands for private business R&D efforts and is proxied by private business R&D expenditures per capita expressed in PPS and deflated by the GDP deflator with respect to the price level of 1990 (Source: Eurostat – REGIO);
UR&D	stands for university R&D efforts and is proxied by university R&D expenditures per capita expressed in PPS and deflated by the GDP deflator with respect to the price level of 1990 (Source: Eurostat – REGIO);
HQ	stands for human capital with a high level of qualification and is proxied by the proportion of the working age population with total tertiary education (ISCED 5-7) in 1997 (Source Eurostat);
MQ	stands for human capital with a medium level of qualification and is proxied by the proportion of the working age population with upper secondary education (ISCES 3) in 1997 (Source Eurostat);
ε_1	is a random error term.

In equation (4), innovative output is modelled as a function of private business R&D expenditures, university R&D expenditures and the qualification level of the working age population. As far as innovative output is concerned, it is proxied by patent applications to the EPO, which is the only available harmonised innovation measure at the European regional level. Even if patent data do not perfectly reflect innovations (Griliches, 1979)

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[5] Appendix 2 reports the most important descriptive statistics of the variables taken into account in the model as well as their correlation matrix.

there is a strong link between patents and inventions (Guellec and van Pottelsberghe, 1999; Acs et al., 2002). Innovative inputs are respectively proxied by university and private business R&D expenditures. Furthermore, innovative output is supposed to depend on the qualification level of the region's workforce. Both high and moderate qualification levels are considered. The former is supposed to play an important role in the conceptualisation stage while the latter provides technical assistance at later stages in the innovation process.

Following Jaffe (1989), the potential interaction between university and private business R&D is captured by extending the model with two additional equations that allow for simultaneity between these two variables:

$$ln\,(BR\&D) = ln\,b_1 + b_2\,ln\,(UR\&D) + b_3\,ln\,(I) + b_4\,ln\,(HQ) + b_5\,ln\,(MQ) + \varepsilon_2 \tag{5}$$

and

$$ln\,(UR\&D) = ln\,c_1 + c_2\,ln\,(BR\&D) + c_3\,ln\,(GR\&D) + c_4\,ln\,(HQ) + c_5\,ln\,(MQ) + \varepsilon_3 \tag{6}$$

where: *BR&D*, *UR&D*, *HQ*, and *MQ* are as before, ε_2 and ε_3 are random error terms and

I is the structure of the productive system which is proxied by the ratio of indu try employment over total employment (Source Eurostat - REGIO);

GR&D stands for government R&D efforts and is proxied by government R&D expenditures per capita expressed in PPS and deflated by the GDP deflator with respect to the price level of 1990 (Source: Eurostat – REGIO).

Equation (5) explains private business R&D as a function of university R&D, the structure of the productive system and the qualification level of the region's workforce. As far as university R&D is concerned, it has been shown in the introductive part that it importantly fuels private business R&D through mechanisms of technology transfer and diffusion. The structure of the productive system, proxied by the employment concentration in industry, is introduced as a control variable in the sense that innovation is believed to be mainly driven by the industrial sector. Despite the fact that technological progress in recent years is increasingly generated by the service sector, industrial patenting activity is still predominant. The introduction of qualification is motivated by the same arguments as for equation (5).

Finally, equation (6) states that university R&D depends on private business R&D expenditures, government R&D expenditures and the qualification level of the region's workforce. Since the innovation process is characterised by manifold linkages and feedbacks (Kline and Rosenberg, 1987), private business R&D is supposed to fuel university R&D. Government R&D is another determinant of university R&D. Part of government R&D which is often associated with high risks, is realised in universities. Through this channel, universities may have access to highly promising strategic fields of research

R&D. Part of government R&D which is often associated with high risks, is realised in universities. Through this channel, universities may have access to highly promising strategic fields of research which enables them to acquire a specific expertise which in turn gives rise to further research.

Jaffe (1989) introduced an additional term in equation (4) to compensate for the inappropriateness of using US states as units of observation acknowledging that states are too large to accurately capture the local spatial interactions between universities and private business. The additional term is a "geographic coincidence index" of industry and university R&D for each state. As stated by Anselin et al. (1997), this term is not needed when the spatial units of observation correspond more closely to the spatial scale of interaction between firms and universities. This can reasonably be assumed for the units of observation investigated in this study which are mainly NUTS II regions that correspond to a much higher degree of spatial disagregation than the level of US states.

In summary, the model we estimate in this paper is a simultaneous system of 3 equations (4 to 6). All of them are just identified and the rank condition for identification is satisfied. Therefore unique estimates will be obtained for our coefficients.

Before turning to the estimates of the model, it is worth highlighting for the European regional landscape some striking facts and figures in the field of innovation and R&D expenditures. This step provides a useful overview about the distribution of innovative activity in Europe and enables a better understanding of the econometric analysis and its resulting policy implications.

2. FACTS AND FIGURES

Neither R&D effort, nor knowledge creation is uniformly distributed among the European Union. This observation emerges when comparing national performances and even more when the regional level is considered. Globally, Germany, France and the United Kingdom account for more than 70 % of patents applied to the EPO during the period 1989-1998 (Table 2). In terms of patents per capita, Germany remains the leading innovative country and is closely followed by Sweden and to a lesser extent by Finland and The Netherlands. For the two former countries the number of patents per capita is twice as high as the European average.

TABLE 2. INNOVATION INDICATORS OF EUROPE (AVERAGE OVER THE PERIOD 1989-1998)

	shares of patent applications	patent applications per capita relative to the European average[6]	annual average growth rate of patent applications	total R&D investment relative to GDP	annual average growth rate of total R&D spending
Germany (DE)	40.78	2.19	1.45	2.51	-0.80
France (FR)	16.66	1.02	1.37	2.39	1.33
United Kingdom (UK)	13.97	0.85	0.25	2.11	-1.93
Italy (IT)	7.93	0.49	3.24	1.16	-5.60
The Netherlands (NL)	5.58	1.30	2.14	2.07	3.50
Sweden (SE)	4.62	1.87	9.17	3.17	3.40
Belgium (BE)	2.56	0.90	7.26	1.62	1.96
Austria (AT)	2.34	1.05	1.75	1.49	5.88
Finland (FI)	2.16	1.51	14.47	2.19	6.70
Denmark (DK)	1.66	1.13	9.48	1.78	9.15
Spain (ES)	1.24	0.11	13.81	0.84	0.41
Ireland (IE)	0.32	0.31	15.39	1.14	20.30
Greece (GR)	0.11	0.04	11.73	0.42	-3.26
Portugal (PT)	0.04	0.01	14.47	0.58	0.45
European Union	100	1	2.46	1.93	-0.01

Source: own calculation based on data from Eurostat – REGIO

Average annual growth rates of patent applications over the period 1989-1998 of most European countries with very low per capita values are well above the European average. Among this group of countries which covers essentially "objective 1" regions, Ireland is the fastest growing country, followed by Portugal and Spain. Although this positive evolution may be due to increased R&D efforts, especially in the case of Ireland which also shows a relatively high R&D intensity, for some "objective 1" countries such as Portugal and Greece, these high rates of growth are mainly due to the fact that at the beginning of the considered period innovative activity was extremely low or even absent. It can also be observed that the R&D intensity of these countries remains far below the European level.

Among the European countries with high values of patent applications per capita, Sweden, Finland and Denmark perform exceptionally well. Conversely to Germany, their fast growing patenting activity is associated to continually increasing R&D investment, a fact that may provide them an important future competitive advantage.

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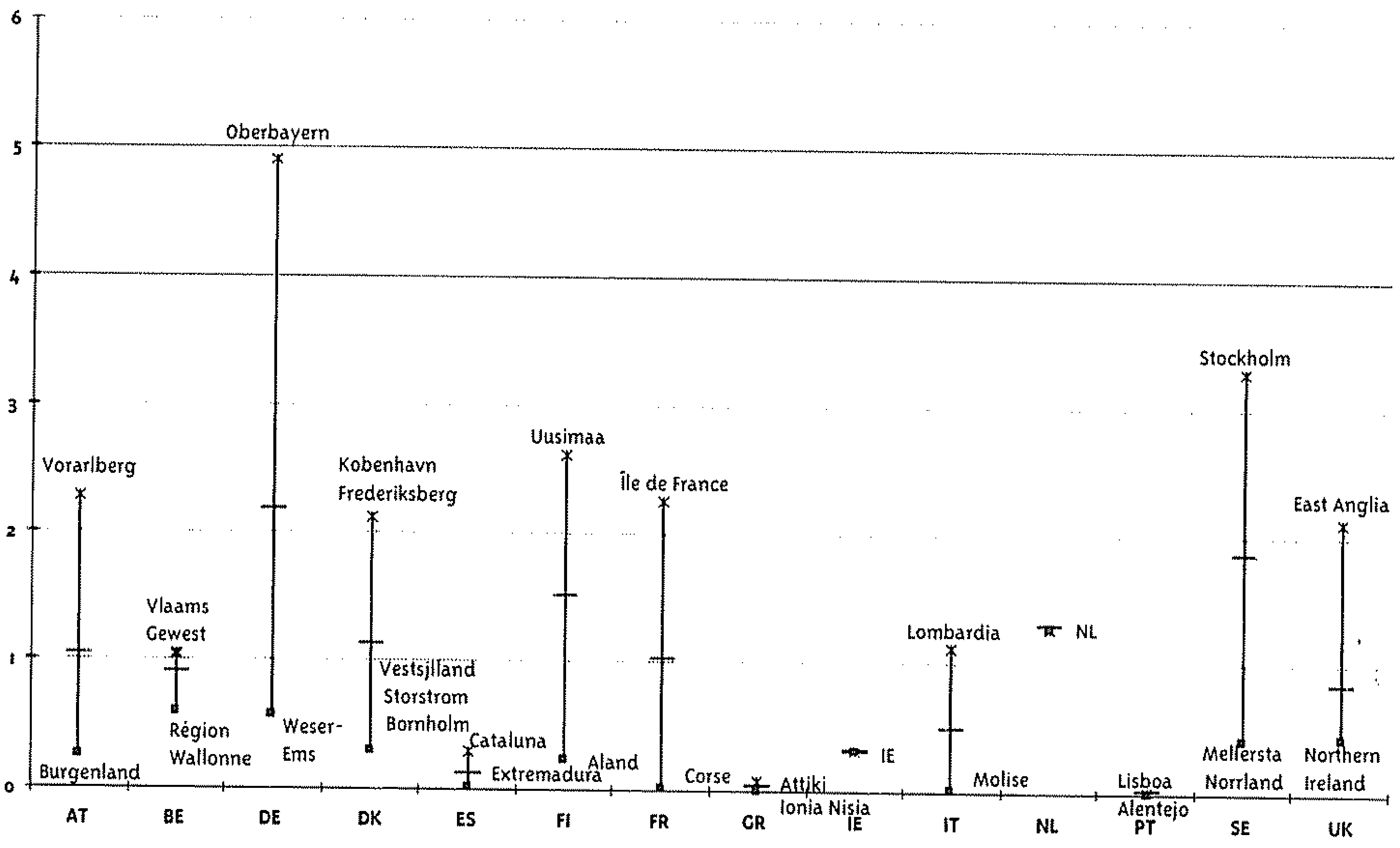
[6] Formally the measure is defined as follows: $\frac{P_i}{pop_i} \Big/ \frac{\sum_i P_i}{\sum_i pop_i}$ where i is a country index, P stands for patent applications and *pop* for population. A value of 1 indicates a performance equal to the European average. A higher/ lower value indicates a higher / lower performance.

FIGURE 1. PATENT APPLICATIONS PER CAPITA RELATIVE TO THE EUROPEAN AVERAGE (1989-1998)



Source: own calculation based on data from Eurostat – REGIO.

As stated previously, at the regional level, the disparities in terms of innovative activity are even more pronounced compared to the national divergences. Over the period 1989-1998, 50% of patent applications were concentrated in 13 European regions out of which 7 were German. Figure 1[7] indicates respectively for each country the region with the highest and the lowest number of patents per capita relative to the European average as well as the national value. It clearly illustrates the greater dispersion of patent applications per capita for the regional level compared to the national one. The Figure also highlights the extremely strong innovative capacity of Germany. Firstly, Oberbayern appears to be the most innovative European region with a level of patent applications per capita of about five times the average European value. Secondly, the German national average is far above the ones observed for the other European countries and is almost as high as the best performing Danish, French, Austrian and British regions. Thirdly, Weser-Ems, the weakest German region in terms of patent applications per capita performs better than the less innovative regions of the other countries. Furthermore, Figure 1 clearly indicates the weak position of the "objective 1" countries and permits to temperate their apparently strong growth performance in the field of patent applications suggested by Table 2.

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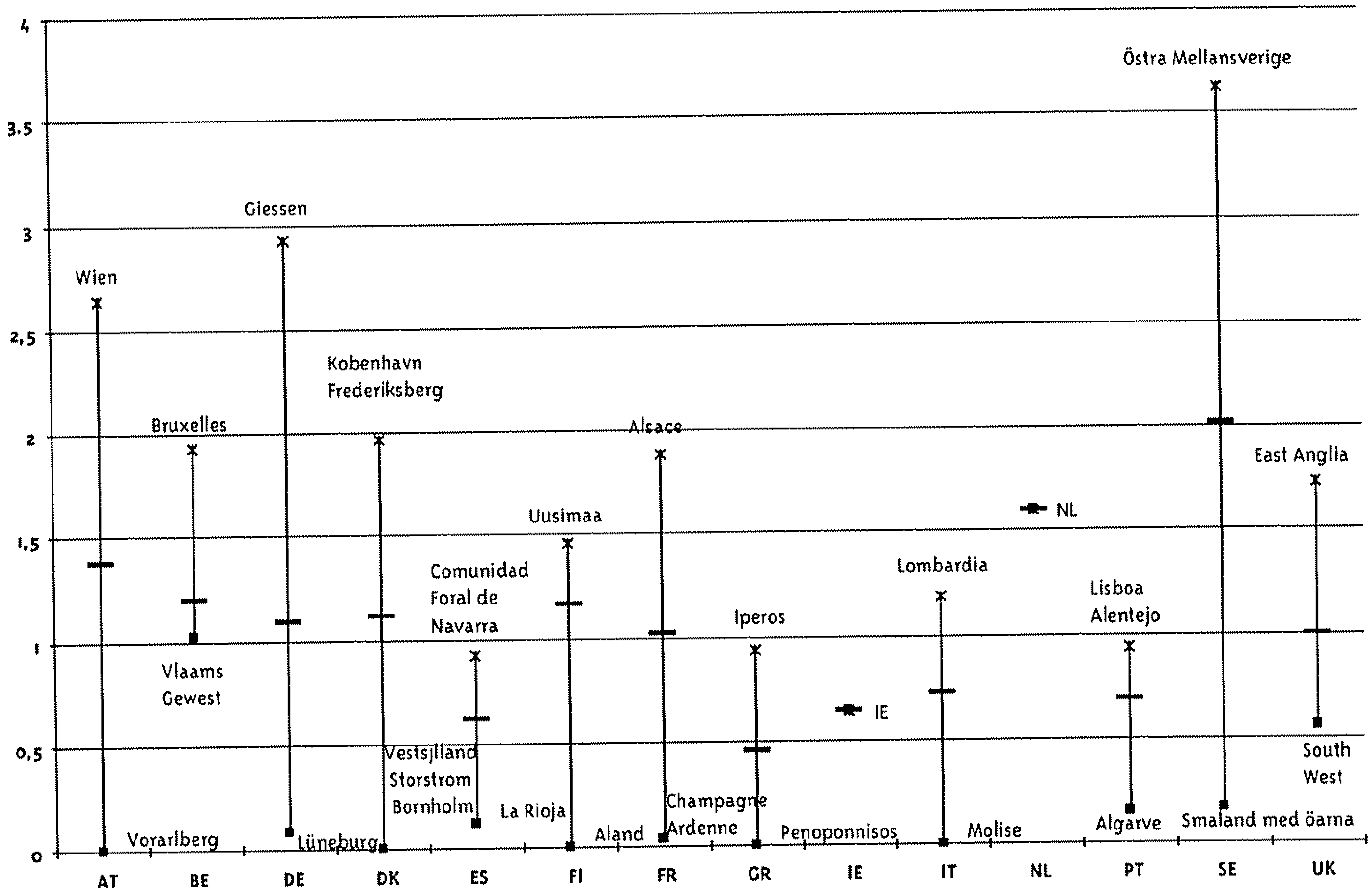
[7] Minimum values are indicated by a quadrangle, maximum values by a star and the national average by a dash. Although patent application data are available for NUTS III regions, the graph is based on the largest regional sample for which R&D expenditures are available over the period 1989-1996 and which is used for the econometric analysis of the next section. For this reason only national averages are reported for Ireland (IE) and The Netherlands (NL) and the NUTS I level for Belgium. For a detailed description of the sample see appendix 1.

FIGURE 2. INTENSITY OF UNIVERSITY R&D RELATIVE TO THE EUROPEAN AVERAGE (1989-1996)



Source: own calculation based on data from Eurostat – REGIO

As explained in the previous section, patents are proxies for the innovative output. The latter is produced by innovative inputs, R&D efforts, which are generally proxied by R&D expenditures or employment. Figures 2, 3 and 4 illustrate respectively the intensity of university R&D, private business R&D and government R&D relative to the European average[8]. A global comparison of Figures 1, 2, 3 and 4 indicates that despite the strong position of Germany in terms of patenting, it is outperformed by Sweden for university and private business R&D intensities and by France for government R&D intensity. This observation suggests that Germany's R&D productivity is considerably higher than the ones of other European countries, since relatively less innovative inputs are needed to produce a comparatively higher R&D output.

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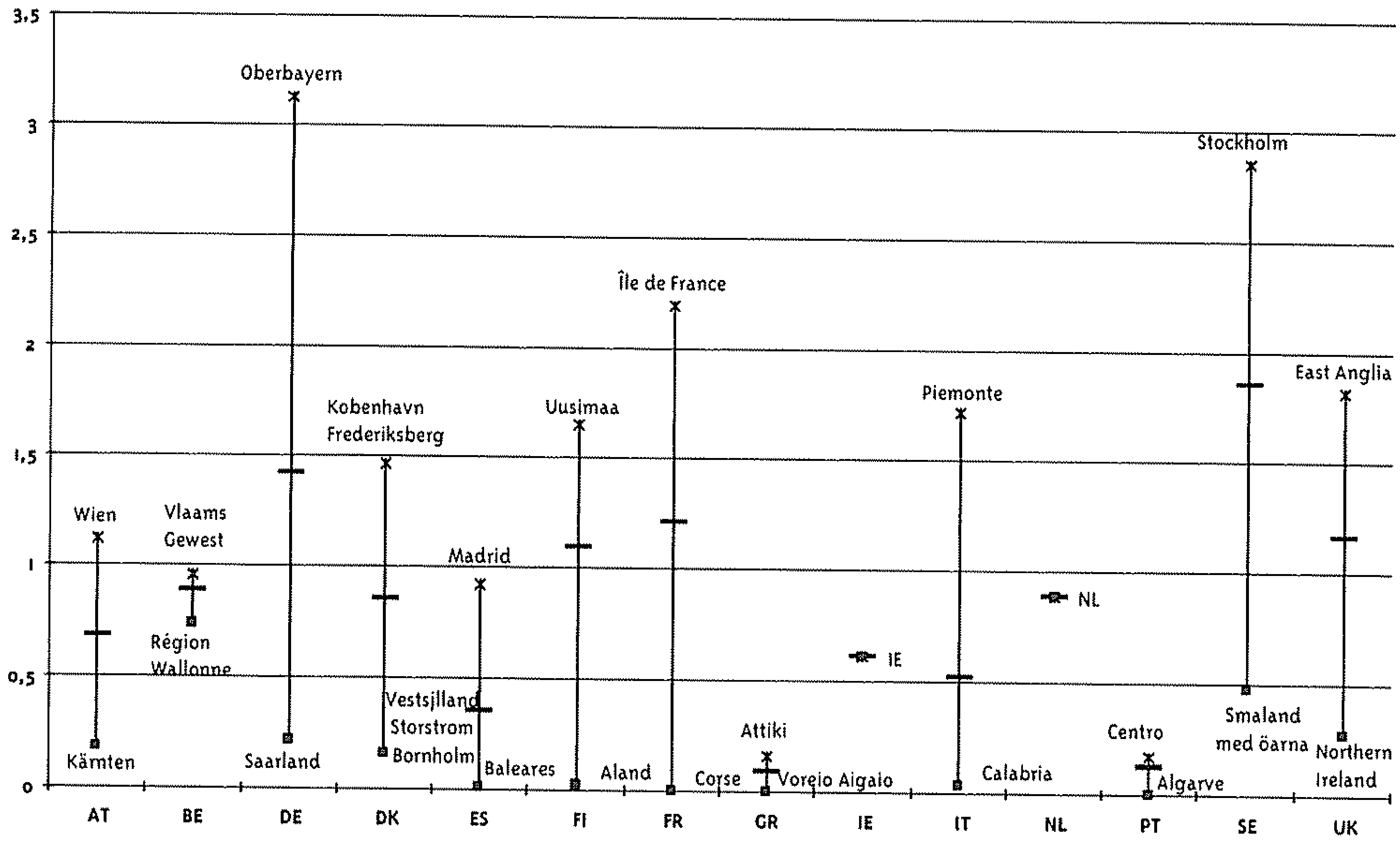
[8] Formally the measure is defined as follows: $\frac{R\&D_{ki}}{GDP_i} \Big/ \frac{\sum_i R\&D_{ki}}{\sum_i GDP_i}$ where *i* indexes the region, *k* indexes the institutional sector, *R&D* stands for research and development expenditures and *GDP* for gross domestic product. A value of 1 indicates a performance equal to the European average. A higher / lower value indicates a higher/ lower performance.

FIGURE 3. INTENSITY OF PRIVATE BUSINESS R&D RELATIVE TO THE EUROPEAN AVERAGE (1989-1996)

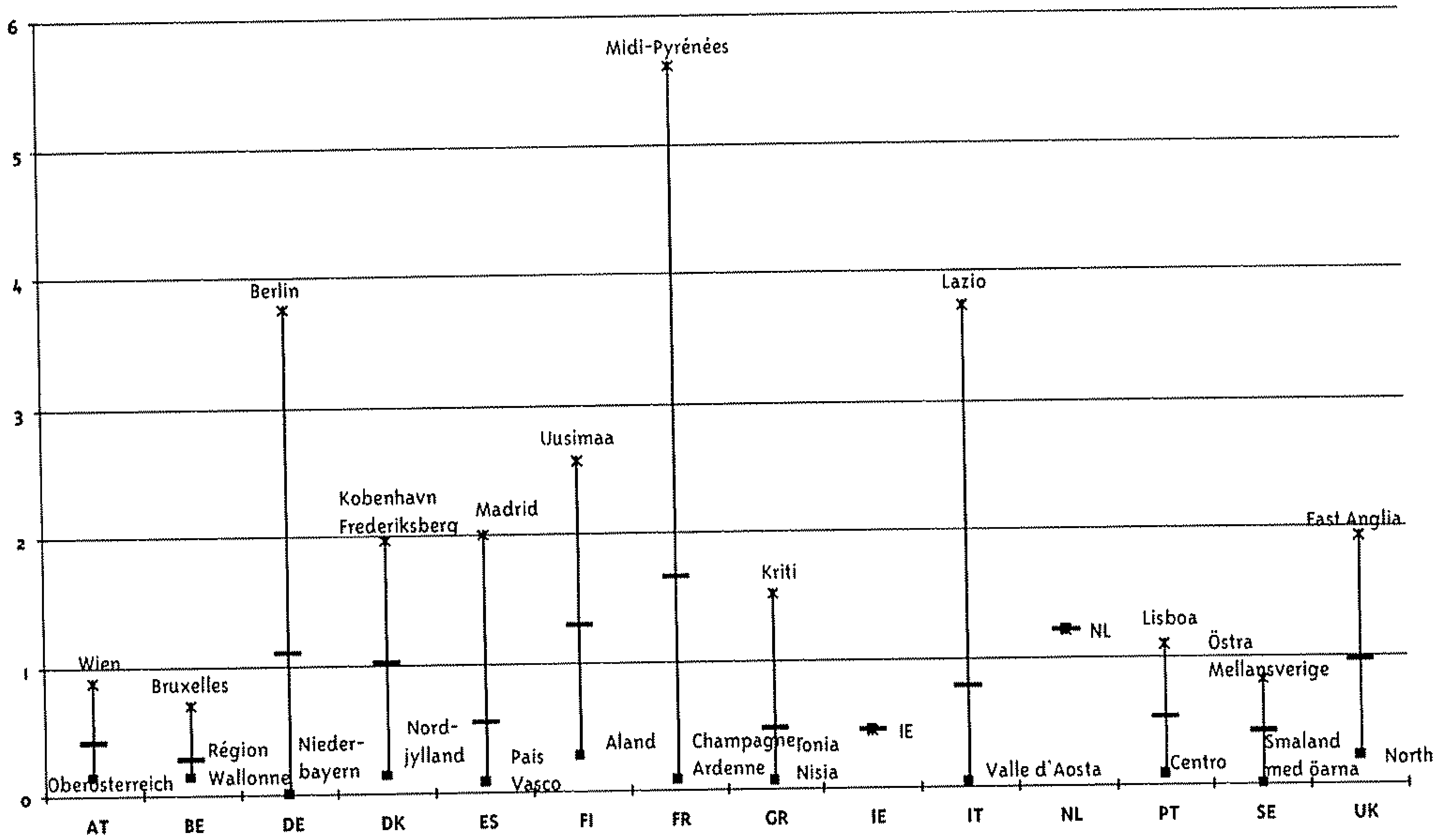


Source: own calculation based on data from Eurostat – REGIO.

As far as university R&D intensity is concerned, Sweden is clearly the best performing country, despite strong regional differences. While at the European level university R&D investment accounts for about 0.37 % of GDP, this proportion is more than three and a half times higher in Östra Mellansverige. Figure 2 illustrates that the Swedish average university R&D intensity is higher than the ones obtained by most best performing European regions. Only some German regions, Giessen and Berlin, and Austrian regions, Wien and Steiermark, are situated above this average. Among the "objective 1" countries Spain, Greece, Portugal and Ireland, for which innovative output is extremely low (Figure 1), best performing regions hardly achieve the European average of university R&D intensity.

Sweden is also the leading country in terms of private business R&D intensity. While at the European level, private business R&D expenditure accounts for about 1.23 % of GDP, in Sweden it accounts on average for 2.29 %, a value that is higher than the ones obtained by most best performing regions of other European countries. Only some German regions namely Oberbayern, Stuttgart, Tübingen, Mittelfranken, Braunschweig and Reinhessen-Pfalz and the French capital region, Île de France,are situated above this average. As indicated by Figure 3, private business R&D intensities of most "objective 1" regions are situated far below the European average.

FIGURE 4. INTENSITY OF GOVERNMENT R&D RELATIVE TO THE EUROPEAN AVERAGE (1989-1996)



Source: own calculation based on data from Eurostat -- REGIO.

The situation is slightly different in the field of government R&D intensity. Although "objective 1" countries do not reach the European average which is about 0.32 % of GDP, Madrid, Kriti and Lisboa e Vale do Tejo are situated above. While Sweden clearly outperformed the other European countries in terms of university and private business R&D intensities, Figure 4 illustrates its weak position in the field of government R&D. This time, the strongest country is France for which we observe however important regional differences. While for Midi-Pyrénées, Languedoc-Roussillon and Île de France government R&D accounts for about 1.3 % of GDP, this value is only 0.02 % for Champagne-Ardenne, Franche-Comté and Limousin.

Since the average values reported in Figures 1 to 4 provide a static overview, it is worth expanding the analysis by adding some dynamic aspects. An index that reflects the degree of spatial concentration of a variable within a given entity is the Herfindahl index[9]. The higher the value of this index, the higher the geographical concentration in a certain entity. Its evolution over a period of time enables to assess whether an activity has become increasingly concentrated or, on the contrary more evenly distributed.

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[9] The Herfindahl index is defined as $\sum_{i=1}^{n} S_i^2$, where S_i denotes the share of a variable of region i in the total of an entity and n is the number of regions covered by this entity. Since under this formulation, the extreme values of the Herfindahl index depend on the number of regions in a given entity, in Table 2, the index is rescaled to bring it within the interval [0, 1] for each entity. Formally, the applied index is then defined as follows: $HF = 1 + \frac{\ln \sum_{i=1}^{n} S_i^2}{\ln n}$

TABLE 3[10]. HERFINDAHL INDEX FOR EUROPEAN ENTITIES AND DIFFERENT TIME PERIODS

	all regions	objective 1 regions	other regions	AT	BE	DE	DK	ES	FI	FR	GR	IT	PT	SE	UK
patents application average index over the period															
89-98	0.27	0.40	0.23	0.15	0.40	0.20	0.54	0.49	0.38	0.50	0.72	0.44	0.51	0.24	0.31
89-96	0.28	0.41	0.24	0.15	0.40	0.21	0.55	0.50	0.37	0.51	0.70	0.44	0.59	0.25	0.31
89/90	0.30	0.48	0.26	0.17	0.33	0.25	0.57	0.59	0.38	0.52	0.68	0.47	0.96	0.28	0.33
95/96	0.26	0.41	0.22	0.15	0.43	0.19	0.54	0.48	0.39	0.49	0.65	0.42	0.63	0.24	0.26
university R&D average index over the period															
89-96	0.28	0.26	0.27	0.56	0.11	0.14	0.60	0.25	0.29	0.60	0.52	0.17	0.49	0.24	0.38
89/90	0.28	0.29	0.27	0.57	0.11	0.13	0.61	0.29	0.28	0.61	0.53	0.17	0.55	0.24	0.40
95/96	0.28	0.25	0.27	0.55	0.12	0.14	0.60	0.25	0.30	0.57	0.51	0.17	0.46	0.25	0.35
business R&D average index over the period															
89-96	0.34	0.40	0.31	0.43	0.32	0.26	0.58	0.52	0.42	0.61	0.71	0.48	0.38	0.32	0.50
89/90	0.36	0.31	0.32	0.38	0.25	0.26	0.58	0.55	0.41	0.64	0.72	0.50	0.41	0.32	0.56
95/96	0.32	0.51	0.29	0.46	0.38	0.26	0.57	0.48	0.43	0.58	0.69	0.46	0.38	0.31	0.37
government R&D average index over the period															
89-96	0.38	0.29	0.36	0.62	0.16	0.31	0.68	0.65	0.58	0.56	0.58	0.56	0.89	0.44	0.52
89/90	0.39	0.30	0.37	0.59	0.16	0.31	0.69	0.67	0.57	0.57	0.58	0.57	0.92	0.40	0.56
95/96	0.37	0.31	0.35	0.64	0.19	0.31	0.68	0.57	0.59	0.56	0.58	0.50	0.84	0.52	0.45

Source: own calculation based on data from Eurostat – REGIO

Several striking observations emerge from Table 3. Firstly, whatever the considered time period, patenting activity is spatially considerably less evenly distributed in "objective 1" regions than on average in other European regions. The highest values for the Herfindahl index in 1989/90 are observed for Portuguese, Greek and Spanish regions. Austria and Germany has the most even distribution of patents among their respective regions. Table 3 indicates that from 1989/90 onwards, the spatial concentration of patenting activity has steadily declined except in Belgium and to a lesser extent in Finland. The tendency towards a more even distribution of patents was slightly more pronounced in "objective 1" regions than on average for Europe as a whole. While in 1995/96 the geographical concentration of patenting activity is still the highest in Greece, and Portugal, in Spain it is geographically less concentrated than in France and Denmark.

Secondly, the more even distribution of patenting activity among "objective 1" regions may be the outcome of public policy. Indeed, for university R&D, the Herfindahl index has

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[10] Since for our sample of 153 European regions, data on patent applications are only available since 1989 and since the latest data on R&D investments go back to 1996, Table 3 covers the period 1989-96. This corresponds also to the time period selected to estimate the model presented in section 2.

not only considerably declined during the period 1989/90 – 1995/96 but also, it has got less important than the European average. For Belgian, German and Italian regions, university R&D is the most evenly distributed and the opposite is the case for Danish, French and Austrian ones. Similarly to the observations regarding university R&D, Table 3 indicates that, whatever the considered time period, government R&D in "objective 1" regions is less concentrated than on average in other regions. Since patenting activity in these regions is highly concentrated, the fact that university and government R&D are relatively evenly distributed clearly suggests redistributive efforts in the field of public R&D.

Thirdly, as far as private business R&D is concerned, the geographical concentration is generally higher than the ones of university and government R&D. This is confirmed by the indexes reported in Table 3. However, during the period 1989/90 – 1995/96, the concentration in this field has steadily declined in almost all European countries. Exceptions are Austrian, Belgian and Finish regions. Even if in "objective 1" regions the tendency of a more even distribution of private business R&D can be observed, it is less pronounced than for the other European regions.

Before turning to the estimation of the model explained in section 2, it is worth summarising the most important facts and figures characterising the innovative activities and R&D efforts of European regions. On average, over the period 1989-1998, 50% of patent applications were concentrated in 13 European regions from which the majority were German ones. This fact highlights firstly, the strong performance of the German innovation system and secondly, the important spatial concentration of knowledge creation in Europe. However, from a dynamic point of view, knowledge creation has got more evenly distributed among regions during the considered period. This observation prevails not only for regions with high levels of developments but also "objective 1" regions. While for the latter, patenting activity is still extremely low, we observe nevertheless a more equal distribution in this field, which in turn may be the result of a more even distribution of university R&D as well as government R&D. Sweden is clearly the country with the highest university and private business R&D intensities but also with an important regional dispersion. A similar observation prevails for France in the field of government R&D.

3. ESTIMATES

The model explained in section 2, is tested on the European regional landscape over the period 1989 - 1996. A total of 153 European regions are covered by the sample which is composed of 120 NUTS II regions, 31 NUTS I regions and 2 NUTS 0 regions. For the latter - The Netherlands and Ireland - no regional data on R&D is available. This is also the case for the Açores and Madeira. Belgian regions could only be covered at the NUTS I level. As far as Danish regions are concerned, aggregations of NUTS III regions have been performed since R&D data are only available in this aggregated form. Germany's new Länder as well as Luxembourg are excluded since R&D data are not available for these regions[11].

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[11] See appendix 1 for a detailed description of the regional sample.

The simultaneous system of equations (equations 4 to 6) has been estimated using tree different econometric methods: Full information maximum likelihood (FIML), two stage least squares (2SLS)[12] and three stage least squares (3SLS)[13]. The Ordinary least squares method (OLS) is not appropriate in our case since some variables are endogenous.

The degree of stability of our estimated coefficients has been investigated by a test procedure which consisted to eliminate in turn each individual region from the sample and to perform 153 different estimations of the system. This procedure enabled us to identify two outliers, namely Corse and Peloponnisos. Both of them significantly influence the estimation results of equation 5. Compared to other "objective 1" regions but also to the Austrian and Italian averages, the proportion of the working age population with high qualification is relatively important while business R&D expenditures in these regions are extremely low. Ceteris paribus, with respect to their level of qualification, business R&D expenditures should be more important than they actually are. Both regions are characterised by a low industrial activity. A distinctive feature for Peloponnisos is the extremely low value of university R&D expenditures which is the main reason why it is also an outlier in equation (6). In order to achieve a better stability of the estimated coefficients, the above mentioned regions are accounted for by the introduction of dummy variables. Table 4 summarises the main empirical findings.

Globally, Table 4 indicates, first of all, a high similarity between the estimates obtained by the three alternative methods. Statistically, the differences between the FIML estimates (column 1), the 2SLS estimates (column 2) and the 3SLS estimates (column 3) are not significant. Secondly, for each equation the coefficient of determination indicates a satisfactory goodness of fit which is not influenced by the adopted estimation method. Thirdly, all coefficients are statistically significant at the 5 % level except the one relative to high qualification in the patenting equation.

As far as the patenting equation (4) is concerned, it is positively influenced by private business and university R&D expenditures. The elasticity of patenting activity with respect to private business R&D expenditures is not only highly significant but also relatively important. A one percentage increase of business R&D investment per capita generates a 0.74 percentage increase of patent applications per capita. For university R&D the elasticity is about 0.17.

Even if a comparison with other studies seems difficult since neither the periods covered nor the model specifications are the same, it is worth mentioning that our estimated private business R&D elasticity is lower than the one obtained by Jaffe (1989) but significantly higher than the ones estimated by Anselin et al. (1997) and Feldman and

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[12] In a first stage we regress each endogenous variable on all exogenous variables in the system and get fitted values. In a second stage, the fitted values together with the exogenous variables are regressed on the dependent variables.

[13] The first two stages of 3SLS are the same as in 2SLS. In the third stage, we apply feasible generalised least squares to the equations in a manner analogous to the SUR estimator.

Florida (1994). However, for university R&D, Anselin et al. (1997) and Feldman and Florida (1994) obtain for the US case, an elasticity comparable to the one that we observe for European regions.

While the proportion of the working age population with a medium level of qualification significantly influences patenting activity, this is not the case for the proportion with a high level of qualification. At a first sight, this outcome seems quite irrelevant but it is not. Firstly, it is important to note that our estimates indicate that high qualification significantly and

TABLE 4. ESTIMATES OF THE SIMULTANEOUS SYSTEM OF EQUATIONS CHARACTERISING THE EUROPEAN REGION'S INNOVATION PROCESS

		basic model		average model			lag model
	FIML (1)	2SLS (2)	3SLS (3)	2SLS (4)	2SLS (5)		2SLS (6)
equation (4): dependent variable: $\ln(P_t)$							
c	-5.67	-5.59	-5.60	-5.65	-5.73	*c*	-5.69
	(-14.90)	(-15.14)	(-15.19)	(-30.09)	(-16.37)		(-30.71)
$\ln(BR\&D_t)$	0.73	0.74	0.74	0.74	0.75	$\ln(BR\&D_t)$	0.76
	(17.95)	(15.73)	(15.77)	(17.32)	(9.46)		(19.57)
$\ln(UR\&D_t)$	0.18	0.16	0.16	0.17	0.17	$\ln(UR\&D_{t-3})$	0.14
	(4.41)	(3.41)	(3.43)	(3.49)	(1.87)		(3.63)
$\ln(MQ_t)$	1.48	1.48	1.48	1.48	1.45	$\ln(MQ_t)$	1.40
	(17.00)	(14.50)	(15.55)	(15.13)	(7.94)		(15.49)
$\ln(HQ_t)$	-0.00	0.02	0.02				
	(-0.00)	(0.16)	(0.17)				
R_2a	0.79	0.79	0.79	0.79	0.88		0.80
equation (5): dependent variable: $\ln(BR\&D_t)$							
c	6.57	6.61	6.57	6.61	6.73	*c*	8.27
	(10.41)	(14.31)	(14.60)	(14.31)	(6.23)		(13.31)
$\ln(UR\&D_t)$	0.76	0.77	0.76	0.76	0.76	$\ln(UR\&D_t)$	0.30
	(9.24)	(11.91)	(11.91)	(11.91)	(5.17)		(1.87)
$\ln(I_t)$	2.09	2.15	2.09	2.15	2.25	$\ln(I_t)$	2.31
	(10.44)	(11.87)	(13.79)	(11.87)	(5.16)		(16.18)
$\ln(HQ_t)$	0.61	0.61	0.61	0.61	0.61	$\ln(HQ_t)$	0.99
	(3.91)	(4.63)	(4.67)	(4.63)	(1.99)		(6.46)
$\ln(MQ_t)$	1.29	1.29	1.29	1.29	1.28	$\ln(MQ_t)$	1.24
	(11.09)	(13.65)	(13.88)	(13.66)	(5.77)		(17.46)
DGR25	4.32	4.38	4.29	4.38	4.42	DGR25	1.72
	(2.12)	(6.32)	(6.25)	(6.32)	(2.74)		(1.72)
DFR83	-4.08	-3.82	-4.07	-3.82	-3.77	DFR83	-4.67
	(-6.14)	(-6.75)	(-9.97)	(-16.75)	(-12.84)		(-9.39)
						$\ln(GR\&D_{t-5})$	0.25
							(2.91)
R^2a	0.49	0.49	0.49	0.49	0.52		0.73

equation (6): dependent variable: $\ln(UR\&D_t)$

c	1.77	1.75	1.75	1.75	1.58	c	1.43
	(2.67)	(3.19)	(3.21)	(3.19)	(1.23)		(2.67)
$\ln(BR\&D_t)$	0.22	0.22	0.22	0.22	0.23	$\ln(BR\&D_t)$	0.24
	(2.48)	(3.51)	(3.54)	(3.51)	(1.58)		(4.06)
$\ln(GR\&D_t)$	0.45	0.46	0.46	0.46	0.47	$\ln(GR\&D_{t-2})$	0.47
	(7.19)	(10.64)	(10.62)	(10.64)	(4.53)		(11.11)
$\ln(HQ_t)$	0.57	0.57	0.57	0.57	0.54	$\ln(HQ_t)$	0.50
	(3.62)	(3.83)	(3.84)	(3.83)	(1.53)		(3.43)
$\ln(MQ_t)$	-0.36	-0.37	-0.37	-0.37	-0.39	$\ln(MQ_t)$	-0.42
	(-2.28)	(-2.54)	(-2.54)	(-2.54)	(-1.16)		(-2.99)
DGR25	-5.25	-5.15	-5.24	-5.15	-5.11	DGR25	-5.30
	(-4.78)	(-8.38)	(-8.57)	(-8.38)	(-3.49)		(-8.70)
R^2a	0.37	0.37	0.37	0.37	0.38		0.38
nb. observ.	918	918	918	918	153		918

Note: t-statistics in brackets
Source: own estimations

positively influences both, private business R&D (equation 5) and university R&D (equation 6). In other words, high qualification is a prerequisite for basic research mainly realised by universities but also for applied research and experimental development essentially performed by the private business sector. Since the input of high qualification is already incorporated in these research activities, it is not surprising that it turns out to be not significant in the patenting equation. One may be concerned about the fact that this reasoning does not apply to medium qualification. In fact, this variable enables us to clearly distinguish between regions with high and / or moderated levels of development and regions with low economic performances. Indeed, the European poorest regions are characterised by a low proportion of the working age population with medium qualification. On average, medium qualification is lowest in Ireland, Greek, Spanish and Portuguese regions while it is highest in German, Swedish and Austrian regions. Although, the share of the working age population with low qualification also would have enabled us to distinguish between "poor" and "rich" regions, the division would have been less clear cut. Indeed, on average this proportion is higher in Italy than in Greece or Ireland for instance. A similar reasoning applies to the proportion of the working age population with high qualification. On average, this share is lower in France than in Spain an Ireland. Globally, it is lowest in Italian and Austrian regions which, in great majority, do not belong to the group of poorest European regions. In short, the share of the working age population with a moderate level of qualification gives a better view of the European spatial dichotomy between "poor" and "rich" regions.

The estimates of equation (5) indicate that private business R&D efforts are a positive function of university R&D efforts with an elasticity of about 0.76. The latter is relatively close to the one obtained by Jaffe (1989) for the US case but higher than the ones estimated by Feldman and Florida (1994) and Anselin et al (1997). The structure of the productive system heavily influences private business R&D activities. Despite the fact, that in recent years, technological progress is increasingly driven by the service sector, it appears that industry still remains "the engine of growth". As stated previously, high qualification is a prerequisite for research activities and positively influences private business R&D. However, not only the share of highly but also the share of moderately qualified working age population is important for the private business research process. Indeed, there are elements characterising a given technology which are tacit and best understood by working with, and using it. The practical experience that is gained from using a product or a process is an important source of incremental innovations. In other words, highly qualified workers intervene more at the conceptualisation stage but there is also a need for technical assistance as well as for technical capabilities for the commercial exploitation of research results.

Finally, the estimates of equation (6) clearly indicate a significant interaction between university R&D and private business R&D. Indeed, a one percentage increase in private business R&D expenditure per capita generates a 0.22 percentage increase in university R&D expenditure per capita, a result which is similar to the one obtained by Feldman and Florida (1994) for the US case. As expected, government R&D also significantly contributes to foster university R&D. Since university R&D is highly knowledge intensive, it is not surprising that it is positively influenced by high qualification but negatively by the proportion of the working age population for which the qualification level is "only" moderate.

Column (4) of Table 4 simply indicates the estimates for the model when the non significant variable of equation (4) is removed. With respect to the previous estimates, the results remain unchanged.

Since the estimated coefficients obtained by the three estimation methods (columns 1 to 3) are statistically similar, it is relatively difficult to choose a particular one. Therefore we follow the advise of Klein (1974, p. 150) and Gujarati (1995, p. 679) who argue that "single equation methods, in the context of a simultaneous system, may be less sensitive to specification errors in the sense that those parts of the system that are correctly specified may not be affected appreciably by errors in specification in another part" and adopt the 2SLS method.

In column (5) of Table 4 we report the estimates of the model when variables are expressed in terms of average values over the period 1989-1996. Compared to the previous cases, in equation (4), R&D efforts realised by universities has lost a lot of significance when explaining a region's patenting activity. Similarly, in equation (6), private business R&D efforts do no longer significantly influence university R&D. What is the rationale behind this outcome? In fact, the innovative process takes time and it is not instantaneous as has been assumed for the estimates reported in columns (1) to (4) of Table 4[14].

While "year by year" regressions as well as regressions with average values clearly high-

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[14] Most empirical analysis however implicitly assume an instantaneous process of innovation. Some examples among others are Anselin at al. (1997), Acs et al. (2002), Jaffe (1989), Varga (1989).

light this fact, cross section time series analysis and panel data econometric models introduce some kind of smoothing.

A more plausible formulation of the innovation process is therefore presented in column (6) of Table 4 where we allow for time lags. The latter has been determined by estimating the system with different combinations of lagged explanatory variables and the combination which yield the highest t-statistics and coefficients of determination has been retained. It appears that patent applications (equation 4) are best explained by contemporaneous private business R&D expenditures together with university R&D realised 3 years previous to the application. It is worth noting, that this specification compared to the reference equation in column (4) increases the significance and the impact of private business R&D on patenting activity but also on university R&D efforts (equation 6). For the latter, the significance for patent applications is increased but its impact is lower compared to the reference equation in column (4). Overall goodness of fit is slightly improved. As far as private business R&D is concerned, several authors[15] have investigated the dynamic structure relationship between patenting and R&D expenditures in considering the number of patent applications as a function of present as well as lagged R&D investment and found a "U-shaped" lag structure (Cincera, 1997). Although our estimates confirm this "U-shape", in the sense that not only contemporaneous but also business R&D realised 4 years previous to the patent application is significant, the overall fit of the system is best when only contemporaneous efforts are considered. The higher significance of lagged university R&D in this equation may reflect the more basic character of knowledge generated by university labs which needs to pass trough further stages of research such as applied research and experimental development before getting commercially interesting.

As far as the private business R&D equation (5) is concerned, contemporaneous university R&D efforts appear to be highly significant in the average model. This is also the best fitting variable when we allow for lagged variables. Contrary to the previous models, in the lagged model (column 6) it is possible to estimate the effect of government R&D[16]. The best fitting variable is government R&D with a time lag of 5 years. Government R&D appears to significantly influence private business R&D and the elasticity is comparable to the one of university R&D. With respect to the reference model (column 4), the impact of university R&D has decreased. This highlights the fact that in the contemporaneous models, the university R&D variable also captured the effects of government R&D. At this stage it should be noticed that public research is carried out in both, public laboratories but also universities. Its main aim is to satisfy public needs and to provide basic knowledge useful to firms for their own applied research. Since university R&D is largely funded by public resources through grants and contracts, it is, at least to a certain extent, controlled by the government, and can potentially be used as a policy making instrument.

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[15] Cincera, (1997) offers an extended overview of the literature in this field.

[16] Because equation (5) would not have been identified when introducing this additional variable, it was not possible in the "contemporaneous models" to test for the influence of this variable

it is, at least to a certain extent, controlled by the government, and can potentially be used as a policy making instrument.

Finally, the best fitting formulation of the university R&D equation (6) is the one which considers as explanatory variables, contemporaneous private business R&D and two years lagged government R&D expenditures. This specification simultaneously increases the importance and significance of both variables.

Before investigating more closely the innovation process of European less developed regions, it is useful to sum up the main findings of this section. In a nutshell, the patenting activity of European regions depends on both, private business and university R&D. Since university R&D is essentially concerned with the generation of basic knowledge its direct impact on patent applications is lower compared to private business R&D which is more market oriented. The relation between university R&D and private business R&D is characterised by feedback relations. University R&D and private business R&D positively influence each other through various channels of knowledge transmission. While private business R&D depends on both, the region's endowment of high and medium qualified workforce, only high qualification positively influences university R&D.

4. SOME CONSIDERATIONS REGARDING EUROPEAN LESS DEVELOPED REGIONS

Section 3 highlighted the low innovation capacity of "objective 1" regions and clearly indicated their weak performance in terms of university and private business R&D despite the fact that all "objective 1" regions are not necessarily disadvantaged in terms of high qualification compared to other European ones. By means of different kinds of indexes reflecting a region's creative capacity, transfer capacity and absorptive capacity, Capron (2001) observes that most "objective 1" regions own the ingredients to build up a sufficient absorptive capacity but experience major difficulties to valorise them. However for these regions, the development of a sufficient absorptive capacity is the first stage of their innovation process and an underlying condition for the development of a transfer and creation capacity. According to the author, "substantial efforts must be made by these regions to ensure that they master the initial stage of the research process" (Capron 2001, p. 205).

In this context it is interesting to investigate our simultaneous equation model in paying a special attention firstly, to "objective 1" regions as a whole and secondly, to the part of "objective 1" regions which are moreover characterised by extremely low levels of university R&D investment. The adopted approach consists to introduce into equations (4) to (6) dummy variables for each kind of regions. This investigation should enable us to identify the most important leverages which are prime candidates for an adequate S&T policy in these regions.

TABLE 5A. PATENTING ACTIVITY IN EUROPEAN LESS FAVOURED REGIONS

		model with dummy variables for			
dependent variable: $\ln(P_t)$	**lag model**	**"objective 1" regions**		**"objective 1" regions with low *UR&D***	
	(1)	(2)	(3)	(4)	(5)
c	-5.69	-4.00	-4.10	-4.74	-4.78
	(-30.71)	(-17.41)	(-17.32)	(-16.25)	(-17.53)
$\ln(BR\&D_t)$	0.76	0.38	0.39	0.62	0.60
	(19.57)	(9.15)	(9.08)	(11.91)	(13.02)
$\ln(UR\&D_{t-3})$	0.14	0.11	0.11	0.05	0.06
	(3.63)	(3.78)	(3.71)	(1.54)	(1.76)
$\ln(MQ_t)$	1.40	0.96	0.89	1.30	1.23
	(15.49)	(8.05)	(7.78)	(11.22)	(11.09)
oI		-3.60	-3.30		
		(-6.96)	(-12.35)		
$\ln(BR\&D_t)_{oI}$		0.36	0.32		
		(3.82)	(3.79)		
$\ln(UR\&D_{t-3})_{oI}$		0.21	0.22		
		(3.62)	(3.78)		
$\ln(MQ_t)_{oI}$		-0.18			
		(-0.68)			
oIf				-2.51	-2.06
				(-3.80)	(-10.32)
$\ln(BR\&D_t)_{oIf}$				-0.05	
				(-0.45)	
$\ln(UR\&D_{t-3})_{oIf}$				0.19	0.20
				(2.97)	(3.10)
$\ln(MQ_t)_{oIf}$				-0.37	
				(-1.10)	
R^2a	0.80	0.81	0.81	0.79	0.79
nb. obs: 918					

Notes: o_I denotes the dummy variables for "objective 1" regions while o_{If} stands for dummy variables for "objective 1" regions with low levels university *R&D* expenditures. Heteroskedasticity-consistent t-statistics in brackets.

Source: own estimations

Tables 5a to 5c report the results for the different equations in the system. In each Table, the first column (1) reports the estimates obtained for the lag model of Table 4. The second and the fourth columns (2 and 4) report the results when allowing for both, a different intercept and different slopes for each variable. And the third and fifth columns (3 and 5) indicate the final estimates after having successively eliminated the non significant variables. It is worth mentioning that for the dummy variable estimates "non significance" simply indicates that the behaviour or impact of a given variable does not statistically differ from the one obtained for the overall sample. Therefore our comments mainly concentrate on the final results reported in columns (3) and (5).

Table 5a indicates the results for the patenting equation. A striking observation is the potentially high leverage effect of increased private business and university R&D expenditures in "objective 1" regions as indicated in column (3). Compared to the effect for the entire sample, in "objective 1" regions the impact of private business R&D on patenting activity is about twice a high and about three times higher for university R&D. While for "objective 1" regions with a low level of university R&D expenditures (column 5) the impact of private business R&D is statistically not different from the one we observe for the overall sample, increased university R&D has a potentially high leverage effect. However, the latter is lower compared to the one we obtain for "objective 1" regions. Now, if the potential leverage effects are high, naturally the question arises of how these potentialities can be realised. Together the estimates of the private business R&D equation (Table 5b) and the university R&D equation (Table 5c) provide some pieces of information.

As far as "objective 1" regions are concerned, the estimates reported in column (3) of Table 5b indicate that the impact of university R&D, of high and medium qualification as well as of government R&D is statistically not different from the one we obtain for the overall sample. However, an increased industrial activity could substantially increase R&D activities of the private business sector. In general, and compared to the European average, "objective 1" regions are characterised by a relatively high employment concentration in agriculture. Since for the agricultural sector market and technological opportunities are weak, the growth potential of these regions is relatively low. Although this is not a new discovery, the results confirm that the industrial base of "objective 1" regions is insufficient. This result also indicates that science and technology (S&T) policies alone are probably not enough to increase the innovation capacity of "poor" regions but must be integrated in a global structural program that fosters the development of activities generating higher value added. Once a sufficient industrial base is created, then technology transfers from universities and government to the private business sector can take place, provided that the region's absorptive capacity is sufficiently developed.

TABLE 5b. PRIVATE BUSINESS R&D ACTIVITIES IN EUROPEAN LESS FAVOURED REGIONS

		model with dummy variables for			
dep. variable: $\ln(BR\&D_t)$	**lag model**	**"objective 1" regions**		**"objective 1" regions withlow *UR&D***	
	(1)	(2)	(3)	(4)	(5)
c	8.27	6.65	6.65	7.83	7.58
	(13.31)	(11.98)	(14.65)	(11.58)	(15.77)
$\ln(UR\&D_t)$	0.30	0.22	0.16	0.13	0.21
	(1.87)	(1.75)	(1.62)	(0.78)	(1.96)
$\ln(I_t)$	2.31	0.88	0.94	1.35	1.32
	(16.18)	(4.83)	(5.69)	(6.56)	(7.57)
$\ln(HQ_t)$	0.99	0.81	0.79	1.00	0.92
	(6.46)	(6.12)	(7.00)	(6.35)	(7.74)
$\ln(MQ_t)$	1.24	0.87	0.74	1.23	1.26
	(17.46)	(7.96)	(7.83)	(17.21)	(18.06)
$\ln(GR\&D_{t-5})$	0.25	0.17	0.22	0.25	0.19
	(2.91)	(2.20)	(3.91)	(2.50)	(3.00)
$DGR25$	1.72				
	(1.72)				
$DFR83$	-4.67				
	(-9.39)				
$o1$		1.38	2.76		
		(1.39)	(5.39)		
$\ln(UR\&D_t)_{o1}$		-0.02			
		(-0.18)			
$\ln(I_t)_{o1}$		3.15	3.09		
		(8.60)	(8.16)		
$\ln(HQ_t)_{o1}$		-0.39			
		(-1.63)			
$\ln(MQ_t)_{o1}$		-0.39			
		(-1.91)			
$\ln(GR\&D_{t-5})_{o1}$		0.10			
		(0.98)			
$o1f$				0.84	
				(0.64)	
$\ln(UR\&D_t)_{o1f}$				-0.13	-0.14
				(-1.97)	(-2.45)
$\ln(I_t)_{o1f}$				2.51	2.27
				(5.59)	(9.96)
$\ln(HQ_t)_{o1f}$				-0.02	
				(-0.05)	
$\ln(MQ_t)_{o1f}$				-1.07	-1.30
				(-4.48)	(-7.05)
$\ln(GR\&D_{t-5})_{o1f}$				-0.13	
				(-1.03)	
R^2a	0.73	0.76	0.76	0.77	0.77
nb. obs: 918					

Notes: o_1 denotes the dummy variables for "objective 1" regions while o_{1f} stands for dummy variables for "objective 1" regions with low levels university *R&D* expenditures. Heteroskedasticity-consistent t-statistics in brackets.
Source: own estimations

A similar reasoning prevails for "objective 1" regions with low levels of university R&D. From column (5) of Table 5b we observe that an increase of the industrial base in these regions has a potentially important impact on private business R&D while the effect of increased university R&D is lower than the one we obtain for the overall sample. It is worth noting that for "objective 1" regions with low university R&D activities, an increase of the workforce with medium qualification would hinder the development of private business R&D which is not the case for "objective 1" regions. For both kinds of regions a higher endowment of high qualified workforce positively contributes to the development of private business R&D activities and this contribution is even higher for "objective 1" regions with low levels of university R&D.

TABLE 5c. UNIVERSITY R&D ACTIVITIES IN EUROPEAN LESS FAVOURED REGIONS

		model with dummy variables for			
dep. variable: $\ln(BR\&D_t)$	**lag model**	**"objective 1" regions**		**"objective 1" regions with low *UR&D***	
	(1)	(2)	(3)	(4)	(5)
c	1.43 (2.67)	1.09 (1.04)	0.14 (0.18)	1.67 (1.74)	1.42 (1.70)
$\ln(BR\&D_t)$	0.24 (4.06)	0.39 (2.81)	0.52 (5.09)	0.21 (1.72)	0.24 (2.19)
$\ln(GR\&D_{t-2})$	0.47 (11.11)	0.41 (8.20)	0.39 (8.15)	0.45 (9.22)	0.44 (9.28)
$\ln(HQ_t)$	0.50 (3.43)	0.50 (2.13)	0.38 (1.94)	0.43 (2.06)	0.38 (1.99)
$\ln(MQ_t)$	-0.42 (-2.99)	-0.20 (-0.71)	-0.45 (-1.95)	-0.34 (-1.39)	-0.39 (-1.75)
DGR25	-5.30 (-8.70)				
o_l		-2.64 (-1.67)			
$\ln(BR\&D_t)_{o_l}$		-0.33 (-1.64)	-0.60 (-4.78)		
$\ln(GR\&D_{t-2})_{o_l}$		0.52 (3.30)	0.48 (3.17)		
$\ln(HQ_t)_{o_l}$		-0.38 (-0.99)			
$\ln(MQ_t)_{o_l}$		-1.22 (-3.19)	-0.51 (-2.96)		
o_{lf}				-1.44 (-0.80)	
$\ln(BR\&D_t)_{o_{lf}}$				-0.51 (-2.46)	-0.62 (-4.18)
$\ln(GR\&D_{t-2})_{o_{lf}}$				0.41 (2.43)	0.38 (2.35)
$\ln(HQ_t)_{o_{lf}}$				0.61 (1.44)	1.01 (4.25)
$\ln(MQ_t)_{o_{lf}}$				-1.30 (-3.21)	-1.09 (-4.98)
R^2a	0.38	0.33	0.32	0.36	0.36
nb. obs: 918					

Notes: o_l denotes the dummy variables for "objective 1" regions while o_{lf} stands for dummy variables for "objective 1" regions with low levels university R&D expenditures. Heteroskedasticity-consistent t-statistics in brackets.
Source: own estimations

As far as university R&D activities are concerned (Table 5c), in both kind of regions (columns 3 and 5) government has an important role to play. Indeed, government R&D investment in "objective 1" regions as a whole as well as in the part of "objective 1" regions with low levels of university R&D has an impact about twice as large as the one we estimate for the overall sample. For the latter group of regions, extremely important effects on university R&D could be achieved by an increase of highly qualified human capital. A one percentage increase of the working age population with high qualification could induce a more than one percentage increase of university R&D. On the opposite, we observe for both kinds of regions a negative impact of an increase of the working age population with medium levels of qualification, an impact which significantly more pronounced than for the overall sample.

The estimates reported in Table 5c also indicate that in European less favoured regions, an increase in private business R&D does not positively influence university R&D while it is clearly an important determinant for the overall sample. This result should be interpreted with caution and replaced into the regional context. As stated previously, in these regions the entire innovation process is not yet in place and this appears to be particularly true for the feedback relations from the private business sector to university R&D. In order to increase the knowledge flows from the private business sector to universities it could be beneficial for both parts to condition public R&D support on industry - university collaborations. We have stated previously that even in European less favoured regions university R&D positively influences private business R&D. This result could reflect that university R&D in these regions is used as a public policy instrument aimed at fostering private business R&D since large parts of university R&D are funded by the public sector.

In terms of policy implications, the investigation of the innovative process in European less favoured regions leads to the following suggestions. Firstly, it is important to strengthen their absorptive capacity. From equations (5) and (6) we deduce that this can be achieved by an increase of the working age population with high qualification even if some "objective 1" regions are not disadvantaged in this field with respect to some other European countries. The strengthening of the qualification level enables not only to upgrade university research but also private business R&D. This is especially true for "objective 1" regions with low university R&D. In these regions it may well be the case that university R&D is low because high qualified human capital is scarce. Our estimates also suggest that the impact of an increased regional workforce with "only" medium qualification importantly hampers both, university and private business R&D. This result implies that a shift from medium to high qualification has to be achieved by means of adequate training programmes closely tailored with respect to local latent and expressed needs. Secondly, government R&D has an important role to play. Its impact is highly important for university R&D and for private business R&D it is about the same that we observe for the overall sample. While in general, government R&D should mainly aim at satisfying public needs, its role is larger in less favoured regions especially with respect to the development of sufficient absorptive and transfer capacities. The latter could be strengthened if public funding in favour of private businesses gets more importantly oriented towards university – industry collaborations. Finally, in European less favoured regions, the implementation of an S&T policy alone may fail to hit the target to increase their innovation capacity. S&T policies need to be integrated into an overall structural policy which gradually increases the industrial base and favours the development of high value added creating activities.

CONCLUSION

Despite the fact that innovation is considered to be the "engine of growth", little attempts have been undertaken so far to explicitly model the innovation process of European regions, taking into account the potential mutual influences between university and private business R&D efforts. Our paper aimed at filling this gap.

Inspired by Jaffe's approach (1989) who investigated this topic for the US case, we built a simultaneous equation model based on the Griliches (1979) knowledge production function framework. The first equation in this model considers innovation output, proxied by patent applications to the EPO, as a function of innovative inputs, namely R&D efforts realised by the private business sector and universities. The potential interaction between university and private business R&D is captured by two additional equations: one explains private business R&D as a function of university R&D, the other considers university R&D as a function of private business R&D. In all equations we control for structural characteristics such as the qualification level of the region's workforce and the structure of the productive system and include also government R&D expenditures as an exogenous explanatory variable.

The model is tested onto an extended sample of 153 European regions and suggests the following. European region's patenting activity depends on both, private business and university R&D. Since university R&D is essentially concerned with the generation of basic knowledge its impact on patent applications is lower and takes more time compared to private business R&D which is more market oriented. The relation between university R&D and private business R&D is characterised by feedback relations. University R&D and private business R&D positively influence each other through various channels of knowledge transmission. While private business R&D depends on both, the region's endowment of highly and moderately qualified workforce, only high qualification positively influences university R&D. The structure of the productive system is a main determinant of the region's private business R&D activity which, on average, is higher in regions with an important industrial base. Both, university R&D and private business R&D are significantly and positively influenced by lagged government R&D investments.

Although we observe for the period 1989 – 1996 a tendency towards a more even distribution of innovative activities, the European landscape is still characterised by important regional as well as national disparities. European "objective 1" regions suffer particularly from low levels of university and private business R&D activities and, as a consequence, from a low knowledge creation capacity. Although these regions are not necessarily disadvantaged in terms of high qualification, they have difficulties to develop a sufficient absorptive capacity. In order to enhance the latter, the development of a sufficient industrial base is necessary and further efforts in order to upgrade human capital are required. Our estimation results suggest that an increase of the proportion of highly qualified workforce combined with a decrease of the proportion with medium qualification would stimulate both, university and private business R&D. In European less favoured regions government R&D has a particularly important role to play since it heavily influences university R&D which in turn sustains the development of private business R&D.

While our model certainly provides a closer insight into the mechanisms driving the innovation process of European regions compared to studies focusing on single aspects, all facets of this process could not be covered. Limited data availability made it impossible to investigate some important aspects such as the region's endowment of specialised business services, network relations within and between the components of the region's technological infrastructure, the region's degree of openness and its cross border collaborations. The constitution of a detailed database in these fields would be highly useful for scientific investigations and more fundamentally for the conception of "regionally tailored" S&T policies.

This last consideration naturally leads us to suggest some exciting topics for further research. Besides the investigation of the above mentioned areas, it would be highly interesting to study the impact of specialisation and diversification in the field of knowledge creation. More precisely, it would be useful for policy making to assess the extent to which Marshall (1890) – Arrow (1962) – Romer (1986) externalities and / or Jacobs (1969) externalities influence the innovative output of European regions. In this field, existing literature focuses basically on US MSA but no investigation has yet been undertaken at the European regional level. From a purely technical point of view, the analysis could be affined by means of spatial econometric estimation methods that enable to account for spatial dependence among European regions.

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APPENDIX 1. CROSS SECTION SAMPLE

NUTS	Code	Region
0	**BE**	**BELGIQUE**
1	*BE1*	*Région Bruxelles-capitale*
1	*BE2*	*Vlaams Gewest*
1	*BE3*	*Région Wallonne*
0	**DE**	**DEUTSCHLAND**
1	DE1	BADEN-WÜRTTEMBERG
2	*DE11*	*Stuttgart*
2	*DE12*	*Karlsruhe*
2	*DE13*	*Freiburg*
2	*DE14*	*Tübingen*
1	DE2	BAYERN
2	*DE21*	*Oberbayern*
2	*DE22*	*Niederbayern*
2	*DE23*	*Oberpfalz*
2	*DE24*	*Oberfranken*
2	*DE25*	*Mittelfranken*
2	*DE26*	*Unterfranken*
2	*DE27*	*Schwaben*
1	*DE3*	*Berlin*
1	*DE5*	*Bremen*
1	*DE6*	*Hamburg*
1	DE7	HESSEN
2	*DE71*	*Darmstadt*
2	*DE72*	*Gießen*
2	*DE73*	*Kassel*
1	DE9	NIEDERSACHSEN
2	*DE91*	*Braunschweig*
2	*DE92*	*Hannover*
2	*DE93*	*Lüneburg*
2	*DE94*	*Weser-Ems*
1	DEA	NORDRHEIN-WESTFALEN
2	*DEA1*	*Düsseldorf*
2	*DEA2*	*Köln*
2	*DEA3*	*Münster*
2	*DEA4*	*Detmold*
2	*DEA5*	*Arnsberg*
1	DEB	RHEINLAND-PFALZ
2	*DEB1*	*Koblenz*
2	*DEB2*	*Trier*
2	*DEB3*	*Rheinhessen-Pfalz*
1	*DEC*	*Saarland*
0	**DK**	**DANMARK**
2	*DK01*	*København og Frederiksberg(1)*
2	*DK02*	*Vestsjællans, Storstøms amt(2)*
2	*DK03*	*Fyns amt*
2	*DK04*	*Sønderjyllands amt(3)*
2	*DK05*	*Arhus amt*
2	*DK06*	*Nordjyllands amt*
0	**GR**	**ELLADA**
1	GR1	VOREIA ELLADA
2	*GR11*	*Anatoliki Makedonia, Thraki*
2	*GR12*	*Kentriki Makedonia*
2	*GR13*	*Dytiki Makedonia*
2	*GR14*	*Thessalia*
1	GR2	KENTRIKI ELLADA
2	*GR21*	*Ipeiros*
2	*GR22*	*Ionia Nisia*
2	*GR23*	*Dytiki Ellada*
2	*GR24*	*Sterea Ellada*
2	*GR25*	*Peloponnisos*
1	*GR3*	*Attiki*
1	GR4	NISIA AIGAIOU, KRITI
2	*GR41*	*Voreio Aigaio*
2	*GR42*	*Notio Aigaio*
2	*GR43*	*Kriti*
0	**ES**	**ESPAÑA**
1	ES1	NOROESTE
2	*ES11*	*Galicia*
2	*ES12*	*Principado de Asturias*
2	*ES13*	*Cantabria*
1	ES2	NORESTE
2	*ES21*	*Pais Vasco*
2	*ES22*	*Comunidad Foral de Navarra*
2	*ES23*	*La Rioja*
2	*ES24*	*Aragón*
1	*ES3*	*Comunidad de Madrid*
1	ES4	CENTRO (E)
2	*ES41*	*Castilla y León*
2	*ES42*	*Castilla-la Mancha*
2	*ES43*	*Extremadura*
1	ES5	ESTE
2	*ES51*	*Cataluña*

APPENDIX 1. CONTINUED

	1		*DEF*	*Schleswig-Holstein*
0			**FR**	**FRANCE**
	1		*FR1*	*Île de France*
	1		FR2	BASSIN PARISIEN
		2	*FR21*	*Champagne-Ardenne*
		2	*FR22*	*Picardie*
		2	*FR23*	*Haute-Normandie*
		2	*FR24*	*Centre*
		2	*FR25*	*Basse-Normandie*
		2	*FR26*	*Bourgogne*
	1		*FR3*	*Nord-Pas-de-Calais*
	1		FR4	EST
		2	*FR41*	*Lorraine*
		2	*FR42*	*Alsace*
		2	*FR43*	*Franche-Comté*
	1		FR5	OUEST
		2	*FR51*	*Pays de la Loire*
		2	*FR52*	*Bretagne*
		2	*FR53*	*Poitou-Charentes*
	1		FR6	SUD-OUEST
		2	*FR61*	*Aquitaine*
		2	*FR62*	*Midi-Pyrénées*
		2	*FR63*	*Limousin*
	1		FR7	CENTRE-EST
		2	*FR71*	*Rhône-Alpes*
		2	*FR72*	*Auvergne*
	1		FR8	Méditerranée
		2	*FR81*	*Languedoc-Roussillon*
		2	*FR82*	*Provence-Alpes-Côte d 'Azur*
		2	*FR83*	*Corse*
0			***NL***	***Nederland***
0			**AT**	**ÖSTERREICH**
	1		AT1	OSTÖSTERREICH
		2	*AT11*	*Burgenland*
		2	*AT12*	*Niederösterreich*
		2	*AT13*	*Wien*
	1		AT2	SÜDÖSTERREICH
		2	*AT21*	*Kärnten*
		2	*AT22*	*Steiermark*
	1		AT3	WESTÖSTERREICH
		2	*AT31*	*Oberösterreich*
	2		*ES52*	*Comunidad Valenciana*
		2	*ES53*	*Baleares*
	1		ES6	SUR
		2	*ES61*	*Andalucia*
		2	*ES62*	*Murcia*
	1		ES7	Canarias (ES)
0			***IE***	***Ireland***
0			**IT**	**ITALIA**
	1		IT1	NORD OUEST
		2	*IT11*	*Piemonte*
		2	*IT12*	*Valle d 'Aosta*
		2	*IT13*	*Liguria*
	1		*IT2*	*Lombardia*
	1		IT3	NORD EST
		2	*IT31*	*Trentino-Alto Adige*
		2	*IT32*	*Veneto*
		2	*IT33*	*Friuli-Venezia Giulia*
	1		*IT4*	*Emilia-Romagna*
	1		IT5	CENTRO (I)
		2	*IT51*	*Toscana*
		2	*IT52*	*Umbria*
		2	*IT53*	*Marche*
	1		*IT6*	*Lazio*
	1		IT7	ABRUZZO-MOLISE
		2	*IT71*	*Abruzzo*
		2	*IT72*	*Molise*
	1		*IT8*	*Campania*
	1		IT9	SUD
		2	*IT91*	*Puglia*
		2	*IT92*	*Basilicata*
		2	*IT93*	*Calabria*
		1	*ITA*	*Sicilia*
	1		*ITB*	*Sardegna*
	0		**PT**	**PORTUGAL**
1			PT1	CONTINENTE
		2	*PT11*	*Norte*
		2	*PT12*	*Centro (P)*
		2	*PT13*	*Lisboa e Vale do Tejo*
		2	*PT14*	*Alentejo*
		2	*PT15*	*Algarve*
0			**UK**	**UNITED KINGDOM**

APPENDIX 1. CONTINUED

2	*AT32*	*Salzburg*	*1*	*UK1*	*North (NUTS95)*
2	*AT33*	*Tirol*	*1*	*UK2*	*Yorkshire Humberside (NUTS95)*
2	*AT34*	*Vorarlberg*	*1*	*UK3*	*East Midlands (NUTS95)*
0	**FI**	**SUOMI/FINLAND**	*1*	*UK4*	*East Anglia (NUTS95)*
1	FI1	MANNER-SUOMI	*1*	*UK5*	*South East (UK) (NUTS95)*
2	*FI11*	*Uusimaa (NUTS95)*	*1*	*UK6*	*South West (UK) (NUTS95)*
2	*FI12*	*Etelä-Suomi (NUTS95)*	*1*	*UK7*	*West Midlands (NUTS95)*
2	*FI13*	*Itä-Suomi*	*1*	*UK8*	*North West (UK) (NUTS95)*
2	*FI14*	*Väli-Suomi*	*1*	*UK9*	*Pays de Galles (NUTS95)*
2	*FI15*	*Pohjois-Suomi*	*1*	*UKA*	*Ecosse (NUTS95)*
1	*FI2*	*Åland*	*1*	*UKB*	*Northern Ireland (UK)(NUTS95)*
0	**SE**	**SVERIGE**			
2	*SE01*	*Stockholm*			
2	*SE02*	*Östra Mellansverige*			
2	*SE03*	*Smland med öarna (NUTS95)*			
2	*SE04*	*Sydsverige*			
2	*SE05*	*Västsverige (NUTS95)*			
2	*SE06*	*Norra Mellansverige*			
2	*SE07*	*Mellersta Norrland*			
2	*SE08*	*Övre Norrland*			

Composition of the cross section sample (in italic)
NUTS 0 regions : 2
NUTS 1 regions : 31
NUTS 2 regions : 120

(1)København og Frederiksberg Kommuner, Københavns a., Frederiksborg a., Roskilde a.
(2)Vestsjællands a., Storstrøms a., Bornhoms a
(3)Sønderjyllands a., Ribe a., Vejle a., Ringkøbing a., Viborg a. Viborg a.

APPENDIX 2A. CORRELATION

	log(BR&D)	log(UR&D)	log(GR&D)	ln(MQ)	ln(HQ)	ln(I)
ln(BR&D)	1.00					
ln(UR&D)	0.45	1.00				
ln(GR&D)	0.48	0.50	1.00			
ln(MQ)	0.58	0.16	0.29	1.00		
ln(HQ)	0.51	0.35	0.31	0.17	1.00	
ln(I)	0.50	0.10	-0.04	0.27	0.10	1.00

APPENDIX 2B. DESCRIPTIVE STATISTICS

	mean	standard deviation	minimum	maximum
ln(P)	-3.72	2.23	-10.86	0.98
ln(BR&D)	4.03	1.82	-5.51	7.26
ln(UR&D)	3.15	1.88	-5.95	5.78
ln(GR&D)	2.69	1.38	-3.74	5.98
ln(MQ)	-0.31	1.13	-2.41	0.97
ln(HQ)	-1.82	0.49	-2.99	0.97
ln(I)	-0.93	0.96	-2.70	1.00