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ASYMMETRIC SPILLOVERS FROM NATIONAL INNOVATION SYSTEMS TO KNOWLEDGE CREATION PROCESSES IN THEIR REGIONS

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A Knowledge Production Function (KPF) analyzes if the national innovation systems (NIS) generate knowledge spillovers for their regions. Therefore, we include in the traditional KFP some variables that reflect the NIS of each region. In fact, we included 52 national and regional explanatory variables and applied a factorial analysis to reducing them to a few 'synthetic' ones. Our study offers some evidence on the existence of 'national' spillovers and they seems to be asymmetrical. Its intensity is lower in the technologically less developed regions than in those of intermediate technological development and scarcely exists in the case of the more developed or central regions.

Key words: Knowledge Production Function, knowledge externalities or spillovers, regional innovation systems.

JEL classification: O18, O33, O52.

The present work studies the flows of knowledge from the national systems of innovation (NIS) to the processes of knowledge generation of their regions within the framework of the Knowledge Production Function (KPF) for 170 European regions in the period 2000-2010, with special attention to the asymmetry of such knowledge flows.

In the European Union –as in almost all industrialized nations– the regional aspects of innovation have acquired special relevance in their policies, thus making the regions important actors in economic development. Early theorists on economics and technological change were not primarily concerned with space and its geographical implications (such as Schumpeter or Solow) and its importance was even denied [see Arrow (1962)]. However, the theoretical bases of the existence of externalities or spillovers were identified by neoclassical economists such as Von Thünen (1826), Marshall (1920), Perroux (1955) and Myrdall (1957), and were released again by the literature of the new growth theory [see Romer (1986)], while the importance of the national system for competitiveness has been highlighted by Porter (1990). These authors highlight the strengths or internal advantages of a region or country in order to generate externalities or spillovers towards firms located in such areas. One of the central concepts of these authors is the 'effects of agglomeration' which refers to those aspects of a geographical area that attract factors of production. With this, more advantages are allowed to accumulate in the area and thus attract more investments. Such a process of cumulative causation [see Myrdal (1957)] leads to the geographical concentration of production in poles of growth (Perroux, 1955), which implies that these authors use a clear regional focus to deal with the existence of externalities. The theoretical literature distinguishes between three types of externalities [as defined by Glaeser *et al.* (1992)]. The first ones are the so-called 'Marshall-Arrow-Romer' or MAR[1] externalities based on spillovers of local knowledge between firms of the same industry or related sectors within the same region. The second type is related to the concept of clusters promoted by the work of Michael Porter, initially with a clear national focus of interdependent synergies or spillovers among national actors. The conceptual framework of innovation systems is analogous to the MAR approach also pointing to the advantages and mutual reinforcement (synergies) derived from similar co-localized activities. The third type of spillovers or externalities are based on diversification (Jacob externalities) in which dissimilar activities influence each other in a positive way.

In this paper we analyze the learning effect or the spillovers –both those desired by means of market mechanisms and those not desired based on copying, imitation, mobility of human capital, etc.– from National Innovation Systems on the production of knowledge in their regions. As will be discussed in section 1, it seems to be easier to find the combination of all forms of proximity within the same country rather than between different countries or regions of different countries. Normally a country has a certain level of similarities in its cultural, institutional and social behavior. Especially in the European case the differentiation of languages creates certain distances in terms of understanding and mutual communication between agents with their corresponding impact on trust or cultural attitudes. Moreover, National Innovation Systems and their institutions and scientific and technological infrastructures (S&T) are mostly designed in terms of national interests in order to improve the competitiveness of firms in all their regions. For these reasons, we estimate a knowledge production function (KPF) at the regional level using a sample of 170 European regions belonging to 17 countries. In this study we include as independent variables not only regional data but also indicators at the national level in order to assess the multiplier effect (spillovers) of National Innovation Systems on their regions[2] within the framework of the evolutionary theory of technological change and an holistic and systemic approach of the innovation.

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(1) This abbreviation is based on many basic articles that offer explanations of the existence of such externalities [see Marshall (1920); Arrow (1962); Romer (1986)].

(2) In the national variables assigned to each region, a correction was applied, subtracting the value of the region itself, so that only the spillovers of the other regions are incorporated, thus avoiding double counting of the region's data.

A first novelty of the work is the inclusion in the estimation of the regional KPF of variables that characterize the national system. That is, each region includes variables or factors that reflect (discounting the effort of the region itself) to what extent there are spillovers from the national level to the regional system. Another relatively new aspect –following the approach of Buesa *et al*. (2010)– is the evolutionary perspective. Both the evolutionary economy and the Schumpeterian framework use a holistic view where all the agents and factors of the NIS interact (in)directly and influence or complement each other. For this reason, it has been decided to include the maximum number of variables (initially 52) to reflect in this way the greatest possible number of agents and aspects for which statistical data are available for the period analyzed. To solve the multicollinearity problem, a factorial analysis has been applied, reducing the broad set of 52 indicators –highly correlated– in a small number of synthetic factors or 'composite' variables that reflect the underlying structure of national and regional innovation systems.

A third important aspect is the analysis of the intensity of the spillovers. Bearing in mind that innovation is cumulative and the fact that learning capacity depends on pre-existing knowledge, it is not possible to expect all regions to have the same opportunity to absorb public knowledge, not only regarding codified information but also especially in the case of more complex knowledge with a large tacit load (see section 1.1). For this reason, and once the importance of national systems for the production of regional knowledge was detected, it was decided to form clusters between regions to measure such externalities in the sense of analyzing whether knowledge flows differ by type of regions. There is ample evidence in the literature that the existence of spillovers or knowledge flows depends to a large extent on absorption capacity and that this capacity is very different among different countries and / or regions (see sections 1.1 and 1.4). In fact, the results of this work indicate that these flows do not reach each of the regions with the same intensity, since such flows travel less intensely towards the less developed regions (in technological terms), possibly due to their lower absorption capacity. While the intermediate regions are those that maybe could take most advantage of innovative activities at the national level.

The article has the following structure: in the next section we discuss the different concepts related to knowledge externalities and the role of proximity in the generation of such spillovers. Sections three and four offer our empirical analysis. Section two discusses the database, the creation of composite variables and the methodology used, while section three offers and interprets the results obtained by our empirical analyzes. Finally comes a fourth and final section with some conclusions.

1. Proximity, absorption capacity and the generation of asymmetric knowledge externalities

The literature on economics and technological change –especially the evolutionary economy and the innovation systems approach– highlights the role of local spillovers both within and between regions and countries [see Lundvall (1992); Nelson (1993); Castellacci (2008); Christ (2009); Carrincazeaux & Coris (2011); Marrocu *et al*. (2013)]. However, the recognition, assimilation and application of external knowledge are not easy tasks and will depend to a large extent on the absorption or technological capacity [see Cohen & Levinthal (1989); Caragliu & Nijkamp (2012)]. Such capacity is defined as the ability to recognize, acquire, assimilate, transform and exploit external knowledge [see Zahra & George (2002); Lane *et al*. (2006); Lau & Lo (2015)]. All these authors maintain that such learning capacity is cumulative and depends on pre-existing knowledge, especially if these are related to new technological changes developed externally. Caragliu & Nijkamp (2012, p. 571) argue that: "If prior knowledge is needed for a firm's staff to understand and decode new knowledge, why should regions not behave similarly?" That is, as in the case of firms not all the regions have the same technological capacity, so the spillovers between regions will be unequal or asymmetric.

This asymmetry depends not only on the proximity of possible pre-existing knowledge to those of the region (cognitive proximity) but also on other forms of proximity. Boschma (2005) argues that the ability to absorb or learn from external knowledge depends simultaneously on many complementary forms of proximity: geographical, cognitive, organizational, institutional or cultural, and social. These different forms of proximity have complementary and reinforcing effects on the transmission of knowledge desired (based on market mechanisms) or unwanted ones (imitation, mobility of human capital, etc.). Based on the work of Boschma and others it is to explain, on the one hand, that effects of overflow are not limited between regions of a single country and, on the other, they are expected to be asymmetric and depend on the absorption or technological capacity of the region itself and the level of proximity.

1.1. Geographical proximity and absorption capacity versus the existence and asymmetry of spillovers

Despite the fact that external knowledge and innovations can be acquired at national or international levels and despite the existence of a-spatial relationships between innovative agents, geographic proximity is probably still the main factor to ensure spillovers [see Carrincazeaux & Coris (2011)], although such proximity is not always necessary or sufficient. The regional limits of knowledge spillovers were questioned by authors such as Arrow (1962), who considered knowledge as a public good based on codified information that flows freely across regional and national boundaries. However, the new evolutionary theory of technological change, and especially the notion of tacit uncoded knowledge [see Polanyi (1958, 1966)], suggests that part of technological progress cannot be codified and therefore can only be transferred directly in frequent face-to-face contacts [see Von Hippel (1994)]. In this way, the tacit and cumulative nature of knowledge explains why geographical proximity is –in general– necessary to ensure an optimum of interregional externalities or collective learning [see Maskell & Malmberg (1999)]. This could be particularly the case in new and / or complex technological fields with high levels of dynamism and uncertainty.

The tacit aspects of knowledge lead to the importance of the accumulation of technical skills that determine the capacity for learning, which is defined as the skills to draw, understand, assimilate and apply new tacit knowledge. The understanding of new (external) technologies by firms (learning or absorption capacity) requires a minimum level of cognitive proximity in order to recognize and apply them. In the case of having large cognitive distances between the central and peripheral regions, it is not clear that all regions have the same absorption capacity. Especially peripheral regions could have more difficulties in learning and assimilating tacit and complex knowledge from other regions –especially from the core regions of the country–. First, due to a lower level of pre-existing knowledge, they will have more difficulty in absorbing coded information or tacit knowledge. Second, because of the geographical distance of these regions, since it hinders the learning of tacit knowledge. On the other hand, the more advanced core regions probably could not learn much from the less developed ones due to the low technical level of the latter. For this reason, it would be mostly the 'intermediate' regions that would learn the most from public knowledge, since they would have sufficient technical and absorption capacities to take advantage of the spillovers from the most technologically advanced regions. Such regions have a sufficient technological level to understand the advanced technologies of the core regions and often are better connected due to the design of the national transport system. Therefore, they would have a greater level of geographical proximity in a broad sense, not only the distance measured in real distance but taking into account the time and costs of transportation and communications.

1.2. Institutional, social and organizational proximity

A second argument to explain why geographical proximity is required to ensure or facilitate spillovers is related to the incorporation of knowledge diffusion and / or collective learning in a given institutional and socio-cultural context [see Edquist (1997); Asheim & Gertler (2004)] and the relevance of social networks [see Granovetter (1973)]. A large number of authors point out the importance of social, cultural and institutional proximity within their historical trajectory as a requirement for the optimal functioning of innovation systems [see Lundvall (1992); Edquist (1997); Maskell & Malmberg (1999)].

Institutional or cultural aspects reflect common behavior at the 'macro level' including laws and rules (formal institutions) and cultural, ethical or religious values, routines and habits, norms, traditions or shared expectations (informal institutions) that fix or they shape behavior and direct actions [see Edquist & Johnson (1997); Bathelt & Glücker (2014)]. Social proximity refers to personal relationships at the 'micro level' between individuals or agents based on characteristics such as trust, friendship, empathy, truth or common experience. Social proximity is important because the transmission of tacit knowledge is based on long and continuous face-to-face contacts which are facilitated by social closeness and mutual trust [see Boschma (2005)]. A shared institutional or social framework and a common cultural identity facilitate transfer and spillovers because they involve standardized procedures that limit uncertainty and reduce possible transaction costs [see Marrocu *et al.* (2013); Maskell & Malmberg (1999); Gertler (2003)] facilitating a better mutual understanding [see Bathelt & Glücker (2014)].

Organizational proximity refers to the ways in which agents organize or formalize their interaction and coordination. Contracts based on market mechanisms do not always offer the most optimal mode of interaction. This is especially true in the field of innovation, which has significant levels of uncertainty and volatility: as a result, contracts cannot include all possible unforeseen circumstances. The innovation systems approach establishes that interaction and cooperation between agents are basic to ensure technological progress and facilitate the transfer of technology, especially due to the growing interdisciplinarity, complexity and reduction of the life cycle of new products. Due to the importance of secrecy in the case of innovations –as a strategic asset– social proximity based on trust is a basic requirement for cooperation [see Lundvall (1993); Maskell & Malmberg (1999)] and the corresponding spillovers.

1.3. The role of national innovation systems for regions in a globalized world

The above description of the theoretical concepts of externalities and the role of proximity offers many direct and indirect arguments about the importance of national innovation systems for their regions and firms. Boschma (2005) argues that there is an interaction between the five forms of proximity. In fact, many of the forms of proximity seem to be more easily reached between agents of the same region or country. Therefore, intentional or unintentional externalities, *ceteris paribus*, would flow more frequently and intensively among agents from the same geographical area (country or region). They happen more frequently and more quickly through the use of a 'common language', not only in linguistic terms, but also in social and institutional terms.

This is a clear characteristic of national states. So it is in this interaction and in the mutual reinforcement of the different forms of proximity that the national innovation system has a central role since they occur, without any doubt, more intensively between regions of the same country than between regions of different countries.

Being regions of the same country: (1) facilitates the regional proximity between agents of the same national system of innovation and production, facilitating coordination between regions and/or firms of the same country [see Feldman (1994); Carrincazeaux *et al.* (2008)]; (2) because due to the frequent relationships and interactions within a similar national culture there is a higher level of social proximity (trust and empathy) between national agents [see Breschi & Lissoni (2001)] especially in terms of informal relationships [see Audretsch & Feldman (1996)]. Within a nation the possibilities of unexpected and unplanned informal meetings are higher [see Guillain & Huriot (2001)] facilitating the creation of mutual trust, respect and cordiality [see Boschma (2005)]; (3) it increases the similarities in sectoral specialization and common routines –incorporated in education– which implies a high level of cognitive and institutional proximity, increasing agent's interest in face-to-face contacts. And (4) the institutional proximity is strongly related to the national proximity since there are normally common languages, laws, religion and common beliefs within the limits of a country.

1.4. Asymmetric spillovers and absorption capacity: empirical evidence

Since the seminal work of Cohen & Levinthal (1989) regarding the concept of absorptive capacity has been analyzed and widely evidenced the fact that not all firms have the same opportunity to take advantage –based on spillovers– knowledge publicly available in the 'environment', a fact that is also confirmed with respect to spillovers at the level of countries or regions. Spillovers of knowledge are defined as the direct or indirect transfer of knowledge that is embedded in technologically advanced economic activities [see Lall & Narula (2013)] through imitation, mobility of human capital, dissemination based on publication and patents, etc.

The absorption capacity depends on three basic aspects: (1) the stock of previous knowledge and / or innovative experience in the company –or in our case in the region–, (2) the existence of well qualified human capital and (3) the cognitive proximity of these two aspects with the new public knowledge. Absorption capacity is very heterogeneous and the low capacity of firms in technologically less developed regions or countries has been amply demonstrated. In particular, the studies on the technological spillovers generated by foreign direct investments (FDI), show that the lack of technological capacity in countries or underdeveloped regions impede or limited at least partially a greater effect of overflow of technological knowledge. Görg & Greenaway (2004) analyze 40 publications that study the horizontal spillovers derived from the FDI and conclude that such externalities –on firms level– exist basically in the developed countries while in the less developed countries they are non-existent or even negative. Due to their low technological capacity local firms are not able to compete in terms of technological progress. Regarding the studies that relate the existence of foreign investments with the absorption capacity at the regional level, we can cite some recent studies that offer evidence that the technologically less advanced regions (with less absorption capacity) take less advantage or receive a lesser effect of technological spillovers especially in the case of radical innovations [see Lew & Liu (2016)].

Also at the regional level, differences or asymmetries with respect to spillovers have been analyzed. Studies that use regional data have studied especially the role of geographical distance (sometimes in combination with their technological similarity or cognitive proximity). Several studies have analyzed the externalities between different regions in order to test the effect of the core regions on the innovative behavior of their less innovative neighbors and / or between technologically related regions [among others, see Lau & Lo (2015); Miguelez & Moreno (2015); Caragliu & Nijkamp (2012); Karkalakos (2010); Lopez-Fernández *et al.* (2012); Tappeiner *et al.* (2008); Greuz (2003)]. These studies also confirm the existence of asymmetries in the intensity or existence of spillovers. For example, in the study by Caragliu & Nijkamp (2012), the concept of absorption capacity is analyzed and it is shown that the peripheral regions –with low technical level or low absorption capacity– receive less knowledge from other regions. Two other studies that reflect the asymmetry of technological spillovers at a regional level indicate that the regions with a greater absorption capacity take more advantage of the external sources of the region generated on the basis of mobility and networks [see Miguelez & Moreno (2015)] or due to the existence of 'Knowledge Intensive Business Services' (KIBS) [see Lau & Lo (2015)]. Tappeiner *et al.* (2008) analyze to what extent the spillovers found are due to the co-location or self-correlation and spatial distribution of innovative activities.

The theoretical arguments and empirical evidence highlighted in this section justify the focus on the asymmetric role of the national innovation system to analyze the knowledge creation process of their regions. Therefore the present study estimates a regional knowledge production function using a sample of 170 regions belonging to 17 countries. To analyze the role of NISs, we include as independent variables not only regional data, but also national indicators in order to assess the multiplier effect (spillovers) of the national innovation system on their regions. Moreover, as we argued earlier, our hypothesis is that such spillovers flow from national to regional systems asymmetrically. That is, different types of regions (technologically developed versus less developed regions) have different learning and absorption capacities in order to assimilate the potential spillovers from their respective NIS. For this, the study is expanded using subsamples by technological level of the regions as a proxy for their absorption and learning capacity.

2. METHODOLOGICAL APPROACH, DATABASE AND THE USE OF COMPOSITE INDICATORS

2.1. Variables used

Since the pioneering work of Griliches (1979) a large number of authors have tried to identify the determinants of innovation by estimating the KPF at the national or regional level and the flows between the regions cease in geographic and cognitive terms. The review of the theoretical and empirical literature shows a certain consensus regarding the variables that can be considered fundamental in the creation of new knowledge. These can be grouped as follows: regional economy and population size, the efforts in R&D of firms, the role of universities and public research centers as agents of innovation systems, the sophistication (technology) of demand, etc. The standard classification for the variables usually used in this type of study was set by Furman *et al*. (2002), which is based on previous contributions, including the endogenous growth theory of Romer (1986 and 1990), the cluster theory based on the competitive national advantage of Porter (1990), as well as the aforementioned literature referred to the approach of the NIS / RIS. The last two approaches highlight the important role of the socio-economic environment as a factor that influences the behavior of economic and / or innovative agents and that could accelerate innovative activities.

In the present study, we chose a holistic or systemic approach also used by Buesa *et al*. (2010), using simultaneously a large number of variables (52), such that no available variable of interest –even if it plays a secondary role– remains outside the model. That is, the holistic or systemic approach forces the inclusion of the information available on the maximum number of agents and aspects of the innovation system. The inclusion of such broad number of variables can generate a multicollinearity problem, therefore a factor analysis is applied in order to reduce the total number of 52 variables in a few synthetic variables or compound factors. Such a procedure simplifies the interpretation of the models and facilitates the regression processes.

This method is justified for theoretical reasons as well as by econometric or statistical requirements and advantages. From an econometric point of view, the use of a large number of variables –usually correlated– implies a series of problems in the regression models. First, the models tend to be saturated with a high number of variables, forcing the complexity of the innovation systems to reduce to a small number of significant individual variables. This would leave out other variables, which however, according to the literature, should be considered relevant, making the statistical criterion prevail over the theoretical one[3]. Second, in traditional regression models, individual variables are excluded to avoid multicollinearity problems, although such correlated variables should, from a conceptual point of view, reflect situations or relations of complementarity. In this study, to solve these problems, a small number of variables or 'virtual' factors (formed through factor analysis) are used as independent variables to estimate the Knowledge Production Function and thus explain the innovative output of the European regions (using the number of patents and patents per capita as proxies of knowledge creation). In addition, regression mod-

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(3) This is usually misinterpreted as 'empirical evidence' of the irrelevance of a specific variable –of course the objective of econometrics is to contrast the theoretical hypothesis– when this is only the result of certain statistical constraints.

els calculated with factors are statistically more robust in interpretation since: (1) the model is less sensitive to errors of measurement (or data recording) in a particular variable because it is smoothed for the rest of the correlated variables included in the same factor; and (2) this can include alternative variables even when correlated simultaneously while models based on individual variables usually show remarkable changes depending on the variables used, even though they are assumed to be very similar from a conceptual or theoretical point of view.

In fact, from the theoretical point of view it is difficult to defend the use of only a few individual 'representative' variables, especially due to the lack of consensus regarding the most appropriate indicator that reflects the innovative level of a country, region or company. Here a composite indicator[4] is used because, from our point of view, the complex and multidimensional reality of an innovation system is better reflected than composite indicators are. The evolutionary theory of technological change highlights the heterogeneity of innovative performance, considering it a multidimensional activity in which a high number of elements and agents interact and play a complementary role [see Lundvall (1992); Nelson (1993)]. In this way, the use of individual indicators implies the exclusion of other aspects, leaving aside the simultaneity or holistic character of the innovative behavior. As established by Makkonen & Have (2013, p. 251) "an individual indicator is only a partial indication of the total innovative effort made by a subject". In the systemic or holistic approach, 'the whole is more than the sum of its parts' and interaction is as important for the total result as the sum of its elements [see Lundvall (1992)]. The existence of Myrdal-type synergies and virtuous and vicious circles caused by interaction influences the technical result of innovation systems and therefore their efficiency or productivity.

2.2. *Creation of synthetic variables*

A database was created, the IAIF-RIS Database for the European Union[5], which contains regional information from EUROSTAT-REGIO (with the suitably estimated missing values) for the period 2000 to 2010 from 170 regions of 17 countries[6]. In addition, information was added at the national level from different databases of EUROSTAT and the OECD. These national data are adjusted by subtracting for each analytical unit (region) the corresponding regional data. Therefore, each national factor excludes data from the region in question or in other words the national data reflect a weighted quantification of the countries average of all the regions excluding the observed one. The final database consists of a panel of 52 variables, which refer to the national and regional economic environment and innovation systems including the level of productivity, wealth and sectoral specialization.

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(4) For a broad discussion on composite indicators for R&D and innovation see among others: Hagedoorn & Cloodt (2003); Grupp & Schubert (2010).

(5) The Reginal Innovation System (RIS) data base of the "Instituto de Análisis Industrial y Financiero (IAIF) of the Complutense University of Madrid.

(6) According to the following geographical classification (in parentheses the number of regions): NUTS 1 regions: Belgium (3), Germany (16), United Kingdom (12), Bulgaria (2) and Romania (4); NUTS 2 regions: Spain (17), France (22), Italy (21), The Netherlands (12), Austria (9), Portugal (5), Finland (4), Sweden (8), Czech Republic (8), Hungary (7), Poland (16) and Slovakia (4).

As already mentioned, a factorial analysis was carried out in order to reduce the number of variables (52) maintaining a high value of its predictive and explanatory capacities (variance). Thus, 11 factors were obtained that, from our point of view, adequately reflect the reality of the innovation systems and better than what each of the individual variables would do, not only grouping them, but also reflecting the interaction between them and between them and the factors.

The validation or quality of the factor analysis is based on statistical tests and the logic inherent to the factors found. The different tests confirm the quality of analysis[7] and many of the communalities (correlation of each variable with its factor) are relatively high. Moreover, the model retains about 90% of the original variance, losing only less than 10% of the original information. The Varimax type rotation was used to ensure maximum orthogonality between the factors, which is important for our regression models (Hartung & Elpelt, 1999, p. 515).

The 11 resulting factors can be easily explained from a theoretical point of view. The first two can be considered the Regional and National Environment for Innovation reflecting the size of the respective economies and the human capital of their innovation systems. The third factor refers to the innovative effort of the National Firms and their productivity[8]. The fourth reflects the Salary Level and National Sectoral Specialization. From the fifth to the seventh factor are reflected the main agents of regional innovation systems (Regional Universities, Regional Innovative Firms and Regional Public Research Organizations). Factor eight represents the National Public Research Organizations, nine reflects an indicator that synthesize somehow the Level of Cooperation among the Actors of the National Innovation System, the tenth measures the Regional Economic Growth and the eleventh the innovative effort of the National Universities. Table 1 shows the 11 factors and their variables grouped by geographical level (regional versus national).

We consider that the reliability of the resulting synthetic variables is well supported by the three practical criteria to validate the factorial analysis[9]: (1) the variables included in each factor belong to the same component of the regional or national innovation system, (2) the variables belonging to a certain subsystem are located in a single factor and (3) each factor can be classified with a ‘name’ that expresses without doubt its content. Second, the model is in itself easy to interpret (since the variables saturate in a single factor), the factors obtained are related to the theoretical postulates and the model is extremely robust, maintaining a large percentage of the initial variance. Third, it is important to note that our factor analysis is the result of an objective process based on a single estimate without the interference of subjective assignments or weights to certain variables or factors.

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(7) The Kaiser-Meyer-Olkin test gives a value of 0.823 and the null hypothesis of the Bartlett sphericity test can be rejected with 99% confidence.

(8) The fact that this factor includes simultaneously two apparently different aspects (the innovative entrepreneurial effort versus productivity and GDP per capita) is due to the way of performing the factorial. This study is based on a single factorial analysis that starts from the 52 variables and the factor analysis itself assigns or groups the variables correlated to each of the factors. That is, it does not predetermine which variable corresponds to which concept, which we consider a strong point of the work. Concluding, the fact that both types of variables are in the same factor is due to the high level of correlation between them.

(9) As defined by Buesa *et al*. 2010 (p. 727).

Table 1: Matrix of Rotated Components

FACTORS OF REGIONAL CHARACTER	Saturation of the variable with the factorial value
RENV_{it} = Regional Economic Environment Human Capital (RENV)	
Number of people employed (thousand). Regional	.960
Human Resources in C&T – Occupation (thousands of people)	.959
Human Resources in C&T – Core (thousands of people)	.954
GDP (millions of € of 2010). Regional	.949
Gross Added Value (millions of € of 2010). Regional	.949
Annual average population. Regional	.949
Wages (millions of € of 2010). Regional	.947
Human Resources in C&T – Education (thousands of people)	.939
Gross Fixed Capital Formation (millions of € of 2010). Regional	.913
REG_{it} = Regional Economic Growth (REG)	
Rate of growth Regional GDP (%)	.972
Rate of growth Regional GDP per capita (%)	.961
RFIR_{it} = Regional Innovatory Firms (RFIR)	
Regional Firm's R&D expenditure (‰ of GDP). Regional	.835
Regional Firm's R&D staff (FTE.) ‰ of employment. Regional	.830
Regional Firm's R&D staff (HC) ‰ of employment. Regional	.822
Regional Firm's Technological Capital Stock per capita (€ 2010). Regional	.793
Regional Employment Hi-Medium Tech Manufactures (% of employment)	.607
RADM_{it} = Regional Public Research Organisations (RADM)	
Regional Public Administration's R&D staff (FTE) ‰ of employment	.932
Regional Public Administration's R&D staff (HC) ‰ of employment	.915
Regional Public Administration's R&D expenditure (‰ of GDP)	.880
Public Administration's Technological Capital Stock per capita (€ 2010)	.803
RUNI_{it} = Regional University (RUNIV)	
Regional University's R&D staff (HC) ‰ of employment	.902
Regional University's R&D staff (FTE) ‰ of employment	.888
R&D expenditure of the universities (‰ of GDP). Regional	.760
Regional University's Technological Capital Stock per capita (€ 2010)	.709
Regional 3rd cycle students (% population)	.737

FACTORS OF NATIONAL CHARACTER	
NENV$_{it}$ = National economic and productive environment (NENV)	
Number of people employed (thousand). National	.970
Annual average population. National	.968
Human Resources in C&T. Services (thousands of people)	.948
Human Resources in C&T. Intensive Knowledge (thousands of people)	.945
GDP (millions of € of 2010). National	.938
Gross Fixed Capital Formation (millions of € of 2010). National	.915
Imports (% World Imports)	.864
Exports (% World Exports)	.805
NFIR$_{it}$ = Productivity and National Innovatory Firms (NFIR)	
Firm's R&D expenditure (‰ of GDP). National	.895
Firm's R&D staff (HC) ‰ of employment. National	.887
Firm's R&D staff (FTE.) ‰ of employment. National	.875
Relevance R&D National Private Sector (%)	.808
National productivity (€ 2010)	.551
National GDP per capita (€ 2010)	.498
NEST$_{it}$ = National Level of Productivity, Wealth and Sector Specialisation (NEST)	
National average wage (€ 2010)	.877
Wages (millions of € of 2010). National	.813
Industrial Gross Added Value (% Total)	.742
Industrial Gross Added Value (% Total)	-.740
Services Gross Added Value (% Total)	.667
NADM$_{it}$ = National Public Research Organisations (NADM)	
National Public Administration's R&D staff (FTE) ‰ of employment	.948
National Public Administration's R&D staff (HC) ‰ of employment	.913
National Public Administration's R&D expenditure (‰ of GDP)	.796
NUNI$_{it}$ = National University (NUNIV)	
National University's R&D staff (HC) ‰ of employment. National	.742
National University's R&D staff (FTE) ‰ of employment. National	.662
National 3rd cycle students (% population). National	.568
COOP$_{it}$ = Cooperation among NIS agents (COOP)	
Firm's R&D funded by PA (% Total). National	-.700
Copatents per capital. National	.681

Extraction method: principal components analysis. Rotation method: Varimax Normalization with Kaiser. Rotation has converged in 6 iterations.

Source: Own elaboration.

Despite the previous result we must admit that there are many aspects not considered in the set of variables used due to the lacking availability of well-defined homogeneous indicators for all European regions during the period of time considered. There are no homogeneous data available for innovation and R&D policies, the level of entrepreneurship, the existence of large infrastructures, the level of regional cooperation, the existence of clusters, etc.

2.3. THE KNOWLEDGE PRODUCTION FUNCTION (KPF) BASED ON A DATABASE WITH COMBINED REGIONAL AND NATIONAL VARIABLES

In the second stage of our analysis we use the 'synthetic' variables to estimate a knowledge production function by panel data. We propose an additive model, which are common in this type of studies [see Jaffe (1989); Acs *et al*. (1992); Feldman (1994); Anselin *et al*. (1997); Furman *et al*. (2002)], according to the following specification:

$$\begin{aligned} K_{it} = \beta_0 &+ \beta_1 RENV_{it} + \beta_2 RFIR_{it} + \beta_3 RUNI_{it} + \beta_4 RADM_{it} + \beta_5 REG_{it} \\ &+ \beta_6 NENV_{it} + \beta_7 NFIR_{it} + \beta_8 NUNI_{it} + \beta_9 NADM_{it} + \beta_{10} NEST_{it} \\ &+ \beta_{11} COOP_{it} + \varepsilon_{it} + \mu_i + \nu_t \end{aligned}$$

The output variable refers to the 'new economically valuable knowledge' (K_{it} - number of patents and patents per capita), while the explanatory variables are the factorial scores of the 11 factors previously calculated and expressed in table 1[10].

Some points should be clarified regarding this equation. First, the output of the system –that is, the creation of new knowledge– is measured using patents and patents per capita as approximate measures of knowledge production[11]. These output variables correspond to the patents registered in the European Patent Office (EPO), and have the advantage –in comparison to the national patent offices– that they are focused on the same European market and therefore can be assumed to have a similar economic value. Obviously patents are not the perfect indicator of innovative performance among other reasons because they vary enormously in their value and importance [Hu & Mathews (2008), p. 1470]. However, at least they guarantee a minimum 'objective' level of international novelty and there is a significant, growing and sophisticated literature that uses patents as a common measure of innovative output [see Krammer (2009), p. 846]. In addition to the above, for an analysis that begins in 2000, patents represent the best available indicator, as has been repeatedly confirmed by different authors[12], and a recent compatibility check between multiple indicators confirms the utility of patents as

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(10) The global, temporary and specific individual error components are:

ε_{it} = Term of global error.

μ_i = Component of specific error to individual invariant to the time.

ν_t = Component of specific error to time invariant to the individual.

(11) Patent statistics are registered in the residence region of the inventor, which has the advantage of avoiding the 'headquarter-effect'.

(12) For an in-depth discussion about the advantages and limitations of patents as a measure of innovation, see among others: Griliches (1990), Schmoch (1999) or Hu & Mathews (2008, p. 1470).

a measure of output of innovation in the context of regional innovation studies [see Li (2009), p. 345]. Another issue regarding patents is related to the time lag between the effort in R&D and the moment of applying for the patent [see Schmoch (1999); Hall *et al*. (1986)]. Empirical studies show that this relationship is almost contemporary [see OECD (2004), p. 139]. In this way, the model presented in this study does not assume delays between the independent variables and the output[13].

Finally, to take into account the asymmetric flows of knowledge of the national innovation systems to their regions, we repeat the regression models for three subsamples (clusters) according to their potential technological capacity. We assume that the ability to absorb knowledge spillovers depends on the technological level of the regions. The subsamples were created according to the level of regional technological output considering the average of the last 5 years of the sample of applications for patents and high technology patents per capita. The leading regions are located in cluster 3, and then on the basis of geographical proximity, in reference to these regions, clusters 2 (neighboring neighbors) and 1 (peripheral regions) are constituted. In this way, cluster 1 includes 79 regions mainly from the south and east of Europe with low GDP per capita, low technical level and high economic growth. Cluster 2 incorporates 57 regions of a relatively high technological level but with poorly developed innovation systems and cluster 3 groups 34 rich regions of western and central Europe and also have well-developed innovation systems. In this study we will refer to these last regions as the 'core' regions[14].

3. RESULTS OF THE ESTIMATED KPF MODEL

3.1. The general KPF model

Table 2 shows the results of our models[15] including only the eight synthetic variables that were significant in at least one of the econometric estimates[16]. Both general models (number of patents and patents per capita) were estimated for the total sample, showing very similar results in terms of the statistical significance of the variables, although with substantial differences in the magnitudes of their coefficients. The results of the patent models per capita are basically discussed, while the absolute patent ones will only have a validation role.

Where the inclusion of national factors would indicate the existence of spillovers, regional factors have the role of isolating the effect of externalities with respect to the internal productivity of the region itself. Regarding the total sample, it is observed that 4 regional factors are statistically significant. The factor with the

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(13) Anyway, using models with one or two delays, very similar results are obtained.

(14) The means and coefficients of variation (in parentheses) of patents per capita and high-tech patents per capita for each cluster correspond to: 15.71 (1.27) and 3.42 (2.01) for cluster 1; 84.44 (0.31) and 14.2 (0.87) for cluster 2; and 230 (0.50) and 41.35 (0.93) for cluster 3.

(15) For the panel data there are many estimation methods, which were used mostly in this study. The values of the Hausman test and the Wald heteroscedasticity test determined that the fixed effects model with robust standard errors was chosen. In addition, the unit roots test of Levin-Lin-Chu was carried out, confirming the stationarity of the residues in all the models presented.

(16) We exclude the factors: Regional Economic Growth, Public National Research Organisations. and National Universities since they were not statistically significant in none of the successive models.

Table 2: The Final Model (Robust Intragroup panels with correction of the national data distracting regional data)

Dependent variable: Patents pc				
REGIONAL FACTORS	Full Sample	Cluster 1 Peripheral Regions	Cluster 2 Intermediate Regions	Cluster 3 Core Regions
Regional environment	21.7**	21.3***	25.0**	41.1*
	(10.22)	(5.33)	(11.46)	(21.45)
Regional Innovatory firms	22.1***	11.7***	17.1**	43.9***
	(4.96)	(2.56)	(6.71)	(13.14)
Regional University	4.8*	4.8***	6.8*	-7.74
	(2.5)	(0.93)	(4.02)	(13.45)
Regional Public Research Organisations	19.1***	9.7***	25.4***	30.13
	(3.96)	(2.14)	(5.48)	(24.89)
NATIONAL FACTORS				
National Environment	20.7***	5.5	45.9***	55.4
	(5.88)	(3.87)	(1.52)	(35.45)
National Innovatory firms	10.3***	3.1**	17.2**	46.90**
	(3.12)	(1.51)	(6.93)	(18.79)
National level of productivity, wealth and sector specialisation	-0.24	-3.2	-3.64	-5.49
	(3.51)	(2.14)	(6.17)	(16.87)
National Cooperation	2.56	2.0*	15.9**	-17.5
	(2.74)	(1.06)	(6.80)	(14.10)
Nº Observations	1870	869	627	374
Nº Regions	170	79	57	34
Hausman Test	80.43	110.11	106.15	58.87
	(0.000)	(0.000)	(0.000)	(0.000)
R^2	34.7%	21.9%	17.1%	8.6%

***, Significance to 99%; **, 95%; *, 90%.

Source: Own elaboration.

highest value of its beta is that which reflects the role of the Regional Firms (22.1). This is expected if we assume that the firm ise clearly the main one responsible for the patenting activity of the national and regional innovation systems.

The Regional Environment (21.7) has great explanatory power in the model. This is a logical result since this factor groups ‘absolute’ values reflecting the economic size of the region and the efforts of its innovation system (in terms of its human resources) which are highly correlated with output (absolute number of patents). However, also in the model based on the number of patents per capita the regional size is an important explanatory factor, a fact that in some way reflects the importance of the advantages of scale and the internal spillovers among the agents of the region. The other two ‘regional’ factors refer to the research system with an important role for the existence of Public Research Organizations in the region (19.1) and a marginal but statistically significant effect of the Universities. The fifth regional variable (the factor that reflects regional economic growth) is not statistically significant in any of the models and has therefore been excluded from the estimates.

Regarding the national variables that would reflect the evidence of spillovers, two statistically significant factors are identified: the National Firms (10.3) and the National Environment (20.7). That is, in those regions whose countries have these two areas best developed, a higher level of spillovers is shown than in the regions of countries where these aspects are less developed. It is noteworthy that the National Environment is the factor whose beta value is relatively higher (being the factor with the third highest explanatory power). This confirms that a region is more successful in the field of technological change if their country as a whole has a larger number of researchers and productive activities. This can be interpreted as a way of having a better technological absorptive capability.

3.2. The KPF models by subsamples

As we discussed previously, in this study we seek to observe asymmetric knowledge flows between the different groups of regions. Our cluster models confirm this hypothesis by identifying clear differences of the existence and intensity of spillover effects by subsamples in the number of statistically significant variables.

In the patent model per capita there are clear differences regarding the significance of regional variables, since Regional Public Research Organisations and Regional Universities are significant in subsamples 1 and 2 (peripheral and intermediate regions), while the factors Regional Firms and the Regional Environment are significant in each of the three models. This fact reflects in some way that university-industry interaction is complex and does not depend only on geographical proximity but also on other factors such as the presence of support network, infrastructure, etc. (Ponds *et al*., 2010). Regarding spillovers based on the national variables it can be stated that the factor National Firms is relevant in each of the three clusters, being the most important in cluster 3 (46.9) which includes the most technologically developed regions. While the Cooperation Level only affects clusters 1 and 2, with beta coefficients of 2.0 and 15.9 respectively. The National Environment is only significant in cluster 2. The latter would again reflect asymmetric patterns in knowledge flows from national to regional levels according to the particular characteristics of each region. The intermediate regions gain spillovers from the national level while for the central and peripheral regions it is not the case.

Finally, it is worth mentioning the positive impact of cooperation at the national level on the number of patents per capita in the clusters of regions of low and medium technological development. The literature affirms the importance of cooperation and coordination among the agents of innovation systems (especially the interaction between firms and scientific organizations). Our results would indicate that not only regions with sufficient cognitive proximity (in terms of Boschma, 2005) could benefit from spillovers and from cooperation, however especially the firms of intermediate region (15.9) and to a lesser extent the peripheral region –with a beta of 2.0- gains some spillovers from level of culture for cooperation on national level. However, the in-depth study of this question goes beyond the scope of this paper.

4. Conclusions: Relevance of externalities from an evolutionist vision

This paper studies the extent to which regions obtain knowledge flows from their national innovation systems (NIS) within the framework of the Knowledge Production Function (KPF). This study –with data from 170 European regions for the period 2000-2010– bears two novel aspects. First, according to the evolutionary theory of the economy of innovation, all NIS agents interact and influence each other, so the maximum number of available variables is used to reflect each of them and factor analysis has been used to solve the multicollinearity problem. Thus, a broad set of 52 indicators –highly correlated– is reduced to a small number of 'synthetic' or 'composite' variables that reflect the underlying structure of national and regional innovation systems. Second, variables that characterize the national system (discounting the region itself) have been included in the KPF for each region in order to analyze the extent to which there are spillovers.

As discussed in section 1, there are theoretical arguments that suggest [see Boschma (2005); Cohen & Levinthal (1989); Breschi & Lissoni (2001)] the existence of asymmetric technological spillovers between regions based on the differences in absorption capacity. This seems to be the central cause of this asymmetry. That is, those firms or regions with a lower technological capacity would obtain fewer spillovers; first, because they would have more difficulties to detect, recognize and / or access the freely available knowledge, and second, once they have accessed this knowledge, they would have more difficulties to absorb it, assimilate it and exploit it. In fact, there is a wide literature on the relationship between absorption capacity and the existence of spillovers derived from foreign investments in the recipient country[17].

There is no doubt that the generation of new knowledge is mainly due to inherent factors attributable to the regions (their absorption capacity), although, as shown in our models, the externalities derived from the national economic and productive environment, and from the national innovative firms are also relevant. This fact reflects that the concentration of productive factors at a national level is a determining factor in the generation of spillovers. Likewise, the relevance in the transfer of knowledge from the NIS to the region of their own nation dominates, to a certain extent the spillovers between regions of different countries, as has been indicated in pre-

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(17) For a review of this literature see Dishon & Yabs (2017).

vious studies [see Tappeiner *et al*. (2008); Moreno *et al*. (2005)]. As was explained in sub-section 1.3, the possibility of generating spillovers is greater among regions of the same country due to (1) geographical and / or linguistic proximity; (2) a greater frequency of (informal) interactions due to geographic, cultural and social closeness; (3) with the similarities in sectoral specialization and common routines ensuring greater cognitive and, finally (4) the institutional proximity based on common laws and beliefs. Especially in the European case, the differentiation of languages, laws, cultures and institutional norms could maintain or increase the existing distance in terms of communication and mutual understanding. For this reason, spillovers would be more frequent among regions of the same country.

One of the central objectives of this study was to analyze the existence of spillovers or externalities generated by the national innovation system in its regions, with special emphasis on the asymmetry of such externalities due to regional differences in absorption capacity. This last aspect is analyzed using sub-samples based on the number of patents per capita that would reflect the absorption capacity. Regarding spillovers between regions, there are few studies that reflect asymmetric spillovers and most of these studies basically analyze geographical distance. There are some studies [see Fischer *et al*. (2006); Maurseth & Verspagen (2002)] that analyze spillovers based on patent citations. These works indicate that such appointments are generated more frequently between regions of the same country and in the case of geographical proximity. In addition, they occur more frequently between regions with the same language and with the same orientation or productive specialization.

According to the econometric results, the use of national factors improves the global adjustment of models that only include regional variables, which indicates the clear explanatory power of national agents on the knowledge production function of their regions. In other words, the presence of national factors in the estimation models expresses the relevance of national innovation systems in the generation of knowledge at the regional level and, as shown by the existing empirical evidence [among others Fischer *et al*. (2006); Maurseth & Verspagen (2002)] the presence of externalities or spillovers, *ceteris paribus*, are more fluid between regions of the same country due to the different types of proximity reviewed in this study.

However, it is observed that the evolutionist processes of the regions in terms of their economic development and innovative level imply a change in the role of the externalities generated within their national contexts. In both models (absolute and relative patents) the estimates of the two sub-samples of non-central regions (peripheral and intermediate ones) whose innovation systems are moderately developed reflect asymmetric externalities from the national level to the regions. In fact, the number of significant factors and the value of the coefficients are very different. In the case of regions with a medium technological level, three national factors are statistically significant (the National Environment, the National Firm factor and the National Level of Cooperation) confirming the existence of spillovers with beta values between 16 and 46. However, for the spillovers of the national innovation system on technologically more backward regions we found less evidence with a much lower intensity. Only two national factors are statistically significant (the National Firm factor and the National Level of Cooperation) and the beta values are much lower (3 and 2 points respectively). This confirms a lower level of spillovers towards the less developed regions which probably should be explained by the lack of technological capacity.

In the case of the sub-sample of the most innovative regions, the production function is determined almost exclusively by its regional agents. Only the factor of National Firms seems to positively influence the production of patents. This reflects the fact that these regions operate as conclaves from a certain level of development in their innovation systems and the spillovers are mostly internal between the firms of the same region.

On the other hand, it can be indicated that in the less technologically developed regions, the Regional Public Research Organizations have a much more preponderant role in the innovative result if they are compared with the core regions, and only in the regions of low and medium technological development (patents per capita model) do the regional universities play some role in the knowledge function. This confirms the idea that the relationships between the actors of the innovation system, in particular the industry-university relationship, are complex interactions that do not only depend on geographical proximity.

Finally, taking into account that for the most developed regions only one national factor is statistically significant, and only in the relative output or per capita model (National Firms) can it be established that spillovers generated by innovation systems flow in an asymmetric way, and it is the less developed regions of technology and especially the intermediate regions that benefit the most from the knowledge flows from the national systems. To the above we must add the differences between cognitive proximities and regional sectoral specializations that in some way affect the flow of knowledge. The study of these relationships goes beyond the scope of the present study but opens up areas for future research.

ANEX

CLUSTER 1

Region	Country
Vlaams Gewest	Belgium
Severna I Yugoiztochna	Bulgary
Yugozapadna I Yuzhna Tsentralna	Bulgary
Praha	Czech Rep.
Strední Cechy	Czech Rep.
Jihozápad	Czech Rep.
Severozápad	Czech Rep.
Severovýchod	Czech Rep.
Jihovýchod	Czech Rep.
Strední Morava	Czech Rep.
Moravskoslezsko	Czech Rep.
Sachsen-Anhalt	Germany
Galicia	Spain
Principado de Asturias	Spain
Cantabria	Spain
La Rioja	Spain
Aragón	Spain
Comunidad de Madrid	Spain
Castilla y León	Spain
Castilla-la Mancha	Spain
Extremadura	Spain
Comunidad Valenciana	Spain
Illes Balears	Spain
Andalucia	Spain
Región de Murcia	Spain
Canarias	Spain
Åland	Finland
Nord - Pas-de-Calais	France
Poitou-Charentes	France
Corse	France
Közép-Magyarország	Hungary
Közép-Dunántúl	Hungary
Nyugat-Dunántúl	Hungary
Dél-Dunántúl	Hungary
Észak-Magyarország	Hungary
Észak-Alföld	Hungary
Dél-Alföld	Hungary
Valle d'Aosta/Vallée d'Aoste	Italy
Abruzzo	Italy
Molise	Italy
Campania	Italy
Puglia	Italy
Basilicata	Italy
Calabria	Italy
Sicilia	Italy
Sardegna	Italy
Umbria	Italy
Lazio	Italy
Lódzkie	Poland
Mazowieckie	Poland
Malopolskie	Poland
Slaskie	Poland
Lubelskie	Poland
Podkarpackie	Poland
Swietokrzyskie	Poland
Podlaskie	Poland
Wielkopolskie	Poland
Zachodniopomorskie	Poland
Lubuskie	Poland
Dolnoslaskie	Poland
Opolskie	Poland
Kujawsko-Pomorskie	Poland
Warminsko-Mazurskie	Poland
Pomorskie	Poland
Norte	Portugal
Algarve	Portugal
Centro	Portugal
Lisboa	Portugal
Alentejo	Portugal
Macrogiunea Unu	Romania
Macrogiunea Doi	Romania
Macrogiunea Trei	Romania
Macrogiunea Patru	Romania
Bratislavský kraj	Slovakia
Západné Slovensko	Slovakia
Stredné Slovensko	Slovakia
Východné Slovensko	Slovakia
Yorkshire and The Humber	United Kingdom
Wales	United Kingdom

CLUSTER 2

Region	Country
Burgenland	Austria
Kärnten	Austria
Région de Bruxelles-Capitale/Brussels Ho	Belgium
Région Wallonne	Belgium
Brandenburg	Germany
Bremen	Germany
Mecklenburg-Vorpommern	Germany
Sachsen	Germany
Thüringen	Germany
Pais Vasco	Spain
Comunidad Foral de Navarra	Spain
Cataluña	Spain
Pohjois- ja Itä-Suomi	Finland
Champagne-Ardenne	France
Picardie	France
Haute-Normandie	France
Centre	France
Basse-Normandie	France
Bourgogne	France
Lorraine	France
Franche-Comté	France
Pays de la Loire	France
Bretagne	France
Aquitaine	France
Midi-Pyrénées	France
Limousin	France
Auvergne	France
Languedoc-Roussillon	France
Provence-Alpes-Côte d'Azur	France
Piemonte	Italy
Liguria	Italy
Provincia Autonoma Bolzano-Bozen	Italy
Provincia Autonoma Trento	Italy
Veneto	Italy
Toscana	Italy
Marche	Italy
Groningen	Netherlands
Friesland	Netherlands
Drenthe	Netherlands
Overijssel	Netherlands
Gelderland	Netherlands
Flevoland	Netherlands
Noord-Holland	Netherlands
Zeeland	Netherlands
Småland med öarna	Sweden
Norra Mellansverige	Sweden
Mellersta Norrland	Sweden
Övre Norrland	Sweden
North East	United Kingdom
North West	United Kingdom
East Midlands	United Kingdom
West Midlands	United Kingdom
East of England	United Kingdom
London	United Kingdom
South West	United Kingdom
Scotland	United Kingdom
Northern Ireland	United Kingdom

CLUSTER 3

Region	Country
Niederösterreich	Austria
Wien	Austria
Steiermark	Austria
Oberösterreich	Austria
Salzburg	Austria
Tirol	Austria
Vorarlberg	Austria
Baden-Württemberg	Germany
Bayern	Germany
Berlin	Germany
Hamburg	Germany
Hessen	Germany
Niedersachsen	Germany
Nordrhein-Westfalen	Germany
Rheinland-Pfalz	Germany
Saarland	Germany
Schleswig-Holstein	Germany
Etelä-Suomi (NUTS 2006)	Finland
Länsi-Suomi	Finland
Île de France	France
Alsace	France
Rhône-Alpes	France
Lombardia	Italy
Friuli-Venezia Giulia	Italy
Emilia-Romagna	Italy
Utrecht	Netherlands
Zuid-Holland	Netherlands
Noord-Brabant	Netherlands
Limburg	Netherlands
Stockholm	Sweden
Östra Mellansverige	Sweden
Sydsverige	Sweden
Västsverige	Sweden
South East (England)	United Kingdom

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RESUMEN

Dentro del marco de una Función de Producción de Conocimiento (FPC) se estudia la existencia de efectos de desbordamiento de los sistemas nacionales de innovación hacia sus regiones. Para ello se incluye en la FPC tradicional no sólo variables regionales sino también nacionales. La FPC incluye en total 52 variables que –mediante un análisis factorial– se han reducido a unas pocas variables sintéticas.

El trabajo ofrece evidencia de la existencia de efectos de desbordamiento que resultan ser asimétricos. Sus intensidades son menores para las regiones menos desarrolladas tecnológicamente y mayor en las regiones intermedias, mientras que para las regiones centrales o más avanzadas resultan ser casi inexistentes.

Palabras clave: Función de Producción de Conocimiento, efecto de desbordamiento de conocimiento, sistemas regionales de innovación.

Clasificación JEL: O18, O33, O52.

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