Factors of Knowledge Creation in European Regions

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Abstract: The present paper studies the knowledge creation in European regions (measured using the number of patents as a proxy) by means of combining factorial analysis and panel-data regression estimations. This procedure allows reducing the variables of the original dataset to a smaller number of 'synthetic' variables that reflect the underlying structure of the Regional innovation system: *Innovatory firms*, *Regional economic and productive environment*, *Sophistication of the demand*, *Venture capital*, *Public Administration* and *University*. The former three prove to be the most relevant in the creation of knowledge —especially the first one— while the factors Venture capital and Public Administration show to have a less important impact. No significant effect (and when, a negative one) is detected for the *University*.

Keywords: Knowledge creation, Regional Innovation Systems, Europe, R&D.

JEL classification: O30

1.- Introduction

Once that the Schumpeterian concept of 'innovation' (1911) has caught on not just among economists but among policy makers, being recognised as central process in driving economic growth and competitiveness (Hu and Mathews, 2005:1322), the connected concept of 'knowledge creation' has become a major concern in advanced economies (Tödtling and Trippl, 2005:1203), especially in those classified as 'innovation-driven'.[1] Accordingly, favouring knowledge creation has turned out a policy priority in many countries, supported by innovation strategies on several administrative levels (national, regional and local), which have often been underpinned by the establishment of innovation ministries, departments and offices projected to design and implement these policies (Mahroum and Al-Saleh, 2013:320). In the European Union —as in most industrialized nations— innovation policies on the regional level have acquired special relevance, with regions becoming the main actors of economic development (Park and Lee, 2005:185), coinciding with the development and consolidation of the (Regional) Innovation System framework originally presented

[1] Following the classification adopted by the World Economic Forum.

Lundvall (1988) and Freeman (1987) in the context of the expansion of the evolutionary approach in economics (Buesa et al. 2006:463).[2]

Hence, several studies have so far tried to figure out the exact degree to which different factors affect national and regional performance in creating new, innovation capable, knowledge. The regional option has acquired special relevance, as innovation activities are not evenly distributed spatially and the production of new technological knowledge tend to localise spatially (Li, 2009:339). However, this attention on the regional level of innovation has not to be understood as exclusive, but as —although probably the main — one among multiple coexistent systems of innovation levels (cf. Tylecote, 2006). Among the study of regional innovation systems, the focus has been frequently set upon to the regions of the European Union, because this setting represents an extremely interesting case due to the high heterogeneity of these regions with respect to economic as well as innovative performance (Marrocu et al. 2011:3; Tödtling and Trippl, 2005:1211-1212).

It is in this context that the present paper aims to determine the relevant factors in the creation of new knowledge among European regions, taking into consideration the multiple, interrelated elements, which —according to the literature— have a positive (albeit very heterogeneous) impact on innovation. This is achieved by formulating a knowledge production function —originally developed by Griliches (1979) and defined by Fritsch (2002:20) as a quite useful instrument for comparing the quality of regional innovation— which uses the punctuations obtained in a factorial analysis a explanatory variables, following the example of Buesa et al. (2010). However, the present article not only updates that study, but considerably broadens its scope, widening the number of regions included as to encompass the countries which joined the EU in 2004 and 2007 as well as the timespan of analysis (originally 1995 to 2001) up to 2008.

2.- Theoretical framework

The literature regarding the determinants of innovation has grown significantly over the last decades, embedded in the development of the System of Innovation framework. Inspired by Friedrich List´s 'National System of Political Economy' Lundvall (1988) and Freeman (1987) pioneered the RIS-concept, highlighting the importance of adopting a systemic view which considers the interactions between suppliers and customers —and, more generally speaking the different agents of the system— in their role in stimulating and reinforcing innovation. This System of Innovation framework was subsequently expanded conceptually and empirically by a large number of authors, most notably by Lundvall (1992), Nelson (1993), the OECD (1997) and Edquist (2005). Thus, the Innovation System approach has changed the analytical perspective on innovation from the traditional linear model (e.g. that of a 'technology push' and

[2] This rising importance is best exemplified by the growing weight of the regional innovation policies budgets in the European Union´s Structural Cohesion Funds.

‘market pull’ or ‘basic research’ and ‘applied research’) to a more holistic view of interaction between all actors and between them and their environment (Mahroum and Al-Saleh, 2013:322).

Although there is a growing number of empiric studies about the determinants of new knowledge and innovation, most of them can be classified according to a double grid, depending on whether they work on a national or regional basis, and whether they use ‘real’ variables or ‘virtual’, ‘synthetic’ ones resulting from a factorial analysis. Figure 1 gives an overview of this classification for those works which study a set of more than one country (exception made of those of huge size such as the U.S.A. and China).

INSERT HERE FIGURE 1

This increasing number of studies is also allowing to start talking about a certain consensus regarding the variables which can be considered fundamental in the creation of new knowledge: the region´s economic and population size, the (technological) sophistication of the demand, the R&D efforts due to enterprises, the role of universities and public research centres as agents of the innovation systems, the presence of venture capital, etc. The standard classification for the variables usually employed in this kind of study was set by Furman et al. (2002), which itself relied heavily on the previous contributions, namely of Romer´s (1986 and 1990) Endogenous Growth Theory, Porter´s (1990) Cluster based theory of National Competitive Advantage as well as the already mentioned literature referred to the NIS/RIS approach. Accordingly, three key dimensions of determinants have been defined (see for this López-Fernández et al., 2012:2-4 and Buesa et al., 2010:724-726):

(1) Common infrastructure of innovation: this first dimension is made up of three factors related to the investment that supports innovative activities (the aggregate level of technological sophistication of an economy; the availability of qualified scientific personnel dedicated to R&D and a third group of variables related to domestic investment and innovation policies decision).
(2) Specific environment for innovation clusters: this second dimension includes variables such as the involvement of the private sector in financing innovative activities or the technological specialization of the economy.
(3) The quality of the linkages: this third dimension includes economic indicators such as the R&D effort —in terms of expenditure and of personnel employed— of the universities and the availability of financial support in the form of venture capital.

An overview of the different variables used by the main empirical studies, indicating if they are significant and whether their effect is positive or negative, is given in Table 1.

INSERT HERE TABLE 1

Based on this growing literature, a range of determinants of the production of new ideas or knowledge can now be defined, which have alternatively been stressed by different authors and ‘schools of thought’. However, in the present study we opt for a holistic approach, in an attempt to conjunct these different methods and 'emphasis' towards a unified model. This implies the simultaneous use of a huge number of variables, so that no relevant one —even if it only plays a secondary role— is left out of the model. However, as this uses to carry along a series of problems in the validation of the regression frontier, the present work follows the example of Buesa et al. (2006, 2007 and 2010) applying a factorial analysis in order to reduce the total number of variables while minimizing the loss of variance. This procedure not only allows for an easier interpretation of the model´s results, but also offers the advantage of reducing to a minimum the possible correlation between variables, thus facilitating the regression process, as will be explained more in detail in the next section.

3.- Data and formulation of the model

One major problem when estimating complex regression functions —as the ones aimed in this paper— is the fact that the models tend to saturate with a relative small number of variables, thus obliging to reduce such a complex reality as that of Innovation Systems (no matter whether national or regional) to a small number of significant variables, thus leaving aside others which, however, according to literature should be considered of relevance. As a result, these other variables are often set aside, or do only enter in certain specifications of the models thus making the statistical criterion prevail over the economic theory.[3] A second question related to this point is that in order to avoid colineality effects between variables, some variables have to be left out of the model even though the correlation between them may simply reflect a complementary (but not necessarily alternative) relationship.

Hence, the present paper overcomes the above mentioned problems by combining factorial analysis and regression, that is, by using a reduced number of 'virtual' factors as independent variables in the regression function, following the approach first presented by Buesa et al. (2006). The procedure consists of two clearly differentiated steps: (a) A factorial analysis aimed to reduce the number of variables contained in the database to a smaller number of 'synthetic' variables (factors) which retain the highest possible variance contained in the original data, thus revealing the structural factors underlying the dataset; (b) regressions according to different estimation procedures —both pooled and panel data— in which the previously calculated factors are used as independent variables in order to explain the innovative output of the European regions (using the number of patents and high-tech patents as a proxy of knowledge creation).

INSERT HERE MAP 1

In doing so, the IAIF-EU(RIS) database is used, which basically compiles information from EUROSTAT-REGIO (with the missing values conveniently estimated) with two

[3] This is then often misinterpreted as the 'empirical evidence' of the irrelevance of a specific variable —of course the aim of econometrics consists in contrasting theoretic hypothesis— while it is actually a result of a statistical restrictions.

variables (of those which finally enter the model) —the *ICT penetration*[4] and the *Index of Economic Freedom*—[5] from other sources. The database has been constructed for the period 1995 to 2008 and 193 regions mostly on of the NUTS2 level[6] —whenever the level of statistical disaggregation has allowed to do so, the NUTS level which corresponds to an administrative entity with real capability in the design and implementation of innovation policies—belonging to the 26 countries that currently compose the European Union. Consequently, the final database consists of a panel of 60 variables by 2702 cases (193 regions for 14 years). From these, 25 variables referred to the Region´s economic and population size,[7] Human Resources,[8] its Sophistication of the demand (richness),[9] the R&D efforts (both in economic and personnel terms),[10] the availability of Venture capital[11] and other aspects related to the economic infrastructure[12] have entered the model.

3.1 Factorial analysis

As already stated, a factorial analysis is carried out in order to reduces the number of data one is working with, while maintaining the highest level of their explanatory and predictive capacity (variance), thus generating six factors, which are linear combinations of the original variables contained within them. These factors reflect better the reality of an innovation system than each of the individual variables could do, as they not only group together all related variables, but also reflect the interaction between factors, as the model correlates each variable to all factors, not only to the one in which it is included.

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The validation or quality of the factor analysis is based on the statistical tests and the inherent logic of the found factors. The different tests to confirm the quality of our

[4] ITU (2007 and 2010).

[5] As available on http://www.heritage.org/index/.

[6] According to the following geographical classification (in brackets the number of regions): NUTS1: Belgium (3), Germany (16), Ireland (1), United Kingdom (12), Slovenia (1), Bulgaria (2) and Romania (4); NUTS2: Denmark (1), Greece (13), Spain (17), France (22), Italy (20), Netherlands (12), Austria (9), Portugal (5), Finland (6), Sweden (8), Czech Republic (8), Estonia (1), Cyprus (1), Latonia (1), Lithuania (1), Hungary (7), Malta (1), Poland (16), Slovakia (4).

[7] Annual average population, GDP (in millions of € — all economic variables have been expressed in € of 1995), Gross fixed capital formation, Gross added value, Wages and Number of people employed.

[8] Human Resources in Science and Technology (by three different means: education, occupation and core) and 3rd cycle students as % of the population.

[9] GDP per worker and GDP per capita.

[10] R&D staff of Firms, University and Public Administration (both in head-count and full-time-equivalence terms) as % of employment. Also the R&D expenditure (as % of the GDP) of these three actors.

[11] Seed and star-up investment as % of the GDP as well as Development start-up investment as % of the GDP.

[12] Such as the Index of Economic Freedom and the regional ICT penetration.

factor analysis are positive.[13] The communalities (correlation of each variable with regard to the set of the other variables making up this factor) of the variables are relatively high, all of them —exception made of three cases— over 0.800, which guarantees the reliability of the findings and indicates the high degree of preservation of their variance (the matrix of rotated components is presented in Table 2). Moreover, the six factors retain 86.79 per cent of the original variance, that is, there is scarcely a thirteen per cent loss of information originally contained in the 25 variables that compose the factors. We have carried out a Varimax-type rotation, since the factorial pattern obtained by this procedure tends to be more robust than the one obtained from alternative methods and this option assures a maximum orthogonality between factors which is important for the regression procedure in the next step of our analysis.

INSERT HERE TABLE 2

As can be seen in Table 2, the six resulting factors can be easily explained from a theoretical point of view. As usually occurs when clustering variables by means of a factorial analysis, the first factor reflects the 'size', while the others (expressed in relative terms) refer to the 'form' (that is, the configuration) of the innovation system. As can be observed, the factors perfectly fit the above explained three dimensions of innovation determinants established by Furman et al. (2002). Accordingly, the first one —which accounts for 33.6 percent of the total variable— can be considered the *Regional Environment of Innovation*, including variables referred to the region´s absolute economic and population size as well as the magnitude of its cientific and technological system. The second, fourth and fifth ones —which all account for a very similar retained variance of between 12.4 and 11.0 per cent— refer to the three agents of the regional innovation system (*University, Innovative Firms and Public Administration*), while the third —which explains a retained variance of 11.2 per cent— clearly reflects the *(Technological) Sophistication of the Demand*,[14] including variables such as the GDP in per capita terms, the ICT-penetration and the Index of Economic Freedom. Finally, the fifth factor—which accounts for 7.5 per cent of the retained variance— represents the importance *of Venture Capital* in its different forms. This specification meets the three requirements stated by Buesa et al. (2010:727) for validating the outcome of a factorial analysis: (1) The variables included in each factor belong to the same component or subsystem of the overall regional innovation system. (2) The variables belonging to a certain subsystem are located in only one factor; and (3) Each factor can be labelled with a 'name' that without any reservation neatly expresses its whole content. These results thus coincide basically with the determinants pointed out by the theory —specifically with the restricted concept of the innovation system (Asheim and Gertler, 2005:300)— as well as with those of Furman et al. (2002) and Buesa et al. (2006 and 2010).

[13] The Kaiser-Meyer-Olkin test gives a value of 0.854 and the null hypothesis of the Barlett sphericity test can be rejected at the 99% level.
[14] See for this Furman et al. (2002).

INSERT HERE GRAPH 2

Thus, we consider that the model with six factors is supported by two facts: In the first place, it is the result of objective processing (the main components analysis). Second, that the model lends itself to easy interpretation (since the variables —exception made of the *Index of Economic Freedom*) are only saturated in one factor), the factors obtained match the theoretical postulates, and the model is extremely robust, in addition to maintaining a high percentage of the original variance.

3.2 Regression

In the second step of our analysis we use these 'synthetical' variables —that is, the factorial punctuations previously obtained— to estimate a knowledge production function, grouping the regions by the year of their entrance to the European Union, according to the following specifications:

$$K_{it} = \beta_0 + \beta_1 ENV_{it} + \beta_2 UNI_{it} + \beta_3 DEM_{it} + \beta_4 FIR_{it} + \beta_5 ADM_{it} + \beta_6 CAP_{it} + \varepsilon_{it} \quad \text{[I]}$$

for the OLS estimation and

$$K_{it} = \beta_0 + \beta_1 ENV_{it} + \beta_2 UNI_{it} + \beta_3 DEM_{it} + \beta_4 FIR_{it} + \beta_5 ADM_{it} + \beta_6 CAP_{it} + \varepsilon_{it} + \mu_i + \nu_t \quad \text{[II]}$$

for the panel data estimation

Where:

K_{it} = *New economically calculable knowledge* (by means of the number of patents)
ENV_{it} = *Regional economic and productive environment*
UNI_{it} = *University*
DEM_{it} = (*Technological) Sophistication of the demand*
FIR_{it} = *Innovatory Firms*
ADM_{it} = *Public Administration*
CAP_{it} = *Venture capital*
ε_{it} = *Overall error term*
μ_i = *Individual-specific, time-invariant error component*
ν_t= *Time-specific, individual-invariant error component*

Several points have to be cleared regarding this equation. First of all, the system´s output —that is, the creation of new knowledge— is measured using patents and patents per capita as means of a proxy.[15] So far, there is no consensus in measuring firms´ inventive and innovative efforts. However, there seems to be a broad acceptance in considering *Expenditures on research and developmen*t and the number of *Personnel engaged in formal R&D activities* as inputs of any innovation system; while *Patents* and estimates of *Sales associated with new products* are recognized as a count of the system´s output (Bhattacharya and Bloch, 2004:156). In this context, patents are obviously not the perfect indicator of innovative performance, among other because

[15] The patents statistics offered by EUROSTAT have the advantage of overcoming the 'headquarter-effect' as patents are registered in the inventor´s region of residence.

they vary enormously in their importance and value (Hu and Mathews, 2008:1470); however, at least they guarantee —unlikely what happens for example when using innovations as output[16]— an equal minimum level of 'objective' international novelty. Thus, there has been a significant and increasingly sophisticated literature that uses patents as a common measure of innovation output (Krammer, 2009:846). All together, for an analysis that dates back in time up to 1995, patents represent without doubt the best indictor available, as has been repeatedly confirmed by different authors.[17] Also, a recent check of compatibility among multiple indicators has further confirmed the usefulness of patents in measuring innovation output in the context of regional innovation studies (Li, 2008:345).

Another question that arises when using patents as a proxy for innovation is whether there is a temporal delay between the time that R&D effort takes place and the moment when the invention is applied for as patent. It might be assumed, that this takes place after a prolonged period of research, thus presenting a lag between the R&D effort at the patent application (Schmoch, 1999:113), a question that already puzzled Hall et al. (1986). However, empirical studies seem to proof that, in fact, the relationship between patent application and R&D is almost contemporaneous (OECD, 2004:139). Accordingly, the model presented in this paper assumes no lag between the independent variables and the output.

Second, estimating the regression with factors means a series of important advantages: When the number of explanatory variables is reduced —six factors instead of 25 original variables— the risk of saturation of the model through the inclusion of too high a number of variables and the possible problems of colinearity decrease (Hair et al., 1999:152). This problem is minimalized in our model because the regression is calculated with factorial points estimated by the Varimax method in which the orthogonality among the factors is maximised (Hartung and Elpelt, 1999:515). Consequently, the colineality between factors minimised. Moreover, the regression models calculated with factors are statistically more robust and solid in their interpretation because (1) the model is less sensitive to 'leaps' or errors (due to data recording) in a particular variable as they are mitigated by the rest of the variables included in the same factor. (2) The regression with factors is more robust, since it can include alternative —mostly highly correlated— variables in simultaneously. Since they work with variables, the models usually show notable changes on the basis of the variable used, even when these are very similar (for example, GDP and VAB or Human Resources measured in absolute number of persons or in full-time equivalents. (3) They enable the information of the set of variables to be reduced to the essential. The factors,

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[16] However, the shortfalls of patents as innovation measure are usually also present in alternative indicators, and are often subject to even more criticism.

[17] For an in-depth discussion about the advantages and limitations of patens as measure of innovation, see among others, Griliches (1990); Pavitt (1985, 1988); Mansfield (1986); Trajtenberg (1990); Archibugi (1992); Schmoch (1999); European Commission (2001:38); Furman et al. (2002:909-913); Smith (2005:158-160); Rondé and Hussler (2005:1156); Hu and Mathews (2008:1470); Li (2009:345) and Buesa et al. (2010:723-724).

being clear, may turn out even clearer in their interpretation than certain variables. And (4) the factors not only take into account the correlation of each variable with the factor with which it shows the highest degree of saturation, but also with all the other ones, so that, even if it is not explicitly included in the model, the latter takes into consideration the interaction between variables/factors.

4.- Estimation of the model

This empirical section presents the results obtained when estimating two types of knowledge production functions: one using the number of patents (and high-tech patents) in absolute terms as output, and one in order to explain the determinants of the production of patents and high-tech patents in relative, that is, per capita terms.[18] As already stated, these output variables correspond to the patents registered at the European Patent Office (EPO), as they have the advantage —in comparison to national patent offices— of skipping the so called ‘headquarter effect’, since they are allocated not to the region of the firm´s headquarter, but to the one corresponding to the inventor´s place of residence, ergo, where the knowledge is in fact created. The explanatory variables are the factorial points corresponding to the six previously calculated factors: *Regional environment*; *University*; *Sophistication of the demand*; *Innovatory firms*; *Public Administration* and *Venture Capital*.

To prove the consistency and reliability of our the model, the same knowledge production function is calculated by means of different estimation procedures. However the different results obtained are very similar, thus resulting complementary and reinforcing the ‘preferred model’.

More specifically, the regression analysis is presented according to the following steps: First, an ordinary robust least squares (OLS) model is calculated [Equation I], as this procedure usually shows the highest level of robustness. Second, the regression is repeated applying panel data techniques, to take full advantage of the fact that the dataset compounds information not only for 193 European regions but also for several (fourteen) years. Again, the panel data procedure consists of four different models: the intergroup (or between-effects) one [Equation II with μ_i IID $N(0/\sigma_\mu^2)$ and ν_i IID $N(\bar{\upsilon}_{it}/\sigma_v^2)$], which explores the differences between regions; the intragroup model [Equation II], which takes into account the deviations of an individual region with regard to the average for the period; the random effects model, a special case of the previous [Equation II but with μ_i IID $N(0/\sigma_\mu^2)$ and ν_{it} IDD $N(0/\sigma_v^2)$, thus considering independence among the error components]; and, fourth, a Tobit panel data random

[18] The regressions have been run employing alternatively the number patens (and high-tech patents) in per capita terms and terms of the working population, obtaining nearly identical results. Accordingly, only the former are included in this paper.

effects model [Equation II but with the restriction that $K_{it}^{obs}>0$] which accounts for the fact that the dependent variables are left-side censored.[19]

The results estimated according to the above mentioned procedures are recorded in Tables 3 and 4. Both show the same structure, the former when estimating the *output* in absolute terms (total patents and high-tech patents), whereas the latter does so for the same relative variables (total patents per capita and high-tech patents per capita). In both cases the coefficients presented are BETA coefficients, that is, they show the elasticity in terms of standard deviations.[20] This means that the different BETAs within one regression can be compared as a measure of relative importance between independent variables/factors, although they cannot be used for direct comparison of the coefficients between models. Due to the high number of degrees of freedom of the specified regression function, the level of significance is set at the 99 per cent level.

4.1 Output in absolute terms

The results of regressing the independent variables *Regional environment*; *University*; *Sophistication of the demand*; *Innovatory firms*; *Public Administration* and *Venture Capital* according to an OLS estimation show that the determinant with the highest relative importance to explain the absolute generation of patents is the *Regional environment* (with a BETA coefficient of 567.13), followed by the *Innovatory firms* (200.46) and the *Sophistication of the demand* (96.33). The *Venture capital* although significant, presents a negative impact (-22.68). Both the *University* and the *Public Administration* are not significant in statistical terms. The results obtained when using the number of high-tech patents as output, are similar regarding the relative importance of the three factors: *Regional environment* (93.68), *Innovatory firms* (48.17), *Sophistication of the demand* (15.83), to which a fourth relevant factor, *Public Administration* (5.08) is added (however with a much smaller relative importance).

INSERT HERE TABLE 3

As far as the models based on a panel data approach, the intergroup model presents three significant variables when working either with the total number of patents or the high-tech patents. In both cases, the most important determinant is the *Regional environment* (558.85 and 93.60 respectively), followed by *Innovatory firms* (209.65) and the *Sophistication of the demand* (99.85). In the second case, the relative importance between the second and third factor of importance exchange: *Innovatory firms* (50.47) and *Sophistication of the demand* (15.22).

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[19] It should be remembered, that in the coefficients of a Tobit regression estimation have to be interpreted as the combination of (1) the change in K_{it} of those above the limit, weighted by the probability above the limit and (2) the change in the probability of being above the limit, weighted by the expected value of K_{it} if above.

[20] The relation between B coefficients and BETA coefficients is $BETA_i = B_i \times \frac{Sx_i}{Sy}$.

Again, and as occurs in the previous model, also the intragroup one presents similar results both when working with the total number of patents and the high-tech patents. In the former, the variables (in decreasing order of importance), show the following coefficients: *Regional environment* (358.86), *Innovatory firms* (90.14), *Sophistication of the demand* (61.09) and *Venture capital* (23.88). In the latter, the results obtained are: *Regional environment* (73.66), *Innovatory firms* (24.55), *Sophistication of the demand* (18.16), *Venture capital* (12.75) and *University* (although this one with a negative impact of -9.55).

In turn, the random effects model shows the following results: *Regional environment* (451.16), *Innovatory firms* (110.86), *Sophistication of the demand* (60.18), *Venture capital* (24.92), *Public Administration* (21.37) in the case of the total number of patents; and *Regional environment* (89.57), *Innovatory firms* (31.82), *Sophistication of the demand* (17.56), *Venture capital* and —as in the previous model with a negative impact— *University* (-6.04).

In any regression model the assumption of efficiency demands that the residuals are uncorrelated. For this purpose the preference of the random effects model over the intragroup one can be determined by means of the Hausman-test, the null hypothesis of which assumes that both models are consistent, but only the random effects one is efficient, whereas the alternative hypothesis assumes that only the intragroup model is consistent. As can be deduced from the values of the Hausman-test in Table 3, for both outputs the null hypothesis can be rejected —that is, it can be discounted that the coefficients of both models are the same, or, expressed in other terms, it confirms the existence of systemic differences between both— so that, due to its efficiency, the intragroup model has to be considered the preferred one.

Finally, the last column presents the results of a Tobit random effect model, that is, a panel data regression which takes into account the fact that the dependent variable is left-side censored. Due to statistical reasons, this model is only viable for high-tech patents (the variables do not converge in the total-patents one), showing the following results: *Regional environment* (89.32), *Innovatory firms* (31.56), *Sophistication of the demand* (17.56), *Venture capital* (12.76), as well as, though with a negative coefficient (-6.18) the *University*. In this case, the chibar2(01) test, which checks for significant differences between the panel data and the pooled models, rejects the null hypothesis about the equivalence of the Tobit random effect and pooled alternative (as the p-value is smaller than 0.5), thus making the former one prevail. [21]

4.2 Output in relative terms

In analogy to the previous section, first the results for the OLS model are presented, before describing the ones based on panel data analysis (Table 4). StarTing with the

[21] It should be noted that all different models for a same output show very similar adjustments in terms of R^2.

former, when working with the relative number of (total) patents as output, the first determinant in importance is the factor *Innovative firms* (with a relative importance of 65.24), followed by *Sophistication of the demand* (38.68), *Regional environment* (34.61), *Venture capital* (9.43) and *University* (5.48). When shifting the output to high-tech patents per capita, the order of relevance is: *Innovatory firms* (17.34), *Regional environment* (5.90), *Sophistication of the demand* (5.61), *University* (4.86), *Venture capital* (4.57) and *Public Administration* (1.43).

In the case of the intergroup model, only three variables are statistically significant in estimating the output in terms of the total number of patents per habitant: *Innovatory firms* (67.63), *Sophistication of the demand* (38.86) and the *Regional environment* (34.54). Instead, when predicting number of high-tech patents per habitant, the model includes two additional significant variables: *Innovatory firms* (18.06), *Regional environment* (5.81), *University* (5.26), *Sophistication of the demand* (5.21) and *Venture capital*, although its coefficient is so small (0.006), that it can be skipped.

In the intragroup or fixed effect model, all independent variables except the University, present a significant positive impact, headed by the *Innovatory firms* (27.55) and, with a nearly identical relative importance, the *Sophistication of the demand* (26.55), followed by the *Regional environment* (20.63), *Venture capital* (6.25) and the R&D carried out by the *Public Administration* (4.42). However, when limiting the model to high-tech patents, only three factors are of relevance: *Innovatory firms* (8.00), *Sophistication of the demand* (6.76) and *Venture capital* (3.54). However, this model presents an adjustment significantly below that of the others (R^2 of 0.356).

Regarding the random effects model, the *Innovatory firms* (36.06) present the highest impact, followed by the *Regional environment* and the *Sophistication of the demand* (both with very similar values, respectively 30.27 and 29.40) and, to a certain distance by the factors *Venture capital* (7.05) and *Public Administration* (4.35), while the same specification, but using the high-tech patents as output, gives the following result: *Innovatory firms* (10.85), *Sophistication of the demand* (6.80), *Regional environment* (with a relative impact close to the previous one, 6.15) and *Venture capital* (3.71).

As can be deduced from the values of the Hausman-test in Table 4, in both cases the null hypothesis can be rejected, thus confirming the existence of systemic differences between the fixed effect (intragroup or within model) and the random effects model. Accordingly the intragroup model has to be considered the preferred one, as it is the only efficient one.

Obviously, a very similar pattern to the one of the previous model is observed in the final Tobit panel data model: *Innovatory firms* (34.18), *Regional environment* (28.98), *Sophistication of the demand* (28.64), *Venture capital* (6.87) and *Public Administration* (4.52) in the case of the total number of patents per capita; and, once more, *Innovatory firms* (10.57), *Sophistication of the demand* (6.80), *Regional environment* (6.10) and *Venture capital* (3.69). Again, the chibar2(01) test allows to reject the null hypothesis about the equivalence of the Tobit random effect and pooled alternative makes the latter prevail. [22]

5.- Comparison with previous studies

The results of the 'preferred model' using the output in relative terms (patents per capita) —as it allows to correct for the 'size effect'—, presents the *Innovating firms* as most important factor, followed by the *Sophistication of the demand*; at a certain distance, the *Regional environment* and, again with a much less relative importance, the availability of *Venture capital* and *Public Administration* as an actor of the regional innovation system. In comparison with Buesa et al. (2010), some important differences arise, as in that work the *Regional environmen*t led the ranking of relative importance, while the *Innovatory firms* only ranked second. Also, in that occasion, the role of the *University* was significant (although with a low impact). Comparing the results of the 'preferred model' with the existing empirical literature referred to regional innovation systems, importance of the *Innovating firms* coincides with nearly all previous papers.[23] However, the results are less clear regarding the two other agents of the regional innovation system, namely the *University* and the *Public Administration*, as most of the papers which have worked with 'real' variables, have obtained contradictory results depending on whether they measure their role in terms of their expenditure or of their personnel employed,[24] although they contradict the ones obtained by most other authors[25] — thus this question clearly requires further study. Surprisingly, the 'preferred model' shows a significant positive impact of the *Public Administration*, while several other works either found unclear or clearly negative relationships.[26] The results for the factor *Sophistication of the demand*, coincide with the work by Furman et al. (2002) Finally, the importance of the *Venture capital*, neatly contradicts those of previous studies, which all show not significant or negative coefficients.[27] Regarding the 'preferred model' obtained when using the high-tech patents per capita as output, in comparison with the results obtained by Buesa et al. (2010), instead of the *Regional environment*, the most important factor now is again *Innovating firms*, the *Venture capital* maintains its relative position. No comparison with other of the cited papers is possible, as none model for high-tech patents.

Also, the models working with the output in absolute terms, essentially coincide with the 'preferred model' except for the major importance that in this case presents the

[22] Again, all different models for a same output show very similar adjustments in terms of R^2, except for the already mentioned intragroup model for high-tech patens.

[23] Notably Jaffe (1989), Acs et al. (92), Feldman (1994), Acs et al. (2002), Greuz (2003), Li (2009) and Karkalakos (2011).

[24] This occurs with Li (2009) and López (2012).

[25] Jaffe (1989), Acs et al. (92), Feldman (1994), Acs et al. (2002), Greuz (2003), Li (2009) and Karkalakos (2011).

[26] So in the case of Li (2009), Karkalakos (2011) and López (2012).

[27] Furman et al. (2002), Furman et al. (2014), Hu et al. (2005) and Hu et al. (2008), all referred to the national level.

Regional environment, as an indicator of size. In comparison with the results obtained by Buesa (2010), in this case the factors *University* and *Public Administration* are not significant. Instead, the *Sophistication of the demand* (a factor which was not included in the former paper) enters the model, both when working with the total number of patents and when estimating the high-tech patents.

6.- Conclusions

The model presented in this paper shows the relevant determinants of knowledge creation in European regions by means of combining factorial analysis and panel-data regression estimations This procedure allows to reduce the variables of the original dataset to a six ‘synthetic’ variables that reflect the underlying structure of the Regional innovation system: *Innovatory firms*, *Regional economic and productive environment*, *Sophistication of the demand*, *Venture capital*, *Public Administration* and *University*. The former three prove to be the most relevant in the creation of knowledge —especially the first one—, coinciding with most previous studies in the subject, while the factors *Venture capital* and *Public Administration* show to have a significant though less important impact.

While the leading role of the *Innovatory firms* seems obvious and fits all theoretical end empirical postulates, the important role played by the *Regional economic and productive environment*, might require further attention, as it suggests the importance of the size at least in terms of reaching a critical mass (cf. Rogers, 1995:313ff; Erber, 2010 and Asheim et al. 2013, among others), a question not yet sufficiently explored for the case of Regional Innovation Systems. The role of the *Venture capital* is specially noteworthy, as earlier works of this kind usually do not find evidences of any impact of this variable (although it is highlighted as relevant in the theoretical literature). Yet, no significant effect (and when significant, it is a negative one) is detected for the *University*. This might deem puzzling, as especially in the ‘peripheral’ regions, which have joined the EU in 2004 and 2007, the R&D performed by the Public Administration and the University plays a leading role in the creation of knowledge. However, in the overall setting of the database employed in this work, that effect might become diluted by the ‘dominating’ regions of the EU-15, in which the innovating firms play such a prominent part in the creation of new knowledge, that it crowds out any direct effect of the University[28] and the Public Administration[29] — at least in terms of knowledge that is protected by means of an patent application.

Thus, it could be concluded, that the results obtained basically fit the expected by the evolutionary theory, according to which all components of an Innovation System are relevant in the process of knowledge creation (while their application corresponds mainly to firms). Only the role of the University in this process has resulted mostly

[28] As Ponds et al. (2010) have shown for the regions of the Netherlands, the university-industry interaction regarding innovation is complex and depends not only on geographic proximity, but also of other factors such as the presence of supporting networks, etc.

[29] See for this the forthcoming article by [blinded for review purposes].

insignificant, demanding further studies. However, the results also evidences that the relative impact of the different determining factors of regional knowledge creation in Europe present relative impacts which are spread far apart, clearly showing that the innovatory firms, together with the economic and productive environment in which they are located, represent the most important elements of this process. Finally, the present paper also seems to validate the analytical process employed, that is, the combination of factorial analysis and panel-data regression in the framework of the knowledge production function, as it not only allows to overcome usual statistical shortcomings of this sort of studies, but also allows to better measure and represent the intertwined elements of such a complex reality as that of and Innovation System.

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Figure 1: Classification of the main studies regarding the determinants of innovation

Kind of independent variables used		Level of geographical analysis: National	Level of geographical analysis: Regional
	'Real" variables'	Griliches (1989)[1] Furman et al. (2002)[3] Gans and Stern (2003)[2] Riddel and Schwer (2003)[1] Faber and Hesen (2004)[2] Furman and Hayes (2004)[4] Hu and Mathews (2005),[7] (2008)[6] Krammer (2009)[5]	Jaffe (1989)[1] Acs et al. (1992)[1] Feldman (1994)[1] Anselin et al. (1997)[1] Acs et al. (2002)[1] Fritsch (2002)[2] [selected regions] Greuz (2003)[2] Botazzi and Perri (2003)[2] Moreno-Serrano et al. (2005)[2] Li (2009)[6] Karkalakos (2010)[2] Marrocu et al (2011)[2] López-Fernández et al. (2012)[2] [peripheral regions]
	'Synthetical' variables (factors)		Buesa et al (2010)[2]

Source: Own elaboration.

[1]Applied to the United States of America; [2]Applied to the European Union; [3]Applied to the OECD; [4]Applied to 'follower countries'; [5]Applied to Eastern Europe; [6]Applied to China; [7]Applied to East Asia.

Table 1: Knowledge production function. empirical evidence in the literature[30]

	Regional Innovation Systems												National Innovation Systems								
	Jaffe (1989)	Acs et al. (1992)	Feldman (1994)	Anselin et al. (1997)	Acs et al. (2002)	Greuz (2003)	Botazzi and Perri (2003)	Moreno et al. (2005)	Li (2009)	Karkalakos (2010)	Marrocu et al. (2011)	López (2012)	Griliches (1989)	Furman et al. (2002)	Gans et al. (2003)	Riddel et al. (2003)	Faber et al. (2004)	Furman et al. (2004)	Hu et al (2005)	Hu et al. (2008)	Krammer (2009)
Dependent variable	Pat	Inn	Inn	Inn	Pat	Pat	Pat	Pat	Pat	Pat	Pat	Pat	Pat	Pat	Pat	Pat	Pat	Pat	Pat	Pat	Pat
ABSOLUTE R&D EFFORTS																					
R&D expenditures							+				+			+	+				ns	ns	+
Firm's R&D expenditures (a)	+	+	+	+	+	+				+		+		+	+	+	+	+	+		
University's R&D expenditures (b)	+	+	+	+	+	+			-			ns		+	+	-		+	ns	+	+
Government´s R&D expenditures									-			+					+		+	-	+
Coincidence measure (a*b)	ns	+						+													
Number of researchers in Firms							+		+	Ns		-		+		+		+		-	
Number of researchers in Universities							+		+	+		-		+		+		+		-	
Number of researchers in Public Administration							+		+	+		-		+	+	+		+		-	
SPILLOVER EFFECTS																					
General spillovers indicator based on R&D expenditures								+													
Spillovers indicator of firms				ns	+	+															
Spillovers indicator for universities				+	ns	+															
SIZE																					
Size (Population)	ns	ns	+									+		-					-	+	+
Size (Sales - GDP)			+						+	+		ns		+	+		+	+	ns	ns	
Employment (manufacture)								+													
SPECIFIC VARIABLES ABOUT INDUSTRIAL STRUCTURE																					
Industrial structure (% employment in agriculture)					-																
Related industries			+										(+)								
Industrial concentration			+								(+)										
Services for firms			+	+	+																
High-tech employ. / Techn. specialization			+						-			(+)		+*	+		+		+		
Venture capital														Ns				-	-	-	
% of large firms				-	ns																
OTHER ENVIRONMENT VAR.																					
Stock of previous knowledge														+		+			+	-	+
Quality of university´s high tech departments				+																	
Educational level of active population / Spending in higher education					+						+			+	+			+	ns		ns
Openess to international trade									ns					+/-			+/-	+	+	+	
Protection Systems														+	+			+	ns	-	
Anti-monopoly policy														+				ns	ns		

Sources: Own elaboration.

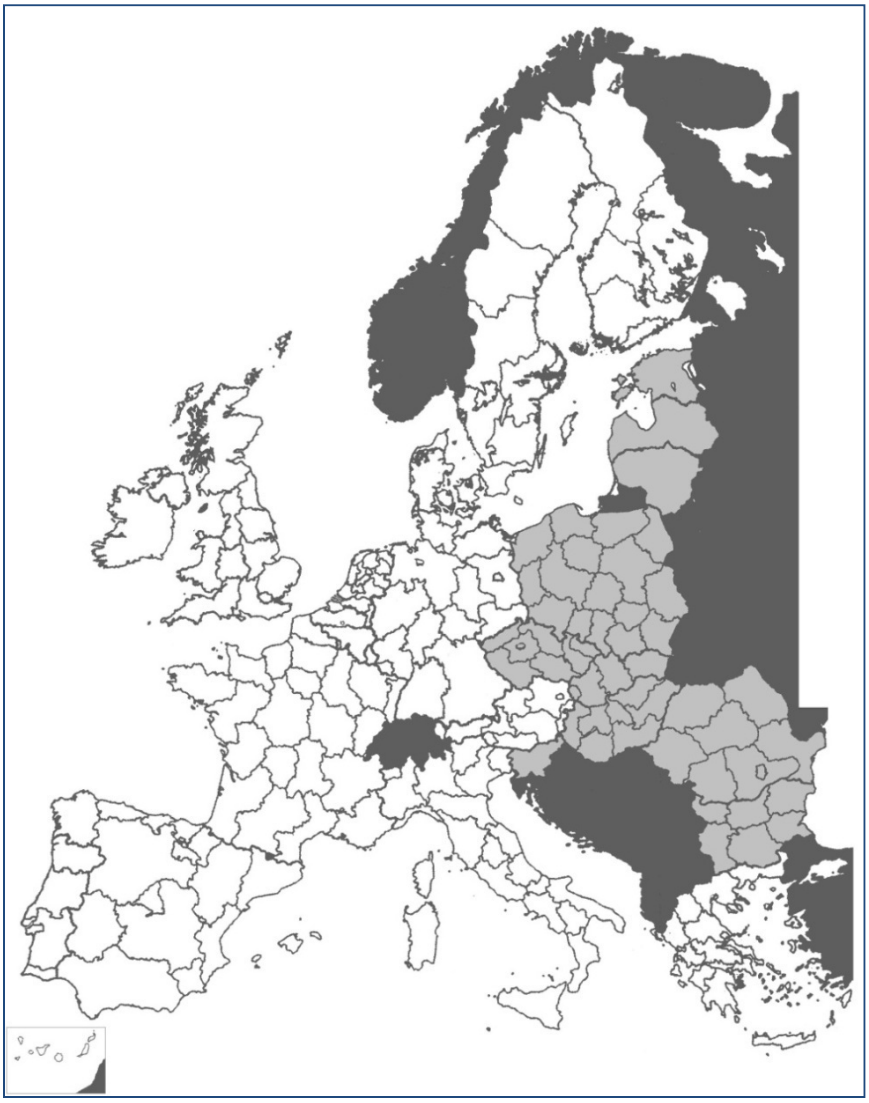
[30] When several alternative models are presented in one paper, the results of the main one are presented. Signs in brackets indicate a variable that is used only in some models for control purposes. The work by Buesa et al. (2010) is not included due to its use of factors as independent variables. *Defense expenditure as % of the GDP.

Table 2: Matrix of rotated components

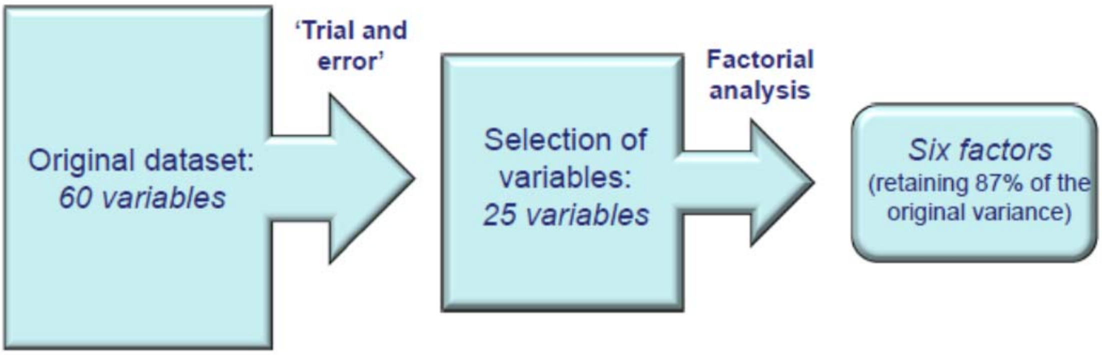
	Component					
	1	2	3	4	5	6
Annual average population	,959					
Human Resources in C&T - Education (thousand of people.)	,937					
Human Resources in C&T - Occupation (thousand of people)	,972					
Human Resources in C&T - Core (thousand of people)	,947					
GDP (millions of € of 1995)	,943					
Gross Fixed Capital Formation (millions of € of 1995)	,913					
Wages (millions of € of 1995)	,937					
Gross Added Value (millions of € of 1995)	,944					
Number of people employed (thousand)	,964					
R&D expenditure of the universities (‰ of GDP)		,711				
University´s R&D staff (HC) ‰ of employment		,936				
University´s R&D staff (FTE) ‰ of employment		,916				
3rd cycle students (% population)		,805				
GDP per worker (€)			,855			
GDP per capita (€)			,862			
ICT penetration			,622			
Economic Freedom Index			,530			,522
Firm´s R&D expenditure (‰ of GDP)				,891		
Firm´s R&D staff (HC) ‰ of employment				,864		
Firm´s R&D staff (FTE.) ‰ of employment				,870		
Public Administration´s R&D expenditure (‰ of GDP)					,901	
Public Administration´s R&D staff (HC) ‰ of employment					,936	
Public Administration´s R&D staff (FTE) ‰ of employment					,952	
Seed and start-up investment (% GDP)						,763
Development start-up investment (% GDP)						,867

Method of extraction: Main components analysis. Method of rotation: Varimax Normalisation with Kaiser. Rotation has converged in 6 iterations.

Map 1: European regions



Graph 1: Reduction of independent variables



Graph 2: Resulting factors – structural elements of the Regional Innovation System

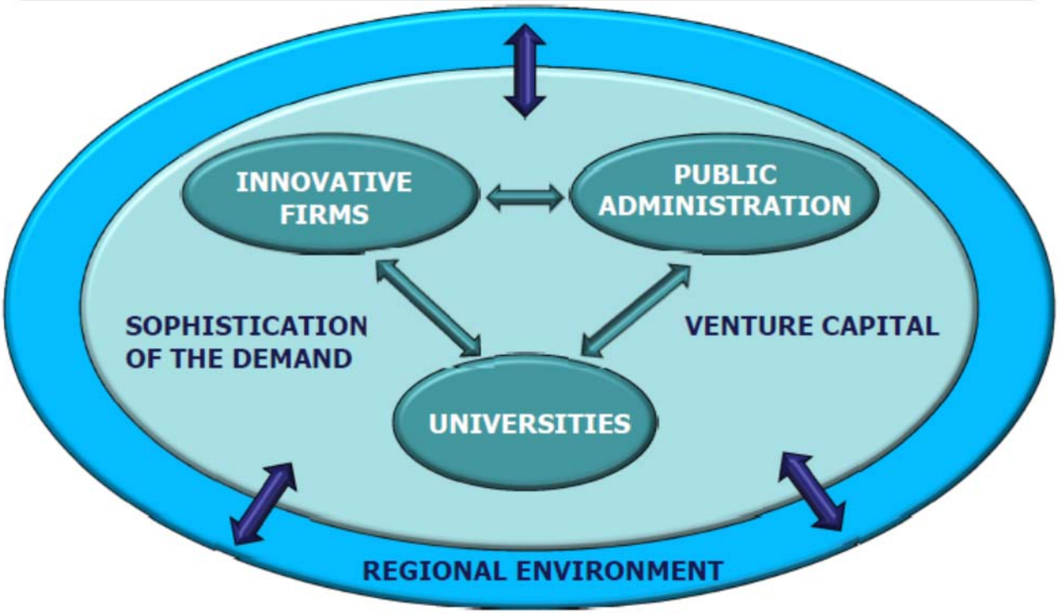


Table 3: Estimation results. Output: patents and hi-tech patents

	Robust OLS		Intergroup panels		Intragroup panels		Random effects panels		TOBIT random effects	
	Patents	High-tech Patents	Patents	High-tech Patents	Patents	High-tech Patents	Patents	High-tech Patents	Patents	High-tech Patents
Regional environment	567.13 (0.000)	93.68 (0.000)	558.85 (0.000)	93.60 (0.000)	358.86 (0.000)	73.66 (0.000)	451.16 (0.000)	89.57 (0.000)		89.32 (0.000)
University	*-16.21* *(0.013)*	*2.29* *(0.140)*	*-19.75* *(0.431)*	*2.30* *(0.678)*	*-13.33* *(0.045)*	-9.55 (0.000)	*-12.90* *(0.043)*	*-6.04* *(0.010)*		-6.18 (0.008)
Sophistication of the demand	96.33 (0.000)	15.83 (0.000)	99.85 (0.000)	15.22 (0.007)	61.09 (0.000)	18.16 (0.000)	60.18 (0.000)	17.56 (0.000)		17.56 (0.000)
Innovatory firms	200.46 (0.000)	48.17 (0.000)	209.65 (0.000)	50.47 (0.000)	90.14 (0.000)	24.55 (0.000)	110.86 (0.000)	31.82 (0.000)		31.56 (0.000)
Public Administration	*1.58* *(0.808)*	5.08 (0.001)	*407.08* *(0.989)*	*5.171* *(0.330)*	*14.12* *(0.143)*	*-1.466* *(0.701)*	*21.37* *(0.016)*	*2.80* *(0.356)*		*2.69* *(0.378)*
Venture capital	-22.68 (0.000)	6.158 (0.000)	*-67.03* *(0.032)*	*0.30* *(0.965)*	23.88 (0.000)	12.75 (0.000)	24.92 (0.000)	12.75 (0.000)		12.76 (0.000)
Constant	-304.97 (0.000)	636.87 (0.000)	-2902.77 (0.000)	-620.29 (0.000)	-1873.63 (0.000)	-424.42 (0.000)	-2356.88 (0.000)	-545.87 (0.000)		
Sigma u							322.12	70.83		73.06
Sigma i							101.12	40.06		40.08
Rho							0.910	0.757		0.768
F test	1,467.70 (0.000)	785.61 (0.000)	114.92 (0.000)	71.25 (0.000)	87.61 (0.000)	39.48 (0.000)				
Wald test							1,109.83 (0.000)	632.18 (0.000)		604.59 (0.000)
Log-Likelihood										-3,2884.11
Hausman							64.43 (0.000)	29.16 (0.000)		
Chibar2 (01)										3,042.28 (0.000)
R^2	0.765	0.636								
R within			0.067	0.033	0.173	0.086	0.171	0.084		
R between			0.787	0.696	0.766	0.649	0.765	0.670		
R overall			0.761	0.634	0.750	0.597	0.750	0.616		

In brackets the p-value. In italics the non-significant coefficients to 99 per cent. *Source*: Own preparation.

Table 4: Estimation results. Output: patents per habitant and hi-tech patents per habitant

	Robust OLS		Intergroup panels		Intragroup panels		Random effects panels		TOBIT random effects	
	Patents	High-tech Patents	Patents	High-tech Patents	Patents	High-tech Patents	Patents	High-tech Patents	Patents	High-tech Patents
Regional environment	34.61 (0.000)	5.90 (0.000)	34.54 (0.000)	5.81 (0.000)	20.63 (0.000)	*4.31* *(0.068)*	30.27 (0.000)	6.15 (0.000)	28.98 (0.000)	6.10 (0.000)
University	5.48 (0.000)	4.86 (0.000)	*6.15* *(0.136)*	5.26 (0.001)	*-0.843* *(0.581)*	*-0.82* *(0.287)*	*-0.27* *(0.844)*	*0.78* *(0.235)*	*-0.42* *(0.767)*	*0.62* *(0.362)*
Sophistication of the demand	38.68 (0.000)	5.61 (0.000)	38.86 (0.000)	5.21 (0.001)	26.55 (0.000)	6.76 (0.000)	29.40 (0.000)	6.80 (0.000)	28.64 (0.000)	6.80 (0.000)
Innovatory firms	65.24 (0.000)	17.34 (0.000)	67.63 (0.000)	18.06 (0.000)	27.92 (0.000)	8.00 (0.000)	36.06 (0.000)	10.85 (0.000)	34.18 (0.000)	10.57 (0.000)
Public Administration	*-0.88* *(0.424)*	1.43 (0.001)	*-1.40* *(0.720)*	*1.34* *(0.351)*	*4.42* *(0.046)*	*0.61* *(0.583)*	*4.35* *(0.023)*	*1.48* *(0.087)*	*4.52* *(0.021)*	*1.43* *(0.105)*
Venture capital	9.43 (0.000)	4.57 (0.000)	*9.54* *(0.062)*	0.006 (0.006)	6.25 (0.000)	3.54 (0.000)	7.05 (0.000)	3.71 (0.000)	6.87 (0.000)	3.69 (0.000)
Constant	-534.31 (0.000)	-145.14 (0.000)	-545.32 (0.000)	-149.61 (0.000)	-263.79 (0.000)	-75.88 (0.000)	-351.57 (0.000)	-105.41 (0.000)	-335.17 (0.000)	-103.17 (0.000)
Sigma u					68.19	22.38	52.72	19.16	62.76	20.70
Sigma i					23.30	11.75	23.30	11.75	23.34	11.76
Rho					0.89	0.78	0.83	0.72	0.87	0.75
F test	957.19 (0.000)	377.84 (0.000)	80.75 (0.000)	35.40 (0.000)	74.47 (0.000)	28.18 (0.000)				
Wald test							805.89 (0.000)	327,43 (0.000)	654.13 (0.000)	297.25 (0.000)
Log-Likelihood									-1,2792.29	-1,0861.31
Hausman							115.40 (0.000)	51.81 (0.000)		
Chibar2 (01)									3989.66 (0.000)	2743.62 (0.000)
R^2	0.680	0.452								
R within			0.127	0.043	0.151	0.063	0.149	0.060		
R between			0.722	0.533	0.674	0.411	0.681	0.472		
R overall			0.680	0.451	0.630	0.356	0.646	0.408		

In brackets the p-value. In italics the non-significant coefficients to 99 per cent. *Source:* Own preparation.