THE INNOVATION FACTOR: AN ECONOMETRIC MODEL OF PRODUCTIVITY IN EUROPEAN REGIONS

VIEIRA, Elvira*
VAZQUEZ-ROZAS, Emilia
NEIRA, Isabel

Abstract
This paper emphasizes the importance of the innovation input in the productive process, as a way to maximize the capacity and effectiveness of the labour factor and its productivity. This work describes some of the factors that are enunciated and that condition the existence of good levels of productivity of the factor work, enhancing with special attention the narrow relation between innovation and productivity. In this direction we proceed to the specification of an econometrical model, inspired by the Solow Growth Model, with the clear objective of placing in evidence the importance of the technological progress and the growth of productivity in 108 NUTS II regions of the European Union, using for such the expense in Inquiry and Development, as a reference measure.
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1. Introduction

The ability of a country to attract foreign capital, create new jobs and achieve good growth rates of wealth, depends largely on its levels of productivity, whose analysis relates to a series of varied elements. Among the many we could deploy, innovation is certainly one of the most important, which, for many authors, represents the key for achieving economic growth (Gu & Tang, 2003). Due to globalization, countries have drawn closer thus offering growing

* Elvira P. Vieira, Instituto Português de Administração de Marketing. IPAM – Matosinhos - Porto, Portugal. evieira@ipam.pt
Emilia Vazquez-Rozas and Isabel Neira, Department of Quantitative Economics. Faculty of Economics. University of Santiago de Compostela. Spain. emilia.vazquez@usc.es; isabel.neira@usc.es

competition so as to gain comparative advantages, forcing the private sector, especially, to be more innovative.

On undertaking a review of the scientific literature pertaining to this issue, we found a great number of economic studies that establish the relationship between productivity and innovation which, though distinct, point to a positive relationship between the two variables. Guisán & Aguayo (2005); Parisi, Schiantarelli & Sembenelli (2005) whose study addressed Italy, Criscuolo & Haskel (2003) who focused their attention on the UK, Gomes, Person & Veloso (2003) was that sought to understand the evolution of the total factor of the productivity of the Brazilian economy.

Many other authors have analyzed and examined this issue, whose econometric study has been stimulated, especially in recent years with the emergence of statistical databases which reflect in a more complete and precise manner the measurement of the technological progress of a society. Mairesse & Mohnen (2003).

Competitiveness depends, to a large extent, on the ability to generate a good momentum of employment, which is the result of issues related to demographics, limitations of the labour market, qualifications of human resources and the achievement of high levels of productivity. Couto, Vieira, Tiago & Natário (2006).

As we share the thoughts of many of these authors and consider productivity, especially the factor of production work, as being one of the key catalysts of growth, we have sought to determine some of the major variables that determine it, with special relevance to the innovative process. We adopted NUTS II of the European Community as a subject of study for the period between 1995 and 2003, in order to proceed with a comparative analysis of these.

The structure of the research work undertaken is as follows: section 2 analyzes the evolution of labour productivity and section 3 proceeds with the specification of an econometric model, inspired by the Solow model of growth, with the clear objective of bringing to light the importance of technical and technological progress to productivity growth in 108 NUTS II of the European Union, for this using the expenditure on research and development, as a reference

measure. Finally, we have completed the study with a set of considerations about the analysis undertaken, emphasizing the positive relationship between productivity and innovation.

2. Productivity and R&D in European Regions

The positive relationship between labour productivity and innovation becomes more evident through the analysis of table nº1, which shows the ranking of the 5 most and least productive regions in Europe, at the level of labour productivity, from among 108 European NUTS II.

Table 1 – Labour Productivity In The Nuts II
(GVA Per Worker, 2000 Euros)

	1995	1998	2000	2002
Centro (PT)	17315	17767	16554	16655
North (PT)	16740	17055	17464	17568
Açores (PT)	16165	16460	20276	21333
Algarve (PT)	19819	21060	22831	22512
Alentejo (PT)	20658	20624	23717	22935
Average 108 NUTS II	40052	41232	42036	43145
Aland (FI)	53053	54555	56552	56419
London (UK)	46270	48530	56450	58307
West Nederland (NL)				59319
Ireland (IE)	41760	50001	55111	59406
Noor Nederland (NL)				60052
Hamburg (DE)	64450	63360	62653	64749
Île de France (FR)	63772	65103	68498	71329

Source: Own elaboration from Eurostat and OCDE.

From these data, it is possible to emphasize the differences in productivity in the working population employed in different

regions: a worker in Île de France is 4 times more productive than a worker in the region of Centro (Portugal).

At the level of the 108 NUTS II regions considered, we found that the average labour productivity has gradually been increasing between 1995 and 2002, at an annual rate of 0.5%. Taking these figures into consideration, there are not seems to be a slight tendency to achieve convergent growth between the more and less developed regions in Europe. In this context it is clear that the Portuguese regions are those where the least productive workers in Europe are concentrated, a problem that, as a whole, is extended to the rest of the southern Europe regions.

3 - Empirical results.

In order to empirically identify the contribution of innovation activities to the increase of labour productivity in the 108 NUTS II regions, in the period between 1995 and 2002, we have estimated a regional econometric model, based on theoretical assumptions presented in the previously mentioned scientific literature.

Table 2 – Variables Definition

Dependent Variable	
VAL_{it}	Gross Value Added per employee (euros, at 2000 constant prices) for the region i, year t.
Independent Variables	
$LRDL_{it}$	Expenditure on R&D per worker (euros, at 2000 constant prices) for the region i, year t.
FCL_{it}	Gross Fixed Capital Formation, per employee (euros, at 2000 constant prices), for the region i, year t.
LSR_{it}	Weight of workers employed in the services sector, over the total employment for the region i, year t.

In most empirical work developed in this area, there is a positive relationship between innovation and productivity, although many authors support that the effect of innovation on productivity is slowed down, according to the time needed for companies to adapt to new production processes, new management practices and organization or even the introduction of new technologies resulting from foreign investment.

The econometric model

With the purpose of undertaking a balanced and sustained analysis of European regions, the sample used for the empirical study corresponds to 108 NUTS II, analyzed in a time period of 8 years, between 1995 and 2002, which has allowed us to estimate panel data. For the estimation we have used an unbalanced pool equation, due to the lack of data in some regions. The general pool equation is

$$y_{it} = x'_{it}\beta + \varepsilon_{it}$$

i = 1, …, N regions; t = 1, …, T_i years

where x_{it} may contain observable variables that change over t but not in i, variables that change over i but not in t and variables that change over i and t. In this equation β_{it} measures the partial effects of x_{it} in the year t, for the region i.

Since this model is too general, it is possible to confer greater subjectivity to the coefficients. A standardized assumption is that β_{it} is constant for all i and t, with the exception of the term of interception. Thus in our case[1], the term of disturbance is the compound error which can be represented as follows:

$$\varepsilon_{it} = \alpha_i + v_{it}$$

where α_i is an unobserved variable, constant in time, usually designated as an individual effect, and v_{it} are the idiosyncratic errors, which change over time and across regions.

[1] Our estimation does not include a timeframe specific component. Indeed, temporal effects can not be accepted in our regressions.

In this context we estimate the following equation:

$Log(VAL)_{it} = \beta_0 + \beta_1 \log(RDL)_{it} + \beta_2 \log(FC)_{it} + \beta_3 LSR_{it} + \varepsilon_{it}$
where i indicates the region and t the years from 1995 to 2002.

The common coefficients can not be accepted; in fact, on conducting the F test of common parametric stability, the model shows a lack of stability. We have taken into account the individual effects using estimations of Fixed (FE) and Random Effects (RE), through the Eviews software (version 6). The ordinary least squares estimation with FE, as well as the use of a redundancy test of fixed effects, leads to the rejection of the null hypothesis of redundant coefficients.

In order to select individual fixed or random effects, we have used the Hausman test [2], which is based on the differences between the estimators of the random effects model (RE) and the fixed effects model (FE). The null hypothesis is that regressors and individual effects are uncorrelated; through the estimated value to the Chi-square (60.09) we concluded with the rejection of the null hypothesis. Thus the assumptions of the random effects are not met, and the estimator of the fixed effects is the only consistent one. Furthermore, we have rejected the null hypothesis that the variance between the series of residuals are equal when we ran the Bartlett test (310,96). This test compares the logarithm of the weighted average variance with the weighted sum of the variances logarithms. Under the null hypothesis that the variance subgroups are equal and that the sample is distributed normally, the statistical test is distributed as a Chi-square. The results of the Estimation Generalized Least Squares are:

$Log(VAL)_{it} = 9.3 + 0.03 \log(RDL)_{it} + 0.05 \log(FC)_{it} + 1.1 LSR_{it}$
(168.1) (5.9) (9.9) (25.9)
$R^2 = 0,98$ N= 104, T=8, Unbalanced observations:628
(t-statistic in brackets)

[2] See Wooldridge (2002) for details

All variables are significant in order to explain the productivity of European regions; however, we emphasize the importance of the coefficient of the employment ratio variable in the tertiary sector over total employment. The constant term indicates the average effect for all regions and the coefficients of the fixed effects indicate the differences in relation to the average.

Although we have concluded that the selected variables are important when explaining the changes in labour productivity, their effect is not the same for all regions. Table 3 shows the results of the estimated coefficients in two regressions: one with the above average regions (in productivity terms) and the other with the regions below the mean. These equations were estimated using the general least squares method, since we rejected the equality of residual variances in the estimation performed by ordinary least squares.

We can denote that the Fixed Capital coefficient is higher in the least productive regions[3], than in the most productive ones. The designated "poor" regions reveal greater deficiencies in infrastructures for production and development and, as such, investments in fixed capital end up being more productive or produce a greater return.

In pooled GLS estimations, we verified our hypothesis on the effect of R&D on productivity: this effect is higher in the poorest regions. Despite the fact that these regions are not at the forefront of research, the import of technology and know-how from more developed regions may induce more accelerated rates of growth. While more developed regions have better conditions to develop activities of intensive R&D, in the poorest regions it may be possible to boost new production processes and enhance the growth of value added generated by investments made.

[3] Regions of below average productivity = “poor” regions

Table 3 – Differences in The Productivity Equation Results In The Most And Least Productive European Regions

Independent Variable: Log(VAL)
Sample: 1995-2002 (8 obs.)
Total panel (unbalanced) observations: 276(1) e 388 (2)

Cross-section	Estimation Method	Constant	Log(FCL)	Log(RDL)	SLR	R^2
(1) Above average Regions (63)	Pooled GLS	8.3 (78.3)	0.2 (15.9)	0.04 (12.3)	0.45 (13.9)	0.76
	Pooled EGLS (Fixed Effects)	9.5 (157)	0.4 (8.2)	0.02 (3.8)	1.05 (15.4)	0.99
(2) Below average Regions (45)	Pooled GLS	7.8 (37.2)	0.13 (5.2)	0.16 (14.6)	0.7 (10.6)	0.82
	Pooled EGLS (Fixed Effects)	8.5 (62.0	0.08 (5.6)	0.05 (4.3)	1.4 (10.6)	0.98

Furthermore, we can highlight the importance of the employment in the tertiary sector, for the increase of an economy's productivity. In addition, we noticed differences between European regions in the coefficient of this explanatory variable; the effect is smaller in the richest regions.

4 – Conclusions

Finally, we can highlight the following:

Firstly, the differences among European regions are pronounced. In our estimation, the implementation of a cross section

of fixed effects is necessary; there are specific variables to each region that explain changes in labour productivity, which are reflected in the fixed effects coefficients.

Secondly, the results of our regressions indicate that the activities of innovation, measured by the expenditure in R&D, are positively related with labour productivity in European regions. Likewise, we believe that this positive influence has an exponential effect in the labour productivity in the long term since the return of the investments is not immediate, and take place in the medium to long term, a return that ultimately enhances the competitiveness of the regional economy.

Thirdly, investments in R&D are more profitable in less developed regions. In this context the structures of these regions must be improved in order to benefit from this type of investment.

Fourthly, the regional disparities in labour productivity and in the efforts of innovation are most evident between northern and southern European regions, especially in relation to the Portuguese, who are at the tail of the productivity ranking. The less skilled human resources and structural deficiencies of the regions of southern Europe have produced a negative effect on attracting foreign investment in activities of higher added value.

Finally, the development process depends on the innovation process. If the investments in technology are large, the economic growth and productivity convergence will be higher; at the same time these regions will be able to absorb new technologies. Despite taking the differences between two groups of regions into account, the results of our estimations lead to the possibility of testing more regions clubs in order to study the convergence process among them at the productivity level.

Bibliography

Aguayo, E., Expósito, P., Rodríguez, X.A. & Vázquez, e. (2000) "Human Capital and other Factors of Total Productivity in Spanish Regions", 40th ERSA Congress.

Benavente, J. M. (2002): "The Role of Research and Innovation in Promoting Productivity in Chile"; Departamento de Economia, Universidade do Chile

Cancelo, M. T., Diaz, M. R. & Guisan, M. C. (1998): "Gasto en investigaciones y su impacto sobre el crecimiento regional". Working Paper of the Series *Economic Development, nº* 32 , on line.[1]
Comín, D. (2002): "R&D? A small contribution to productivity growth"; Economic Research Reports. New York University.
Couto, Vieira, Tiago & Natário (2006). Competitividad de las regiones portuguesas: Análisis comparativo. *Papeles de Economía Española,* Nº 107.
Crepon, B., Duguet, E. & Mairesse, J. (1998): "Research, Innovation and Productivity: an Econometric Analysis at the Firm Level", *NBER Working Paper*, Nº 6696
Criscuolo, C. & Haskel, J. (2003): Innovations and Productivity Growth in the UK: Evidence from CIS 2 and CIS3. Center for Research into Business Activity (CeRiBA).
Eurostat(2003)NewCronos. ttp://www.eurostat.com
Gomes, V., Lisboa, M. C. & Pessoa, S. A. (2002): Estudo da Evolução da Produtividade Total dos Fatores na Economia Brasileira: 1950-2000. Mimeo.
Guisán, M.C; Aguayo, E. (2006) Capital humano, industria y turismo en las regiones de países de la UE-25 *Papeles de Economía Española,* Nº 107
Guisán, M.C. & Aguayo, E. (2007). Efectos del turismo y del capital humano sobre el desarrollo economico de las regiones españolas: Analisis comparativo con la Unión Europea, 1985-2000, Working paper of the Series *Economic Development,* nº. 97, on line.[1]
Griffith, R., Redding, S. & Van Reenen, J. (2000): "Mapping the Two Faces of R&D: Productivity Growth in a Panel of OECD Industries"; CEPR Discussion Paper, 2457.
Griliches, Z. (1998): R&D and Productivity. Chicago University Press, Chicago
Grossman, G. & Helpman, E. (1991): Innovation and Growth in the Global Economy. MIT Press, Cambridge.
Gu, W. & Tang, J. (2003): "The link between innovation and productivity in canadian manufacturing industries"; Working Paper nº 38. Industry Canada Research Publications Program.
Mairesse, J. & Mohen, P. (2003): "R&D and Productivity: a reexamination in light of the innovation surveys"; DRUID Summer Conference 2003.
Parisi, M. L., Schiantarelli, F. & Sembenelli, A. (2005): Productivity, Innovation and R&D: Micro evidence for Italy. Mimeo
Vieira, E. & Neira, I. (2004): "Análise comparativa regional de Espanha e Portugal: implicações da investigação no desenvolvimento industrial (1995-2001)"; *Regional and Sector Economics Studies.* Vol. 4-1

Wooldridge, J.M. (2002): Econometric Analysis of Cross Section and Panel Data. The MIT Press. Cambridge.

[1]available at: http://ideas.repec.org/s/eaa/ecodev.html

APPENDIX. European Regions NUTS II:

1	be Belgium	37	es61 Andalucia	73	ite4 Lazio
2	dk Denmark	38	es62 Región de Murcia	74	itf1 Abruzzo
3	de1 Baden-Württemberg	39	es70 Canarias (ES)	75	itf2 Molise
4	de2 Bayern	40	fr10 Île de France	76	itf3 Campania
5	de3 Berlin	41	fr21 Champagne-Ardenne	77	itf4 Puglia
6	de4 Brandenburg	42	fr22 Picardie	78	itf5 Basilicata
7	de5 Bremen	43	fr23 Haute-Normandie	79	itf6 Calabria
8	de6 Hamburg	44	fr24 Centre	80	itg1 Sicilia
9	de7 Hessen	45	fr25 Basse-Normandie	81	itg2 Sardegna
10	de8 Mecklenburg-Vorpommern	46	fr26 Bourgogne	82	nl1 Noord-Nederland
11	de9 Niedersachsen	47	fr30 Nord - Pas-de-Calais	83	nl2 Oost-Nederland
12	dea Nordrhein-Westfalen	48	fr41 Lorraine	84	nl3 West-Nederland
13	deb Rheinland-Pfalz	49	fr42 Alsace	85	nl4 Zuid-Nederland
14	dec Saarland	50	fr43 Franche-Comté	86	at Austria
15	ded Sachsen	51	fr51 Pays de la Loire	87	pt11 Norte
16	dee Sachsen-Anhalt	52	fr52 Bretagne	88	pt15 Algarve
17	def Schleswig-Holstein	53	fr53 Poitou-Charentes	89	pt16 Centro (PT)
18	deg Thüringen	54	fr61 Aquitaine	90	pt17 Lisboa
19	gr1 Voreia Ellada	55	fr62 Midi-Pyrénées	91	pt18 Alentejo

20	gr2 Kentriki Ellada	56	fr63 Limousin	92	pt2 Região Açores (PT)
21	gr3 Attiki	57	fr71 Rhône-Alpes	93	pt3 Região Autónoma da Madeira (PT)
22	gr4 Nisia Aigaiou, Kriti	58	fr72 Auvergne	94	fi1 Manner-Suomi
23	es11 Galicia	59	fr81 Languedoc-Roussillon	95	fi2 Åland
24	es12 Principado de Asturias	60	fr82 Provence-Alpes-Côte d'Azur	96	se Sweden
25	es13 Cantabria	61	fr83 Corse	97	ukc North East
26	es21 Pais Vasco	62	ie Ireland	98	ukd North West (including Merseyside)
27	es22 Comunidad Foral de Navarra	63	itc1 Piemonte	99	uke Yorkshire and The Humber
28	es23 La Rioja	64	itc2 Valle d'Aosta/Vallée d'Aoste	100	ukf East Midlands
29	es24 Aragón	65	itc3 Liguria	101	ukg West Midlands
30	es30 Comunidad de Madrid	66	itc4 Lombardia	102	ukh Eastern
31	es41 Castilla y León	67	itd3 Veneto	103	uki London
32	es42 Castilla-la Mancha	68	itd4 Friuli-Venezia Giulia	104	ukj South East
33	es43 Extremadura	69	itd5 Emilia-Romagna	105	ukk South West
34	es51 Cataluña	70	ite1 Toscana	106	ukl Wales
35	es52 Comunidad Valenciana	71	ite2 Umbria	107	ukm Scotland
36	es53 Illes Balears	72	ite3 Marche	108	ukn Northern Ireland