PRODUCTIVITY AND INNOVATION ECONOMY: COMPARATIVE ANALYSIS OF EUROPEAN NUTS II, 1995-2004

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ABSTRACT

Innovation is the guarantee of perpetuation and improvement of productive cycles, as well as the improvement of the work of human resources. This article emphasizes the importance of the input of innovation in the production process as a way to maximize the capacity and efficiency of the labour factor, translated by its productivity.

This paper describes some of the factors which determine the existence of good levels of labour productivity, highlighting the relationship between innovation and productivity. Based on the bibliography review of some papers in this area, and in this context, we have tried to determine the main indicators that are normally used to measure innovation. Later, we proceed to the specification of the econometric model, inspired by the Solow growth model, with the clear objective of bringing to light the importance of technological progress in the growth and development of the NUTSII regions in 27 countries of the European Union, using the expenditure on Research and Development (R & D), as a reference measure. Finally, we completed the study with a set of considerations about the analysis carried out, emphasizing the existence of a positive relationship between productivity and innovation.

1 – INTRODUCTION

The constant and rapid technological changes, the revolution in information and communication channels and the global boost of the economy have played a decisive role in the growing competition among countries and regions in attracting investment, skilled human resources and exploring predominantly import markets. Especially among developed countries, there is a factor that makes them highly competitive: their productivity.

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 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. GUISAN & AGUAYO (2005) mention a direct and indirect positive effect of expenditure on research and development (R&D), as an important variable of human capital, on the increase of GDP per capita and employment. In turn, there are a number of authors who, based on the production function of Cobb-Douglas, have demonstrated the variability of productivity in different countries depending on several variables, identifiers of the efforts on innovation. Among these, one should mention PARISI, SCHIANTARELLI & SEMBENELLI (2005)[1] whose study addressed Italy, CRISCUOLO & HASKEL (2003)[2] who focused their attention on the UK, GOMES, PERSON & VELOSO (2003)[3] who sought to understand the evolution of the total factor

[1] For these authors, expenditure in R&D may not directly increase the productivity of enterprises, but the concern with the conduct of R&D will increase the capacity of absorption of innovations, which will surely contribute directly to productivity growth.

[2] CRISCUOLO & HASKEL`s conclusion is that the innovation process, influenced by expenditure on innovation (positively affected by the level of qualifications and governmental support), government support and information systems, contiguous or not to the enterprises, contributes to the growth of the factors of total productivity.

[3] In this study, one of the conclusions points to technological progress as the main source of labour productivity growth; moreover, the growth of the technological frontier, represented by the United States, has positively influenced the accumulation of capital.

of productivity in the Brazilian economy, GU & TANG (2003)[4] who focused their analysis on Canada, and BENAVENTE (2002)[5] whose research focused on Chile.

The positive effects of investing in R&D are also taken into consideration by GRAFFITH, REDDING & REENEN (2001) because, in addition to stimulating innovation and increasing the capacity of absorption of technological progress, this is a significant factor in the process of productivity convergence of the countries and regions. For these authors, expenditure on R&D generates significant social rates of return, particularly in less developed countries that are further away from the technological frontier, represented by the United States. In this context there are increasingly more studies which compare labour productivity in European regions and countries with North American states. At this level, one should mention the research of ATKINSON (2007), which considers that the key factor in increasing productivity in Europe, so as to reach the level of the USA, is the use of more modern and more efficient information technologies and communication, specially when the level of development of the regions is often directly dependent on the strength of its tertiary activity sector. According to this author, the level of the influence of the application of these technologies on the GDP growth can vary between 0,5% and 1% and is specially reflected in the increase of efficiency in the process, work organization and subsequent increase in productivity[6].

Although productivity growth represents one of the main factors in regional development and convergence, this cannot be reached at the expense of an increase in the unemployment rate (KORRES, CHIONIS & TSAMADIAS, 2004). GARDINER, MARTIN & TYLER (2004) actually claim that regions can only be competitive if they

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[4] Just as in previous studies, these authors also considerer that there is a positive relationship between productivity and innovation. However, some of them argue that innovation takes between 1 to 3 years, depending on the industry and the level of development of the country, to generate an impact on productivity. Moreover, they also argue that the measurement of innovation should be based on several indicators, not only one, namely the expenditure on R&D (% of output), patents per worker, adoption of technology (measured in real investment in machinery and equipment) and level of qualification (measured in the percentage of employees with college education).

[5] Establishes a system of 4 equations (two for R & D, one for innovation and for productivity), in which productivity is explained by the physical capital, the workforce employed with a given educational level (percentage of engineers and administrators on the total employees) and output of innovation (innovative sales). However, some econometrical notes applied to Chile, revealed that innovation measures, either input or output, do not have a significant impact on productivity, probably because they do not consider the period of time between the moment when the innovate efforts are made and the moment when this investment is beginning to reflect on the increase of productivity, as presupposed in GU & TANG (2003).

[6] The average annual growth rate in Europe's labour productivity, between 1995-2005, was clearly inferior to the U.S.A. rate (approximately 1,3% and 2,7%, respectively)

manage to reach high productivity indexes and register high employment rates[7]. To achieve this, regions should be able to build a good economic structure with innovation dynamics as well as a skilled workforce, which are some of the weaknesses pointed out in some of the EU regions, especially those of the new member states. According to their research, these have added a large periphery of low productivity to the economic panorama of the European Project.

Similarly COMÍN (2002) believes that R&D is the main source of growth in the long term, since it not only guarantees the right to future returns of the new cluster of innovation, but also allows for the option to develop more clusters in the future, at reduced costs. Finally the process of innovation represents one of the major "engines of growth" of productivity (RAO, AHMAD, HORSMAN & KAPTEIN - RUSSELL, 2001)

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 the measurement of the technological progress of a society (in a more complete and precise manner). MAIRESSE & MOHNEN (2003), present a framework summary of some scientific work in this area, most of which is based on the model of CREPON, DUGUET & MAIRESSE (1998), consisting of a system of three equations that relate the expenditure on R&D, the output of innovation (number of patents or percentage of innovative sales[8]) and productivity.

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 2004, in order to proceed with a comparative analysis of these.

The structure of the research work undertaken is as follows. Chapter 2 lists and describes some of the factors which determine the existence of good levels of labour productivity, highlighting the close relationship between innovation and productivity. In

[7] In their study they make the distinction between two groups of countries/regions: those who have a high growth rate in labour productivity and employment, and those who have a high productivity rate but a gradual decrease in the employment rate.

[8] Sales derived from the introduction of innovative products in the market, or from changes in the production process, that allow a substantial reduction in the product's price.

this sense we have sought to determine the main indicators that are designed to measure innovation based on the review of the bibliography pertaining to several works dedicated to this issue. Chapter 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 in productivity growth in the 192 NUTS II of the European Union, 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 – CONDITIONING FACTORS IN PRODUCTIVITY

The need to become competitive guides development strategies, as well as the planning of the economic growth models of various countries and regions. Therefore, and as is mentioned by COUTO, VIEIRA, TIAGO & NATÁRIO (2006), 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 as well as the limitations of the labour market, the qualifications of human resources and the achievement of high levels of productivity.

These two factors, with special relevance to the second, play an important role in defining the standard and quality of the life of populations. This is the reason why these have been studied by several authors, seeking to determine the factors that influence their growth. We have previously mentioned some studies that address the issue of productivity, so as to identify these factors. Despite the registered differences in the analysis undertaken, we can essentially identify three key factors: the accumulation of physical capital, human capital and the rate of innovation and technological progress. These are and continue to be the main growth factors in many countries and regions, mainly in northern Europe (Norway, Sweden, Denmark and Finland), which based their growth models on knowledge and technological development, whose period of change has already lasted since the nineties, tracking the growth of highly innovative companies related to new technologies, such as Nokia.

However, one cannot ignore that these countries are examples of guided and efficient work policies, and that the productivity they present would not be possible if the population's employment rates was not high. In addition, the jobs created exist predominantly in high productivity industries or services. BASILE & BENEDICTIS (2004) consider that Europe presents a pronounced and persistent central-peripheral structure, with high unemployment rates concentrated in peripheral regions which, despite a slight tendency for convergence, continue to compromise the future growth of their productivity through the creation of jobs of low added value. This keeps them removed from the more productive regions, represented specially by the great metropolises or mega cities. It is the result of the combination of the abovementioned, the way in which these are managed and organized and obviously their quality and abundance, which will naturally determine much of the productive performance. However, in addition to these factors, the economic and business environment of a particular country or sector of reference will also play an important role. Accordingly, we particularly mention the opening to trade and international investment and the level of competition registered by the economy; essentially, the latter encourages change in order to capture the largest share of the market, through gains in productivity, both in products and in production processes, a change which is enhanced by the adoption and development of new technologies.

2.1 – THE RELATIONSHIP BETWEEN INNOVATION AND PRODUCTIVITY

The relationship between innovation and productivity has been studied and analyzed by the scientific community involved in the subject of development. Many of these authors confirm the importance of innovation so as to explain economic growth, considering it to be one of the engines of growth, primarily because of its effects which last far beyond the short term. In this context, innovation can be described as a complex and ongoing process of discovery, development, learning and application of new ideas, commercial and industrial methods as well as technologies. Through this ongoing process, it is comprehensible that countries like the United States or Japan, have been and still are countries of reference in this area.

Many of the processes and techniques derived from innovation efforts are cumulative and interdependent and, much of the ability of a country to develop these efforts, stems from the influence of external factors such as the quality of education, especially in infrastructure-related knowledge (universities, research institutes, among others), the availability of infrastructures to support research and the healthy functioning of markets. These innovation efforts may be reflected on the competitiveness of countries (mainly in two ways). The first may result in changes at the level of organization, methods of production or marketing strategies, to improve the efficiency of the entire production or commercial process; the second can lead to the introduction of new products and the improvement of existing ones. In any case, the process of innovation has inevitably generated gains in productivity, especially the factor of work production.

At the basis of all technological progress are the research and development activities, essential to its achievement. However, and although these activities stimulate innovation, their role extends far beyond this purpose. They also create conditions for the imitation or adoption of technologies discovered or developed by other countries or institutions. Most of the innovations involve the formation of a tacit knowledge, which is very difficult to find in textbooks or even to be transmitted through oral or audiovisual means. In this context, while developing activities related to research and development in a given area of working, the training of tacit knowledge itself results from experience and persistence, allows the creation of foundations, which go well beyond purely theoretical knowledge in order to understand and assimilate, both better and faster, the innovations introduced by others.

The absorption capacity of technical progress generated externally, often ignored or placed in the background by many studies, is emphasized by JAFFE (1986), GEROSKI, MACHIN & REENEN (1993) and GRAFFITH, REDDING & REENEN (2001), whose studies point to benefits for the countries or institutions with a history in the development of research and development activities, especially in the context of international transfer of technology. This study argues that the ability to imitate the technology of others also derives from the quality of human capital, representing a role in this process which is much more significant, when there is a low level of development of the countries and when these are far removed from the technological frontier, represented by the United States of America.

Globalization and the spread of information technology have increased competitiveness and accelerated the need to launch innovations in the market. In this sense, the ever closer relationship between science and specially the industrial structure has taken on an increasing importance, reflected in the growth rate of introducing innovations in the market. Though this does not always happen in the short term, innovation efforts always end up having a positive and significant impact on productivity in the medium and long term.

2.2 – INNOVATION MEASURES

Most of the literature pertinent to this theme seems to highlight the important role played by innovation in enhancing the productivity of countries. Thus, since we want this study to present an empirical analysis of this relationship, it is vital to clarify the main methods used to quantitatively measure the efforts of innovation developed by a society.

Innovation can take on a number of dimensions within society, not only at an economic level but also, and increasingly, at the social and cultural level. Yet, these dimensions are difficult to measure and, therefore, many of the attempts to measure innovation end up stemming from the economic dimension. The indicators most frequently used in the measurement of innovation are expenditure on R&D and the number of patents per worker. However, it is possible to similarly highlight other indicators related to the adoption of new technologies and the level of qualification of labour.

In order to generate innovative new products and processes, the countries or institutions must necessarily invest in Research and Development. The expenditure on R&D is the main indicator used to reflect the efforts of innovation, and this functions as the input/catalyst of the whole innovative process. Despite its importance, this is not a perfect measure of innovation, especially since not all further research and development generates results. However, as we previously stated, even though the ability to innovate is reduced, the ability to absorb technology developed by others is in this case much greater.

Another indicator that together with the expenditure on R&D is mentioned by scientific literature is the number of patents. Patents serve the innovators' interests, in order to protect their intellectual property rights. This essentially represents a means of ensuring that the innovators receive future returns of their investment in research and development and that these are not appropriated by imitators. This indicator is a measure of the output of the innovative process, although it only partially reflects it[9]. Alternatively to patents, many institutions hold marketing secrets or use copyrights in order to protect their intellectual property rights. According to the model set up by CREPON, DUGUET & MAIRESSE (1998), the output of innovation is measured both by the number of patents, as well as the percentage of sales derived from the innovative process (sales of new products to companies or the market).

The indicators of innovation are not limited to these two indicators. The adoption of new technologies is also an important indicator that reflects the impact of innovation on productivity; this may be measured by the number of new products and processes introduced and the percentage of output generated by these new products or processes. One of the sample measures of the adoption of new technologies is embodied in investment in machinery and equipment. Finally, the level of qualification of employees plays an important role in the measurement of innovation. This is supported by most scientific literature, in which we highlight GUISAN & AGUAYO (2005) which consider the qualifications of the labour factor as an important input in the process of innovation. This can be translated by the percentage of employment of scientists, engineers and other qualified professionals in R&D, over total employment.

In order to explain the effect of innovation on productivity, many studies only use one of these indicators. However, none of these indicators alone is able to reflect the multidimensional nature of the innovative process and the real level of a country or institution. Despite everything, it is possible to empirically acquire an approximate and more simplified perspective of the effect of innovation on productivity.

[9] CRISCUOLO & HASKEL (2003) refer particularly to three factors: firstly, not all innovations reflect an invention, secondly the patents have not alone commercial exploitation and thirdly the propensity to patent inventions depends on the sector or area of work.

3 – PRODUCTIVITY AND R&D IN EUROPEAN REGIONS

The positive relationship between labour productivity and innovation becomes more evident in the analysis of table nº1 and nº2, which shows the ranking of the 5 most and least productive regions in Europe, at the level of labour productivity, in the NUTS II regions of the EU15, as well as the NUTS II regions of the new State Members. From these data, it is possible to emphasize the differences in productivity in the working population employed in different regions: a worker in Groningen is 4,5 times more productive than a worker in Centro(NUTII-Portugal), and almost 24 times more productive than a worker in Yuzhen tsentralen.

At the level of the EU27 NUTS II regions considered, we found that average labour productivity has slowly been increasing, between 1995 and 2004, at an annual rate of 0,26%. However, taking these figures into consideration, there clearly seems to be a lack of a convergence tendency between the more and less developed regions in Europe, with the least productive regions registering lower growth rates than the annual average of the EU27. At this level, if we divide the sample in two, separating the top most productive NUTS II from the bottom least productive ones, we can see that the growth rate of the productivity average of each group of regions is far greater in the first 96 regions group (14,36%) than in the second group (6,63%). This difference is even more evident if we consider only the period 2000-2004, in which the most productive NUTS II maintain a positive growth rate of the productivity average (3,65%), while the growth rate of the least productive ones, drops about 2,57%, enhancing the divergence between these regions. With the entrance of the new State Members in the EU, the development gap between the EU27 NUTS II has become even more significant, especially after the inclusion of Romania and Bulgaria, clearly the least developed and least productive countries in Europe.

Considering only the EU15 NUTS II, although slightly different, the observations undertaken for the EU27 regions are almost the same. In this context, we see that the average productivity growth rate of the 72 most productive regions (13,85%) is higher than the 73 least productive ones (12,66%), although this difference is smaller than in the case of the EU27 regions case. However, in this case, if we consider only the 1995-2000 period, we find a slight trend of convergence, with the second NUTS II group reaching a higher average productivity growth rate (10,10%) than the first one (9,66%).

TABLE Nº 1 – LABOUR PRODUCTIVITY IN EU15 NUTS II (GVA PER WORKER, 2000 EUROS)

	1995	2000	2004
	Highest Productivity		
Groningen (NL)		73639	76884
Luxembourg (LU)	71697	74331	73543
Ille de France (FR)	64122	68498	72574
Région de Bruxelles (BE)	65994	66400	70210
Hamburg (DE)	63757	62653	65937
	Lowest Productivity		
Alentejo (PT)	20190	23717	23287
Algarve (PT)	19370	22831	21473
Região Autónoma dos Açores (PT)	15799	20276	21227
Norte (PT)	16361	17464	17413
Centro (PT)	16923	16554	17054
Mean EU27	**35518**	**33821**	**36342**

Source: Eurostat

From table nº1, we can clearly see that the Portuguese regions are those where the least productive workers in EU15 are concentrated, a problem that, as a whole, is extended to the rest of the southern Europe regions. At the EU15 level, Groningen, Luxembourg and Ille de France are the regions which present the highest values of labour productivity, doubling the EU27 average. However, considering the new NUTS II State Members, the gap between regions is even greater. As seen in table nº2, the most productive regions in these countries are reaching the levels of the values presented by the less developed countries of the EU15, though the evolution, between 1995 and 2004 presented by both groups, is positively more expressive in the first one.

The least productive regions of the EU15, mostly Portuguese and Spanish, in which productivity does not reach half of the most developed NUTS II of EU, are now in the middle of the labour productivity ranking, with the inclusion of twelve new Eastem European countries, whose productivity presents values which are even lower, in comparison with the most developed EU countries. These values, and the huge difference detected among the NUTS II regions, have led us to believe that these 27 EU countries are still part of different groups of countries. One can thus talk about two or three EU's, as we will later show in the empirical analysis.

TABLE Nº 2 – LABOUR PRODUCTIVITY IN NEW STATE MEMBERS' NUTS II (GVA PER WORKER, 2000 EUROS)

	1995	2000	2004
	Highest Productivity		
Cyprus (CY)	26461	29661	29032
Praha (CZ)	13916	16589	22322
Malta (MT)		24809	21820
Slovenia (SL)	21506	20164	19619
Közép-Magyarország (HU)	20484	15271	18357
	Lowest Productivity		
Yugoiztochen (BG)	2653	4302	3960
Severoiztochen (BG)	2545	3904	3814
Severen tsentralen (BG)	2315	3421	3350
Severozapaden (BG)	2355	3866	3332
Yuzhen tsentralen (BG)	2437	3154	3245
Mean EU27	**35518**	**33821**	**36342**

Source: Eurostat

The disparities between the southern regions and the other NUTS II in Europe are even more obvious when examining the diagram of the whole European regions. At this level, the Scandinavian regions are those which invest most in R&D per employee, followed by most German and some French and English NUTS II regions. Once again, it is the most developed NUTS II that occupy the first places in the ranking, contributing both to the perpetuation of regional inequalities, as well as to the maintenance and even deterioration of differences in productivity.

In order to empirically identify the contribution of innovation activities to the increase of labour productivity in the 192 NUTS II regions, in the period between 1995 and 2004, we have estimated a regional econometric model based on theoretical assumptions presented in the previously mentioned scientific literature. In most empirical work developed in this area, there is a positive relationship between innovation and productivity, although many authors support that innovation slows down productivity, according to the time needed for companies to adapt to new production processes, new management practices and organization, or even due to the introduction of new technologies resulting from foreign investment.

With the purpose of undertaking a balanced and sustained analysis of European regions, the sample used for the empirical study corresponds to 192 NUTS II, analyzed in a time period of 9 years, between 1995 and 2004, which has allowed us to estimate panel data. First, we studied the cointegration of the variables in the sample, in order to allow for the stationary panel data estimation.

TABLE Nº 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	
RDL_{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.

UNIT ROOTS PANEL

The use of unit root tests has been in widespread use in recent years. In this paper we assume the preference for the use of the individual unit roots test [10].

[10] The Im, Pesaran, and Shin (2003), Fisher-ADF and PP tests all achieve processes of individual unit roots, as ρ_i can vary depending on the cross-sections. The tests are all characterized by the combination of tests of individual unit roots, tests destined to derive a result of a specific panel, for tests with common roots unit. The Levin, Lin and Chu (LLC) (2002), Breitung (2000), and Hadri (1999) tests all assume the existence of a process of root common unit, since ρ_i is identical along the cross-sections. The type of Fischer test using ADF is proposed by Maddala and Wu (1999).

Assuming that a common “a” is too restrictive, due to differences between the 108 regions of Europe, this article proposes the use of two tests.

The suggested test for the unit roots panel tests, results from the approaches undertaken by FISCHER (1932), in which tests are derived by combining the values of π from individual unit roots tests; this idea was proposed by Maddala and Wu and by Choi. If we define π_i, as the value of π of any individual unit root test for the cross section i then, under the null hypothesis of unit root for all cross sections, we have the following asymptotic result:

$$-2\sum_{i=1}^{N}\log(\pi_i) \rightarrow \chi^2_{2N}$$

The Fischer test has an advantage in relation to the IPS test, which results in the fact that it does not require a balanced sample[11], besides allowing for the use of different lag lengths in individual ADF regressions and the fact that it can be applied to any other unit roots test. Additionally, Choi shows that:

$$Z = \frac{1}{\sqrt{N}}\sum_{i=1}^{N}\phi^{-1}(\pi_i) \rightarrow N(0,1)$$

where Φ^{-1} is the inverse of the standard function of cumulative distribution. This test has more general assumptions than other unit root tests. According to CHOI (2001, pp. 249) "First, the number of groups in the panel data is supposed to be finite or infinite. Second, each group is supposed to have different types of stochastic and non stochastic components. Third, the time series covered by the groups are supposedly all different. Fourth, the alternative in which some groups possess a unit root and others not, can be treated with this test". BALTAGI (2005, pp. 245) suggests that "all tests become more incisive as n increases. The Fischer test has a greater adjustment than the IPS test. Above all, the PP Fischer test apparently overcomes the performance of other tests, and so is the recommended one".

[11] Blatagi (2005, pp244)

Since the first test is especially suitable for samples of T=10, we decided to use it in our study, despite the fact that the test based on the approach of Fischer presented more robust results in the case of different time series for the whole group.

TABLE Nº 3 –UNIT ROOTS PANEL TEST

	ADF-Fisher	**PP-Fisher**
Dependent Variable		
$Log(VAL_{it})$	Statistic: 527,7 Prob: 0%	Statistic: 717,27 Prob: 0%
Independent Variables		
$Log(RDL_{it})$	Statistic: 263,2 Prob: 0%	Statistic:344,06 Prob: 0%
$Log(FCL_{it})$	Statistic: 384,5 Prob: 0%	Statistic:503,6 Prob: 0%
LSR_{it}	Statistic: 373,18 Prob: 0%	Statistic: 512,07 Prob: 0%
Exogenous variables: Individual effects, individual linear trends [12] Selection of maximum lags, AIC criterium Newey- West bandwidth selection using Barlett kernel [13]		

What IM, PESARAN & SHIN (2003, pp. 71) suggest is that the test result should be interpreted with caution, and that the rejection of the null hypothesis does not definitely point to the definition of the magnitude of α_i, or to the identification of the private members of the panel, for which the null hypothesis is rejected. Here we accept

[12] Im, Pesaran, Shin (2003) suggest that the specification of the test distributed as standard function $N \rightarrow \infty$ for fixed T, since T> 6 in the case of regressions with cross and linear trends.

[13] We use another method of selection, such as Schwartz and other spectral estimations, with results similar to those in Table nº3. We performed the test with and without trend, with a similar result.

the null hypothesis, considering T=7 (around T=10), which can substantially increase the accuracy of the unit roots test, applied to a single time series[14].

All the results indicate the stationarity of the variables; we can thus proceed with the panel estimation.

THE ECONOMETRIC MODEL

In this point we estimate a log-linear econometric model, in which labour productivity in European regions is explained from the following variables: expenditure on innovation per employee, physical capital per worker and ratio of workers employed in the tertiary sector over the total employment of each region.

For the estimation, we have used an unbalanced pool equation due to the lack of data in some regions. An important advantage of the panel data, compared with the cross section data, is that they allow for the identification of certain parameters without the need to make restrictive assumptions; it is thus possible, for example, to analyse the changes at the individual level. Our cross section econometric model and time series data is a log-linear model of panel data. The general pool equation is

$$y_{it} = x'_{it}\beta + \varepsilon_{it} \qquad i = 1, \ldots, N \text{ regions} \quad ; \quad t = 1, \ldots, T_i \text{ years}$$

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

[14] Breitung & Hadri results in almost all the cases analysed present the acceptance of the null hypothesis, which indicates the strength of the obtained results.

exception of the term of interception. Thus, in our case[15], 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.

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 2004.

In order to choose an estimation method, a key point is to determine whether the unobserved individual effect is uncorrelated with the observed explanatory variables. The term "fixed effect" provides an arbitrary correlation between the unobserved individual effect and the observed explanatory variables; in this sense α_i is designated an "individual fixed effect", and the estimated model will be a fixed effect model. The fixed effect model explains how far y_{it} differs from $\bar{y}_i$, but does not explain, however, why $\bar{y}_i$ is different from $\bar{y}_j$.

An alternative approach maintains that the unobserved variables are independent of the explanatory variables, which leads to the random effect model, where α_i is treated as random. We can obtain consistent estimators, conducting a regression with an equation for all regions, with equal explanatory variable coefficients for all regions. In this case, it is hardly credible that this assumption may occur, since we are working with economic units which are structurally different.

The common coefficients cannot be accepted; in fact, on conducting the F test of common parametric stability, the model shows a lack of stability. We have taken into

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

account the individual effects using estimations of Fixed (FE) and Random Effects (RE), through the Eviews software (version 6). The estimation FE using ordinary least squares, as well as the use of a redundancy test of fixed effects, leads to the rejection of the null hypothesis of redundant coefficients Cross-section F: 81.76, Cross-Section/Period F: 90.06

In order to select individual fixed or random effects, we have used the Hausman test [16], which is based on the differences between the estimators of the random effect model (RE) and the fixed effect model (FE). The null hypothesis is that regressors and individual effects are uncorrelated; through the estimated value to the Chi-square (348.58), 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.

$Log(VAL)_{it} = 7.8 + 0.06\ log(RDL)_{it} + 0,16\ log(FC)_{it} + 1,08\ LSR_{it}$

t-Statistic (61,2) (7,43) (17.8) (8,5)

$R^2 = 0,99$

N= 174, T=10, Unbalanced observations: 1011

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 fixed effect coefficients indicate the differences in relation to the average (its value is represented in the Annex).

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 nº4 shows the results of the estimated coefficients in two regressions: one with the above average regions (in terms of productivity) and the other with the below average regions. 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.

[16] See Woolddridge (2002) for details

TABLE Nº 4 – DIFFERENCES IN THE PRODUCTIVITY EQUATION RESULTS IN THE MOST AND LEAST PRODUCTIVE EUROPEAN REGIONS

Independent Variable: Log(VAL)

Sample: 1995-2004 (10 obs.)

Total panel (unbalanced) observations: 374[(1)] e 637 [(2)]

Cross-section	*Estimation Method*	*Constant*	*Log(FCL)*	*Log(RDL)*	*SLR*	R^2
(1) **Above average Regions (61)**	Pooled EOLS	6,16 (25,59)	0,31 (11,15)	0.07 (4,54)	1,07 (5,64)	0.99
(2) **Below average Regions (113)**	Pooled EOLS	9,04 (57,73)	0.10 (14,29)	0.03 (4,33)	0,78 (4,62)	0.96

t-statistic in parentheses. All coefficients are significant at 1%.

We can denote that the Fixed Capital coefficient is higher in the least productive regions[17], 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 importation 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 added value generated by investments made.

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

[17] Regions of below average productivity = "poor" regions

the effect is more reduced in the poorest regions in relation to the richest. This may be due to the higher concentration of workers with higher levels of qualification in the most productive regions.

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 in each region that explain changes in labour productivity, which are reflected in the fixed effect coefficients.

Secondly, the results of our regressions indicate that the activities of innovation, measured by the expenditure in R&D, are positively related to labour productivity in European regions. Likewise, we believe that this positive influence has an exponential effect in long term labour productivity, since the return of the investments is not immediate, and takes 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 bottom of the productivity ranking. The less skilled human resources and structural deficiencies of the regions of southern Europe have produced a negative effect in attracting foreign investment to activities of higher added value.

Fifthly, the average productivity growth rate is higher in the most productive regions, especially in the 2000-2004 period, allowing for a convergence trend. This may be a sign that the least productive regions are creating lower gross added value jobs than the most productive NUTS II, which means that these jobs do not include a great level of innovation, at least when compared with the jobs created in the most developed NUTS II.

Finally, the development process depends on the innovation process. If investments in technology are great, 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 level of productivity.

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APPENDIX. European NUTS II Regions:

1	*be1 Région de Bruxelles-Capitale/Brussels Hoofdstedelijk Gewest*	39	*es21 Pais Vasco*	77	*fr9 French overseas departments (FR)*
2	*be2 Vlaams Gewest*	40	***es22 Comunidad Foral de Navarra***	78	*ie Ireland*
3	*be3 Région Wallonne*	41	***es23 La Rioja***	79	*itc1 Piemonte*
4	***bg31 Severozapaden***	42	***es24 Aragón***	80	*itc2 Valle d'Aosta/Vallée d'Aoste*
5	***bg32 Severen tsentralen***	43	*es3 Comunidad de Madrid*	81	*itc3 Liguria*
6	***bg33 Severoiztochen***	44	***es41 Castilla y León***	82	*itc4 Lombardia*
7	***bg34 Yugoiztochen***	45	***es42 Castilla-la Mancha***	83	*itd1 Provincia Autonoma Bolzano-Bozen*
8	***bg41 Yugozapaden***	46	***es43 Extremadura***	84	*itd2 Provincia Autonoma Trento*
9	***bg42 Yuzhen tsentralen***	47	***es51 Cataluña***	85	*itd3 Veneto*
10	***cz01 Praha***	48	***es52 Comunidad Valenciana***	86	*itd4 Friuli-Venezia Giulia*
11	***cz02 Strední Cechy***	49	***es53 Illes Balears***	87	*itd5 Emilia-Romagna*
12	***cz03 Jihozápad***	50	***es61 Andalucia***	88	*ite1 Toscana*
13	***cz04 Severozápad***	51	***es62 Región de Murcia***	89	*ite2 Umbria*
14	***cz05 Severovýchod***	52	***es63 Ciudad Autónoma de Ceuta (ES)***	90	*ite3 Marche*
15	***cz06 Jihovýchod***	53	***es64 Ciudad Autónoma de Melilla (ES)***	91	*ite4 Lazio*
16	***cz07 Strední Morava***	54	***es7 Canarias (ES)***	92	*itf1 Abruzzo*
17	***cz08 Moravskoslezsko***	55	*fr1 Île de France*	93	*itf2 Molise*
18	*de Germany (including ex-GDR from 1991)*	56	*fr21 Champagne-Ardenne*	94	*itf3 Campania*
19	*de1 Baden-Württemberg*	57	*fr22 Picardie*	95	*itf4 Puglia*
20	*de2 Bayern*	58	*fr23 Haute-Normandie*	96	*itf5 Basilicata*
21	*de3 Berlin*	59	*fr24 Centre*	97	*itf6 Calabria*
22	*de4 Brandenburg*	60	*fr25 Basse-Normandie*	98	*itg1 Sicilia*
23	*de5 Bremen*	61	*fr26 Bourgogne*	99	*itg2 Sardegna*
24	*de6 Hamburg*	62	*fr3 Nord - Pas-de-Calais*	100	***cy Cyprus***
25	*de7 Hessen*	63	*fr41 Lorraine*	101	***lv Latvia***
26	***de8 Mecklenburg-Vorpommern***	64	*fr42 Alsace*	102	***lt Lithuania***
27	*de9 Niedersachsen*	65	*fr43 Franche-Comté*	103	*lu Luxembourg (Grand-Duché)*
28	*dea Nordrhein-Westfalen*	66	*fr51 Pays de la Loire*	104	***hu10 Közép-Magyarország***
29	*deb Rheinland-Pfalz*	67	*fr52 Bretagne*	105	***hu21 Közép-Dunántúl***
30	*dec Saarland*	68	*fr53 Poitou-Charentes*	106	***hu22 Nyugat-Dunántúl***
31	***ded Sachsen***	69	*fr61 Aquitaine*	107	***hu23 Dél-Dunántúl***
32	*dee Sachsen-Anhalt*	70	*fr62 Midi-Pyrénées*	108	***hu31 Észak-Magyarország***
33	*def Schleswig-Holstein*	71	*fr63 Limousin*	109	***hu32 Észak-Alföld***
34	***deg Thüringen***	72	*fr71 Rhône-Alpes*	110	***hu33 Dél-Alföld***
35	***ee Estonia***	73	*fr72 Auvergne*	111	***mt Malta***
36	***es11 Galicia***	74	*fr81 Languedoc-Roussillon*	112	*nl11 Groningen*
37	***es12 Principado de Asturias***	75	*fr82 Provence-Alpes-Côte d'Azur*	113	*nl12 Friesland (NL)*
38	***es13 Cantabria***	76	*fr83 Corse*	114	*nl13 Drenthe*

Regions under the mean (in productivity terms) in bold.

APPENDIX. European NUTS II Regions:

115	*nl21 Overijssel*	153	***pt18 Alentejo***	191	*no06 Trøndelag*
116	*nl22 Gelderland*	154	***pt2 Região Autónoma dos Açores (PT)***	192	*no07 Nord-Norge*
117	*nl23 Flevoland*	155	***pt3 Região Autónoma da Madeira (PT)***		
118	*nl31 Utrecht*	156	***si Slovenia***		
119	*nl32 Noord-Holland*	157	***sk01 Bratislavský kraj***		
120	*nl33 Zuid-Holland*	158	***sk02 Západné Slovensko***		
121	*nl34 Zeeland*	159	***sk03 Stredné Slovensko***		
122	*nl41 Noord-Brabant*	160	***sk04 Východné Slovensko***		
123	*nl42 Limburg (NL)*	161	*fi13 Itä-Suomi*		
124	***at11 Burgenland (A)***	162	*fi18 Etelä-Suomi*		
125	*at12 Niederösterreich*	163	*fi19 Länsi-Suomi*		
126	*at13 Wien*	164	*fi1a Pohjois-Suomi*		
127	*at21 Kärnten*	165	*fi2 Åland*		
128	*at22 Steiermark*	166	*se11 Stockholm*		
129	*at31 Oberösterreich*	167	*se12 Östra Mellansverige*		
130	*at32 Salzburg*	168	*se21 Småland med öarna*		
131	*at33 Tirol*	169	*se22 Sydsverige*		
132	*at34 Vorarlberg*	170	*se23 Västsverige*		
133	***pl11 Lódzkie***	171	*se31 Norra Mellansverige*		
134	***pl12 Mazowieckie***	172	*se32 Mellersta Norrland*		
135	***pl21 Malopolskie***	173	*se33 Övre Norrland*		
136	***pl22 Slaskie***	174	*ukc North East*		
137	***pl31 Lubelskie***	175	*ukd North West*		
138	***pl32 Podkarpackie***	176	*uke Yorkshire and The Humber*		
139	***pl33 Swietokrzyskie***	177	*ukf East Midlands*		
140	***pl34 Podlaskie***	178	*ukg West Midlands*		
141	***pl41 Wielkopolskie***	179	*ukh Eastern*		
142	***pl42 Zachodniopomorskie***	180	*uki London*		
143	***pl43 Lubuskie***	181	*ukj South East*		
144	***pl51 Dolnoslaskie***	182	*ukk South West*		
145	***pl52 Opolskie***	183	*ukl Wales*		
146	***pl61 Kujawsko-Pomorskie***	184	*ukm Scotland*		
147	***pl62 Warminsko-Mazurskie***	185	*ukn Northern Ireland*		
148	***pl63 Pomorskie***	186	*no01 Oslo og Akershus*		
149	***pt11 Norte***	187	*no02 Hedmark og Oppland*		
150	***pt15 Algarve***	188	*no03 Sør-Østlandet*		
151	***pt16 Centro (PT)***	189	*no04 Agder og Rogaland*		
152	***pt17 Lisboa***	190	*no05 Vestlandet*		

Regions under the mean (in productivity terms) in bold.