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IS EUROPE BECOMING A KNOWLEDGE-DRIVEN ECONOMY? EVIDENCE FROM EU DEVELOPED REGIONS

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IS EUROPE BECOMING A KNOWLEDGE-DRIVEN ECONOMY? EVIDENCE FROM EU DEVELOPED REGIONS

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Abstract

In this paper, a set of knowledge base indicators are used as explanatory variables of the 1995-2002 growth performances of 150 NUTSII regions belonging to ten countries of the former EU15. Their impact is estimated by controlling for the initial levels of the dependent variables, the structural features of the regions and the presence of spatial correlation. The results show that GDP per capita growth is positively affected by the intensity of R&D and the share of adults with tertiary education. The R&D intensity is particularly effective in explaining the growth of labour productivity while that of occupation ratio is significantly influenced by the intensity of higher education. Thus, although structural characteristics and starting levels of economic performances have differently shaped the rates of economic growth across regions, our findings strongly support the Lisbon strategy as they indicate that, also within the EU, a sustained investment in R&D, knowledge and education is rewarding.

Keywords: Regional economic growth. Knowledge, innovation and education endowments.

JEL codes: O18, O33, R11.

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1. Introduction

The weak European knowledge base has been recognised as one of the main causes of the recent “Atlantic divide” in terms of economic growth. Such a recognition is at the roots of the Lisbon strategy aimed at transforming Europe in “the most competitive and dynamic knowledge-based economy in world”. In order to assess whether this strategy will be able to produce the expected outcomes, an inspection to the performances of the European regions could be useful. Indeed, many studies have highlighted that the overall weakness of the EU is coupled by strong regional differences in the endowment of innovation and knowledge capabilities so that to test whether these differences are significantly related to the recent regional patterns of economic growth is a relevant issue.

For this purpose, we analyse, for the period 1995-2002, the changes of per capita GDP, labour productivity and occupation ratio across 150 NUTSII developed regions of the EU (with a level of GDP per capita equal or above 75% of the EU25 average).

As explanatory variables we employ the initial level of each dependent variable and a set of innovation and knowledge indicators: the intensities of R&D, EPO applications, the employment shares in high-tech manufacturing and services and the percentage of adults with tertiary education. As controls for structural characteristics, we use the population density and the shares of employment in total manufacturing and business services. To control for country effects both independent and dependent variables are expressed as deviations from national means. Along with the usual diagnostics for OLS estimates, in order to detect the presence of interdependence in regional growth we perform two Lagrange multiplier tests for spatial error dependence and spatial lags by using, for the 150 regions considered, a binary contiguity matrix. According to the above tests, OLS estimates are robust to spatial correlation.

Our results show that the change of GDP per capita is negatively influenced by the initial level of the same variable but it is positively affected by population density and, above all, by the intensity of R&D and the share of adults with tertiary education. With respect to the growth of labour productivity and occupation ratio, both variables are negatively associated with their initial levels but the former is significantly and positively affected by the intensity of R&D and the share of manufacturing employment while the change in the occupation ratio is positively influenced by the density population and the intensity of higher education. Thus, although the structural features of the EU regions have differently shaped their recent pace of economic growth (more or less based on productivity or employment), our findings strongly support the Lisbon strategy, i.e. that a sustained investment in R&D, knowledge and education is a crucial condition for a growing Europe.

The paper is organised as follows. Section 2 reviews the main theoretical and empirical backgrounds of the present study. Section 3 analyses the recent growth rates of per capita GDP in the whole EU, also decomposed into those of labour productivity and occupation, and then examines the same variables for the 150 EU regions considered in the subsequent sections. Section 4 describes the knowledge base indicators to be used as explanatory variables of regional economic growth while section 5 presents the results of regression analyses. Section 6 contains some concluding remarks.

2. Technology, human capital and regional growth in Europe

The Lisbon strategy launched in 2000 can be rooted on two main arguments. The first relies on the slow rate of economic growth recorded during the last decade by EU countries (especially in the second half of the 1990s) as opposed to the US revival of productivity growth (see the next section). The second is that the “Atlantic divide” in terms of economic growth depends on the “wrong” attitude of European economies with respect to knowledge generation and markets’ regulation. Leaving aside the issues of regulatory reforms, with respect to the crucial role of innovation and knowledge there is a broad consensus among economists.

In contrast with the standard neoclassical framework, endogenous growth models contend that long-run economic growth is influenced, rather than by exogenous changes in technology and population, by the intentional accumulation of knowledge or R&D (Romer, 1990), human capital (Lucas, 1988) as well as the effective introduction of innovations (Aghion and Howitt, 1998); all these activities are themselves determined by economic growth, giving rise to a process of cumulative causation.

Albeit starting from quite different premises, neo-schumpeterian (or evolutionary) economists share many explanations based on endogenous growth theories: however, according to the “technology-gap theory” of economic growth (Fagerberg, 1987 and 1994; Verspagen, 1991), they argue that the successful introduction and assimilation of new technologies requires a broad range of enabling conditions (see also Abramovitz, 1986). Without a consistent socio-institutional setting, the efforts needed to introduce and absorb innovation might be suboptimal, so that there are no deterministic mechanisms which ensures that, even in the long run, lagging economies will converge to the leaders.

A large body of empirical evidence across countries support the above arguments (European Commission, 2003 and 2005; Canton et al., 2005). In terms of economic growth, the returns from R&D and education are substantial and provide permanent rather than transitory advantages to the most knowledge-based economies.

All the above insights and evidences feed the current debate on the EU economic prospects. The Sapir report, for instance, contends that the catching up with the US, mainly based on imitation and accumulation of physical capital, was exhausted when the European countries moved closer to the technological frontier. In the new phase, also shaped by the ICT revolution, "innovation at the frontier has become the main engine of growth" (Sapir at al., 2003, p. 29) and this justifies the need of extra-ordinary investment in R&D and education.

To reinforce this line of argument, it can be stressed that, since the new technologies become more and more complex and knowledge-intensive, it is difficult to exploit them effectively without an adequate knowledge base. A high stock of human capital increases the capability to assimilate new technologies and this effect, originally stressed by Nelson and Phelps (1966), is greater the more an economy is close to the technological frontier. Similarly, R&D activities are necessary not only to introduce innovation at the frontier but also to remain close to it, by maintaining an adequate absorption capacity (Cohen and Levinthal,1988).

Although the above arguments were mainly aimed at explaining why growth rates differ across countries, they have been at the basis of many recent studies on regional growth differentials. The increasing attention to the regional dimension of economic growth is due, among other reasons, to the fact that, even when developed nations converge, the differences within them appear persistent and there is a tendency to find, in each country, spatial clusters of high and slow-growth regions. In spite of the increasing economic integration, this seems the case of Europe during the last two decades (Fagerberg and Verspagen, 1996; Giannetti, 2002; Sapir et al., 2003; Gardiner et al., 2004).

To explain these enduring growth differentials among regions, strong points of agreement arise between the endogenous growth theory and the new economic geography. For instance, by combining a core-perifery model à la Krugman with endogenous growth à la Romer, Fujita and Thisse (2002) conclude that economic growth and agglomeration economies are mutual self-reinforcing phenomena predicting an increasing regional specialisation and concentration of economic activities and, then, no necessary convergence.

In spite of the recognition of the key role played by innovation and, due to the lack of spatially disaggregated data, a few studies have used technology and human capital variables as determinants of the growth differentials among EU regions.

Cappellen et al. (1999) show that, for 106 European regions, the initial share of R&D personnel on total employment is positively associated to the changes of per capita GDP over the period 1980-94 (a result confirmed by Cappellen et at. 2003 for a more recent period). However, when the authors split the sample into two regional groups with high and low R&D intensity, only within the former group the innovation variable maintains a positive and significant coefficient. Being the measure of R&D intensity strongly correlated with the initial level of per capita GDP, the authors conclude that a high propensity to innovation is beneficial only for the regions that are above a certain threshold of development.

Giannetti (2002) argues that international knowledge spillovers benefit in particular the regions more specialised in high-tech sectors and this could explain why, in Europe, a process of cross-country convergence has not reduced regional growth disparities.

In this connection, Mora et al. (2005) consider a set of 108 EU regions and, in a cross-sectional convergence regression for the period 1985-2000, employ as a conditional variable the initial index of specialisation in transport, communication, credit and insurance, regarded as “services with highest levels of technological intensity” (ibid., p. 183). The latter variable affects positively and significantly the change of per capita GDP while the effect of the initial GDP level is negative. Moreover, by splitting the sample into two regional groups according to the initial level of specialisation in low-tech industries, it emerges that conditional convergence did not occur in low-tech regions and the latter obtained lower benefits from the specialisation in high-tech services.

Badinger and Tondl (2003) consider 128 European regions and use both innovation and human capital indicators as explanatory variables of the average growth rate of per capita Gross Valued Added over the period 1993-2000. Using a production function framework to test the “technology-gap” approach (see above), they show that the initial share of adults with tertiary education affects positively and significantly regional growth and the same occurs to the intensity of patent application per employee[1]. Moreover, the catching up process is faster for the regions with greater shares of high educated people.

[1] Paci and Pigliaru (2002) employ a similar indicator (number of patents on GDP) which is found to affect positively the labour productivity growth of 131 European regions over the period 1978-97.

3. The growth components and their regional declination in the EU

GDP per capita is the basic and broad indicator of the economic performance of a geographic area and can be broken down into two main components:

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$$\frac{GDP}{Population} = \frac{GDP}{Employment} * \frac{Employment}{Population} \quad [1]$$

The long rate of growth of per capita GDP from time t_0 to t_n can be expressed in log differences and, then, decomposed as follows

$$\Delta LnPCGDPt_n\text{-}t_0 = \Delta LnLAPt_n\text{-}t_0 + \Delta LnOCCRt_n\text{-}t_0 \quad [2]$$

where *PCGDP* stands for per capita GDP, *LAP* is labour productivity and *OCCR* denotes the occupation (or participation) ratio.

Table 1 – Decomposition of the long growth rates of GDP per capita at constant (1995) prices(*)

	$\Delta LnPCGDP$	$\Delta LnLAP$	$\Delta LnOCCR$
EU-15 1990-95	0.057 (1.15% p.a.)	0.095 (1.89% p.a.)	-0.037 (-0.75% p.a.)
EU-15 1995-2002	0.146 (2.09% p.a.)	0.078 (1.12% p.a.)	0.068 (0.97% p.a.)
EU developed regions 1995-2002			
Mean(°)	0.140 (1.98% p.a.)	0.069 (0.94% p.a.)	0.071 (1.04% p.a.)
Standard deviation	0.055	0.043	0.046
Between country dispersion (%)	41.5	34.6	41.0
Within country dispersion (%)	58.5	65.4	59.0

(*) = average growth rate per annum in brackets; (°) = un-weighted means; the weighted means give rise to almost identical results (ΔLnPCGDP =0.139; ΔLnLAP = 0.066; ΔLnOCCR = 0.073).
Sources: for the EU-15, own computations from the Groningen Growth and Development Centre Total Economy Database (February 2005); for the EU developed regions, own computations from Eurostat regional statistics.

The top part of table 1 reports, for the whole EU15, the results of the above decomposition for the periods 1990-95 and 1995-2002 (the basic data are taken from the Groningen Growth and Development Centre Total Economy Data Base). During the first period the rate of change of per capita GDP was modest (+1.15% per year) and this was due to a relatively good performance of labour productivity (+1.89%) coupled, however, with a decreasing occupation ratio (-0.75%). The picture significantly changed in the subsequent period when the growth of per capita GDP almost doubled (+2.1% per annum) thanks, above all, to a resurgence of the occupation ratio; the labour productivity growth, in fact, was positive but lower than that recorded in the previous period. Thus, during the second half of the 1990s and the early 2000s, the EU countries recovered a good capability of generating jobs and this accelerated the growth of GDP per capita; at the same time, however, there was a deceleration of productivity growth, quite harmful if compared with the performances of the US[2].

The bottom part of the table presents the data concerned with 150 NUTSII regions of the EU considered in our study; how they have been selected and how their GDP at 1995 prices has been computed will be described later. For now it is important to stress the following features.

First, the performances of these regions over the period 1995-2005 are similar to those of the whole EU15, although the growth rates of per capita GDP and labour productivity are slightly lower while that of the occupation ratio higher.

Second, the changes in PCGDP, LAP and OCCR are greatly differentiated among regions; for the last two variables the standard deviation amounts to more than 60% of the mean while for the first one to more than 39% (this relatively lower dispersion is due to the negative correlation between the growth rates of labour productivity and occupation ratio).

Finally, there is a remarkable variety of growth performances within national borders; in effect, the greatest share of the total regional dispersion is attributable to "within country" effects which, according to a standard decomposition of variance, can be distinguished from those "between country": for the 150 regions considered, the former account for about 59% of the total dispersion of the changes in per capita GDP and occupation ratio and 65% of that concerned with labour productivity.

With respect to the GDP per capita expressed at constant (1995) prices, we have computed such a measure for each of the 150 regions considered according to the sectoral composition of their economies. For this purpose, we first take the 6 macro branches of the NACE classification[3] for which national data on Gross Value Added at constant prices are available; then, after allocating the GDP-GVA difference pro-rata among the branches, each national branch is broken down by NUTSII regions using as weights the regional shares of GVA at

[2] Using the same data base, it emerges that, during the period 1995-2002, the US per capita GDP increased at a rate of 2.14% per year, almost identical to that of the EU; however, this was due to a 2.03% growth of labour productivity and a 0.11% growth of the occupation ratio.

[3] NACE A+B = Agriculture, hunting and forestry, fishing; C+D+E = Mining and quarrying, manufacturing, electricity, gas and water supply; F = Construction; G+H+I = Wholesale and retail trade, hotels and restaurants, transport, storage and communications; J+K = Financial intermediation, real estate, renting and business

current prices; finally, the resulting regional values at constant price for each branch are summed-up. To obtain the measure of labour productivity, the regional GDP at 1995 prices is divided by the number of employees coming from Eurostat Regional Accounts.

The 150 NUTSII regions selected are labelled "developed" because they have recorded in the early 2000s a level of per capita GDP (in Purchasing Power Standards) equal to or above 75% of the EU25 average. As a consequence, according to the new regulation of the EU regional policy proposed by the EC for the period 2007-13 (European Commission, 2004a), they will be eligible to the new "regional competitiveness and employment objective" while the remaining low-income regions to the "convergence objective" (which will be in place of the current "Objective 1").

Since our focus is on regional (within country) differences, the European countries containing only one or two NUTSII regions of the first type are not taken into account. The five excluded countries of the former EU15 are Denmark (1 region corresponding to the whole country), Greece (2 regions), Ireland (2), Luxembourg (1) and Portugal (2). Obviously, also the four New Member States containing only one region eligible to the new competitiveness objective (Czech Republic, Cyprus, Hungary and Slovakia) are neglected. After having excluded other five outliers[4], we remained with 150 NUTSII regions belonging to ten countries of the former EU15; map 1 illustrates their geographical location in the EU15 space while the complete list of them is provided in appendix A.1.

In spite of the above restrictions, the set of developed regions under consideration is still characterised by remarkable differences in GDP, labour productivity and occupation, both with respect to growth rates - as previously stressed in commenting table 1 - and in terms of levels. The latter assertion is supported by Gardiner et al. (2004) who compare the 2001 performances of 158 NUTSII regions with a per capita GDP equal or greater than 75% of the EU average: the group of the most developed regions records, on average, a GDP per head 39% higher than that of the mid-developed regions, a 17% higher level of labour productivity, and a 15% higher employment ratio.

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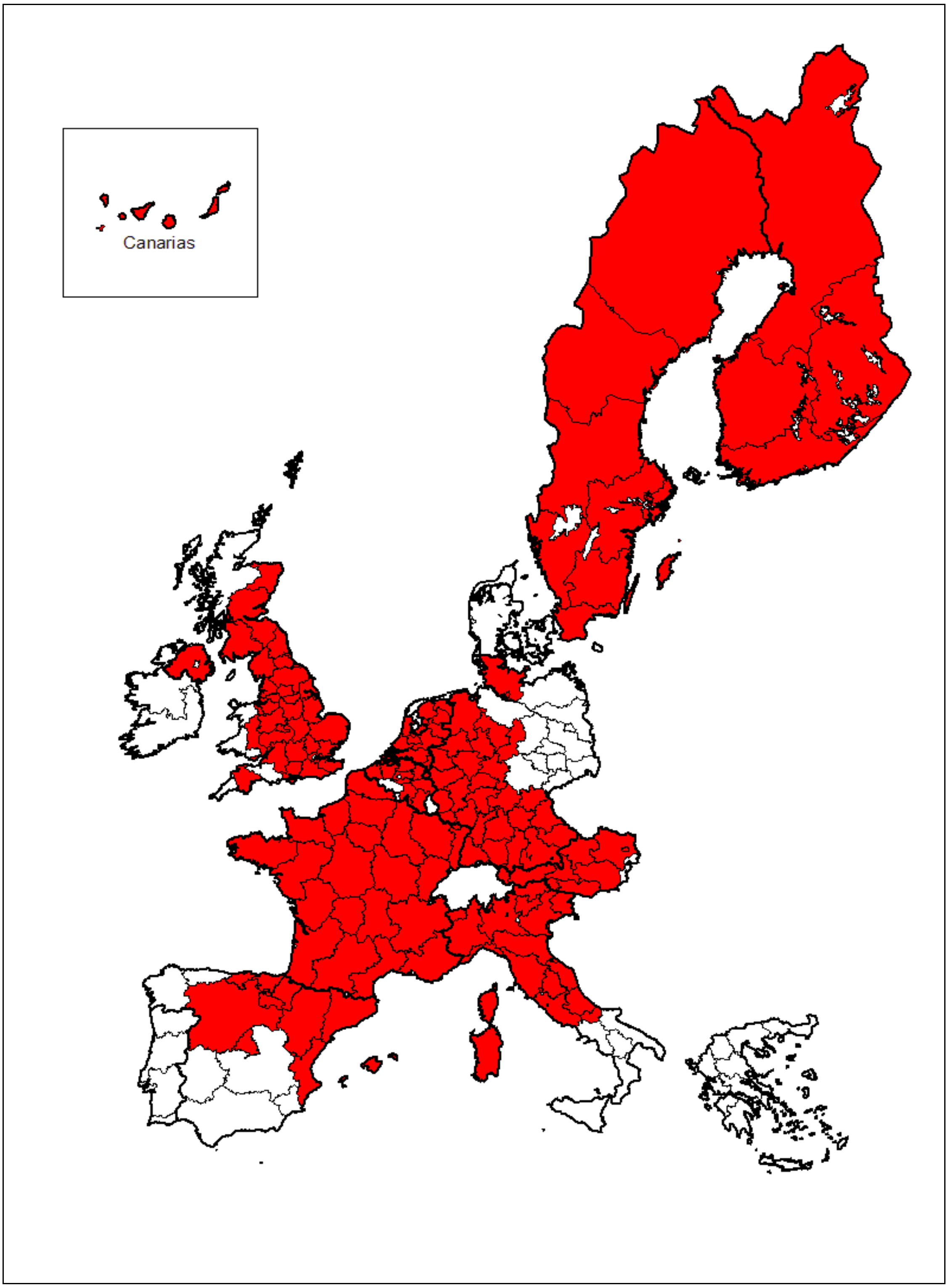
activities; L to P = Other services (public administration and defence, compulsory social security, education, health and social work, other community, social and personal service activities, private households).

[4] The excluded NUTSII regions are the following. Bruxelles and Inner London (coinciding with two of the biggest European capital cities) which record a per capita GDP more than double as compared to the average of EU developed regions. Berlin (the only region of the former East Germany included in the competitiveness objective) having a GDP per capita 20% below the reference average coupled with a decrease of real GDP over the period 1995-2002. Aland in Finland, a small island of 26 thousands inhabitants recording a GDP per capita 50% above the average. Finally, the region of Dorset and Somerset in the UK which, thanks to a marked decrease of employees, has been characterised by an exceptional growth of labour productivity during 1995-2002 (six times higher than the average).

Map 1 – EU15 developed regions considered in the present study



4. The knowledge base indicators for EU developed regions

The 150 developed regions considered in this study form a broad geographical area of the EU in which the growth enhancing policies of the Lisbon strategy should be particularly effective: the reason is that within this spatial aggregate a sufficient knowledge base already exists so that, in contrast with the low income regions of the EU (cf. section 2), it is likely that the returns from investment in innovation, knowledge and education are already substantial and could increase further if sustained by adequate policy measures.

For the purposes of our study we collected five indicators of the regional innovation and knowledge base which are included in the *European Innovation Scoreboard* (European Commission, 2004b). All of them are taken from the regional statistics provided by Eurostat (see Appendix A.2 for details). Since our aim is to use these measures as explanatory variables of the regional growth performance over the period 1995-2002, the following indicators refer, with only one exception, to the initial year:

1) share of total (private and public) R&D expenditures on GVA (Gross Value Added);
2) log of patent applications to the European Patent Office (EPO) per million inhabitants;
3) share of employment in high-tech manufacturing (Office machinery, Radio & telecommunications equipment, Scientific instruments, Aerospace):
4) share of employment in high-tech (or knowledge-intensive) services (Post & communications, Computer, Software and R&D services)
5) share of adult population (aged from 25 to 65) who attained a tertiary level of education; this variable is available for EU NUTSII regions only since 1999.

The first two indicators denote the traditional inputs (or intermediate outputs in the case of patents) of the innovation process; the third and four variables measure the high-tech specialisation of the region and the distinction between manufacturing and services is particularly useful when the most recent years, shaped by the ICT revolution, are taken into account; the fifth indicator is a proxy for the highest level of human capital available in the region.

According to the survey provided in section 2, not all the above indicators have been extensively used in the empirical literature (and, to our knowledge, there are no attempts to considered all of them together). Many studies, focussing on innovation only, have examined the regional distribution of patents and R&D expenditures and how the two measures are spatially correlated. Acs et al. (2002) and Bottazzi and Peri (2003) have linked R&D to patent activities across, respectively, US metropolitan areas and EU regions. They find a pateny/R&D elasticity close to unity also after controlling for spatial spillovers which are found remarkable but strongly localised. Similar findings are attained by Moreno et al. (2005) who analyse EPO applications across 175 European regions and over the period 1981-2001. First, they find that patent applications have been strongly concentrated in Northern and Central European countries. Secondly, patenting activities are correlated with the R&D performed in contiguous areas but this occurs mainly between regions within a country so that innovation or knowledge spillovers appear significantly constrained by national borders[5].

Although we focus on the most developed regions of the EU15, our data confirm the strong geographical concentration of EPO applications and, albeit to a lower extent, R&D activities[6]; moreover, equally strong country effects emerge, confirming the well known "technological" divide between northern (Germany, Sweden, Finland, Netherlands and UK) and southern countries (France, Austria, Italy and Spain) with Belgium playing an intermediate role. As a consequence, when focussing on EU regional differences in innovation it is important to control for country effects. The same need applies to a greater extent when one compares tertiary education attainments across EU regions. At the end of the 1990s there were still remarkable differences in the national systems of university education and this partly explains why the average share of adults with tertiary education in British, Dutch or Spanish regions is more than twice that recorded by the Italian ones and largely above that of the Austrian and French regions. Also the regional differences in terms of employment shares in high-tech manufacturing and services are remarkable, although they appear less strong than those concerned with patents, R&D and tertiary education. Nonetheless, even in this case, it is advisable to control for the different specialisation of the EU countries.

As a consequence, for all the above knowledge-base indicators we use regional data computed as deviations from the national un-weighted mean, where "national" here stands for the set of developed regions belonging to each country.

Table 2 shows that almost all the selected indicators are significantly correlated – though not to the same extent - across the 150 European regions under examination. The R&D intensity is particularly associated with the log of EPO applications per million inhabitants and the share of adults with tertiary education. While, according to the previously mentioned studies,

[5] This conclusion is shared by Maurseth and Verspagen (2002) who have examined, across 112 European regions, geographical spillovers of innovation or knowledge by using patent citations.

[6] Reminding that a 3 per cent share of R&D on GDP is one of the Lisbon target for 2010, it is worth to be noticed that, according to our data, such a target was already achieved in 1995 by 24 NUTSII regions which increased only to 29 in 2002.

the first high correlation coefficient was expected[7], the second one is more interesting since it suggests that the accumulation of knowledge (proxied by R&D expenditures) and the stock of high-level human capital are closely linked. Another interesting finding is that both R&D and tertiary education are highly associated either to patent intensity and the share of employment in high-tech services, while the correlation coefficients with the employment share in high-tech manufacturing are significant but lower (especially with respect to tertiary education).

Table 2 – Correlation matrix of knowledge base indicators across EU developed regions(*)

	R&D expenditures on GVA	Ln EPO applications per million inhabitants	Share of employment in high-tech manufacturing	Share of employment in high-tech services	Share of adults with tertiary education
R&D expenditures on GVA	1.000				
Ln EPO applications per million inhabitants	0.606**	1.000			
Share of employment in high-tech manufacturing	0.340**	0.387**	1.000		
Share of employment in high-tech services	0.494**	0.296**	0.149	1.000	
Share of adults with tertiary education	0.602**	0.535**	0.291**	0.500**	1.000

(*) = All the variables are computed as differences from the un-weighted mean of the developed regions of each country. All of them refer to 1995 with the exception of the share of population with tertiary education which refers to 1999. Source: Eurostat.
** Significant at 0.01 level (2-tails test).

The only variables displaying a non significant correlation are the employment shares in high-tech manufacturing and services and this indicates that the regional patterns of specialisation are somewhat differentiated: probably, a high presence of more advanced manufacturing activities requires a strong "industrial" knowledge base – as witnessed by the relatively high correlation with the intensity of EPO applications - while the geographical concentration of advanced services is fostered by other factors such as a strong tertiary orientation and a large market size which, in turn, depend on the urban nature and the population density of the

[7] Moreover, it could be partially due to the way in which R&D intensities are attributed to some NUTSII regions. In fact, when only R&D data at the level of NUTSI (UK) or NUTS0 (Belgium and Sweden) were available, the R&D intensities were imputed to NUTSII regions in line with the differences arising from the EPO applications per million inhabitants. This procedure was chosen after verifying that, across the EU NUTSII or NUTSI regions for which both R&D and patent data were available in 1995, the correlation coefficient was highly significant and equal to 0.6.

regions. The latter factors need to be taken into account also to establish whether the pivotal role played by the intensity of total R&D and, especially, the share of higher education is real or simply a by-product of the different regional features in terms of economic structure and population density.

The high regional correlation between the five knowledge base indicators may suggest that, instead of using a set of different measures, a composite or synthetic indicator could be applied. For this purpose we run a factor analysis to identify what components capture the maximum possible variance among the original variables. From such an analysis only one important factor emerges, where "important" means with an eigenvalue greater than one. Table 3 shows that this factor is quite informative since it accounts for 54.6 per cent of the total correlation among the basic indicators; moreover, it appears particularly correlated to the share of R&D on GVA and that of adults with tertiary education - hence, confirming the pivotal role of these two knowledge base indicators - followed by the intensity of patent applications and the employment share in high-tech services.

According to the above the results, to each of the 150 EU regions considered in this study a factor score can be attached and taken as a composite indicator of knowledge base.

Table 3 – Factor extracted from the knowledge base indicators(*)

Factor weight (eigenvalue)	2.732
Percentage of total correlation explained	54.638
Correlation with the original variables:	
R&D expenditures on GVA	0.852
Ln EPO applications per million inhabitants	0.783
Share of employment in high-tech manufacturing	0.537
Share of employment in high-tech services	0.659
Share of adults with tertiary education	0.818

(*)= Only one factor with a weight (eigenvalue) greater than one arises from the factor analysis.

5. Knowledge base and regional growth: regression results

This section addresses the crucial issue of our study, that is whether knowledge accumulation and endowments are effective in explaining the economic growth of the EU developed regions over the period 1995-2002. Along with other relevant control variables, the innovation and knowledge indicators described in the previous section will be then used as explanatory variables of growth performances. It is important to point out that our aim is not to provide estimates of the returns from innovation, knowledge or higher education investment; we rather intend to test whether the regions endowed with a higher knowledge base at the beginning of the period were able to grow faster during the subsequent years.

For the growth rate of per capita GDP, the basic specification of the equation to be estimated is the following:

$$\Delta LnPCGDP_i^{02\text{-}95} = \alpha\, LnPCGDP_i^{95} + \mathrm{b}'\boldsymbol{K}_i + \mathrm{g}'\boldsymbol{S}_i + \varepsilon_i \qquad [3]$$

The rate of change of *PCGDP* (at 1995 prices) over the period 1995-2002 is expressed as the long difference of natural logs and depends on its initial level (in logs), a vector ***K*** composed of five knowledge base indicators (respectively, the share of R&D on GVA, the log of EPO applications per million inhabitants, the employment shares of high-tech manufacturing and services and the share of adults with higher or tertiary education) and a vector ***S*** which include three "structural" indicators used as control variables: the log of population density and the employment shares in manufacturing and business services. An alternative specification shall include, instead of the five knowledge base variables, a composite indicator obtained by means of factor analysis (see the previous section).

Equation [3] is estimated by means of OLS. Being a cross-sectional regression, the usual problems of endogeneity and regional heterogeneity arise. Both issues should be properly addressed by implementing a panel analysis with instrumental variables. Unfortunately, the lack of annual data for many of the right-hand side variables prevented us from following this strategy. Nevertheless, the employment of explanatory variables referring to the initial year partly reduces the problem of reverse causality. Moreover, in our framework, the degree of innovation has to be interpreted as a persistent feature of a region showing little variation over the period 1995-2002[8]; in this respect, the time span considered in this study allows one to pick up the growth effect of innovation and knowledge endowments in the medium-run.

Since the growth of per capita GDP can be decomposed into that of labour productivity and occupation ratio (see section 3), two additional equations similar to [3] are subsequently estimated. To be reminded is that all the dependent and independent variables are expressed as deviations from national mean so that, without losing degrees of freedom, the estimated parameters are equivalent to those obtained by including country dummies. For each dependent variable, we first run an OLS regression with all the variables included in the right-hand side of equation [3]. However, since many of the estimated coefficients turned out to be not significant[9], all the tables included in this section shall present the results of the specifications including exclusively the variables whose parameters are statistically different from zero.

5.1 The growth of per capita GDP

Starting from the growth rate of per capita GDP, the first specification reported in table 4 shows that the intensities of R&D and higher education are both highly significant and, in spite of their correlation, exert separate positive impacts. Moreover, the above findings are robust to the inclusion of the population density whose positive coefficient suggests that urban or metropolitan regions were able to grow faster than the others.

By taking into account all the above growth enhancing factors, it emerges that the regions with a lower per capita GDP at the beginning of the period were able to catch up; the size of the estimated coefficient is quite small (-0.076) but this could be due both to the short time span considered and to the fact that we are dealing with regions already recording a relatively high level of per capita GDP.

The diagnostic tests reported in the bottom of the table indicate that this specification is not affected by problems of omitted variables and heteroskedasticity. Since the Jarque-Bera test

[8] This is the case of our innovation and knowledge indicators for which all the annual data for the period 1995-2002 are available. For instance, the log of EPO applications per million inhabitants in 1995 displays a 0.982 correlation coefficient with the same variable averaged over the period 1995-2002.

[9] In all the regressions we run, included those for the growth of labour productivity and occupation ratio, the intensity of EPO applications and the employment shares in high-tech manufacturing and services as well as that in total business services were never significant when we used the complete set of explanatory variables. They obviously were significant when the intensity of R&D and higher education and the log of population density were dropped out; in these cases, however, the goodness of fit of the whole regression was significantly lower and the presence of omitted variables was detected.

rejects the assumption of residuals' normality, we also perform the Koenker-Bassett statistics which confirms the absence of heteroskedasticity.

Table 4 – OLS regressions for the rate of change of per capita GDP 1995-2002

	Specification 1		Specification 2	
	Coefficient	Standard Err.	Coefficient	Standard Err.
Ln GDP per capita	-0.076**	0.025	-0.075**	0.028
R&D expenditures on GVA	1.093**	0.360		
Share of adults with tertiary education	0.353**	0.102		
Composite indicator of knowledge base			0.019**	0.004
Ln Population density	0.009**	0.004	0.011**	0.004
Adjusted R^2	0.253		0.185	
		P-value		P-value
Jarque-Bera test on residuals' normality	18.8**	0.00	12.8**	0.00
Reset test for omitted variables	1.13	0.34	2.39*	0.07
Koenker-Bassett test for heteroskedasticity	3.77	0.44	2.84	0.42
Breusch-Pagan test for heteroskedasticity	6.10	0.20	4.03	0.26
LM test for spatial error dependence	0.01	0.92	0.33	0.57
LM test for spatial lag	0.40	0.52	0.67	0.41

** = significant at a 5% level of confidence; * = significant at a 10% level of confidence.

By employing a second specification including the composite indicator of knowledge base there is a substantial fall in the overall explicative power of the regression, as witnessed by the decrease of R-squared; moreover, the null hypothesis of no omitted variables cannot be accepted at a 5% level of confidence, suggesting that some important sources of variance are neglected.

In order to verify whether the OLS estimates are affected by the presence of spatial correlation in regional economic performances, we employ two Lagrange Multiplier (LM) tests for spatial error and spatial lag dependence (Anselin, 1988) In fact, OLS estimators are inefficient in presence of spatially auto-correlated residuals and biased and inconsistent when there is spatial interdependence in the dependent variable. By exploiting OLS residuals, the two LM tests control for these potential miss-specifications. The latter do not affect our OLS estimates since, in all the regressions, both tests - performed by means of a row-normalised binary contiguity matrix for the 150 EU developed regions[10] - accept the null hypothesis of no spatial correlation.

However, the non normality of residuals may undermine the validity of LM tests. Hence, for a further check of the robustness of OLS results, we run Maximum Likelihood (ML) estimates of our best specification. As displayed by table 5, the resulting parameters of the spatial auto-correlation variables are not significantly different from zero either in a model with spatial errors or spatial lags[11]; moreover, the ML estimates are almost coincident with those arising from OLS.

Table 5 – Maximum likelihood estimates for the change of per capita GDP 1995-2002

	Spatial error model		Spatial lag model	
	Coefficient	Standard Error	Coefficient	Standard Error
Ln GDP per capita	-0.077**	0.025	-0.074**	0.025
R&D expenditures on GVA	1.094**	0.354	1.079**	0.355
Share of adults with tertiary education	0.354**	0.101	0.344**	0.101
Ln Population density	0.009**	0.004	0.009**	0.004
Lambda (spatial error)	-0.112	0.115		
Rho (spatial lag)			0.074	0.125
Log-likelihood	285.88		285.05	
Adjusted R^2	0.274		0.276	
		P-value		P-value
Wald test (lambda or rho = 0)	0.01	0.94	0.35	0.55
Likelihood ratio test (lambda or rho = 0)	0.01	0.94	0.35	0.55
Lagrange multiplier test (lambda or rho = 0)	0.01	0.92	0.41	0.52

** = significant at a 5% level of confidence; * = significant at a 10% level of confidence.

[10] Similarly to Arbia et al. (2005) we treated islands as bordering to the closest continental regions. Florax and Rey (1995) examined the sensitivity of estimates to alternative spatial matrices. Adopting a binary contiguity matrix in place of that built on distance measures should not produce substantially different results for relatively low values of auto-correlation.

[11] Although partially, the absence of spatial error correlation could be ascribed to the usage of variables expressed as deviations from national means, as argued by Armstrong (1995) in discussing the significance of country dummies in this kind of econometric analyses.

5.2 The growth of labour productivity

Table 6 shows that labour productivity changes are again positively affected by the intensity of R&D and to a lower extent by that of tertiary education (in the latter case, in fact, the coefficient is significant at a 0.10 level of confidence only). At the same time, as indicated by the coefficient of the initial share of manufacturing employment, the regions with a wider manufacturing base displayed higher rates of labour productivity growth. The initial level of labour productivity exerts a negative effect and the size of the estimated parameter (-0.120) suggests that, ceteris paribus, the catching up in terms of labour productivity has been relatively more intense than that recorded for the GDP per capita.

Table 6 – OLS regressions for the rate of change of labour productivity 1995-2002

	Specification 1		Specification 2	
	Coefficient	Stand. Err.(°)	Coefficient	Stand. Err.(°)
Ln Labour productivity	-0.120**	0.043	-0.119**	0.049
R&D expenditures on GVA	0.934**	0.318		
Share of adults with tertiary education	0.157*	0.088		
Composite indicator of knowledge base			0.012**	0.039
Share of manufacturing employment	0.130**	0.048	0.114**	0.049
Adjusted R^2	0.162		0.119	
		P-value		P-value
Jarque-Bera test on residuals' normality	1.31	0.52	0.54	0.76
Reset test for omitted variables	0.94	0.43	2.24*	0.09
LM test for spatial error dependence	2.05	0.15	1.87	0.17
LM test for spatial lag	2.24	0.13	2.09	0.15

(°) = Standard errors robust to heteroskedasticity.
** = significant at a 5% level of confidence; * = significant at a 10% level of confidence.

For the first specification all the diagnostic tests reported in the bottom of table 6 suggest that OLS estimates are appropriate; in fact, once controlling for heteroskedaticity by means of robust standard errors, the null hypotheses of normality, no omitted variables and no spatial error and spatial lag dependence cannot be refused. Moreover, the first specification is preferable to the alternative one in which the composite indicator of knowledge base is included; this in fact reduces the goodness of fit of the whole regression and the Reset test indicates the presence of omitted variables.

In conclusion, the factors behind the regional growth of per capita GDP and labour productivity appear quite differentiated. The latter is positively affected by both R&D and higher education as well as the urban nature of the region; the former, instead, depends significantly on R&D only and the "industrial" nature of the region. Obviously, these differences must be ascribed to the other component of the per capita GDP dynamics – the occupation or participation ratio – to which we turn.

5.3 The growth of occupation ratio

Table 7 displays the OLS results for the change in the occupation ratio over the period 1995-2002. The first finding to be emphasised is that, among the knowledge indicators that have been used, only the share of adults with tertiary education records a positive and highly significant coefficient. Thus, the endowment of high-level human capital has been a crucial prerequisite for the employment increase of the EU developed regions. Obviously, this does not imply that, for the increase of occupation, the overall knowledge base of the regions did not matter. In fact, contrary to the previous findings, the alternative specification including a composite indicator of knowledge base gives rise to equally sound results.

The latter are robust to the inclusion of population density whose positive effect denotes the higher speed of employment growth recorded by the most urbanised regions of the EU. Taking into account all the above factors, the initial level of the occupation ratio displays a negative parameter with a size suggesting that the catching up in terms of participation ratio has been the most intense one as compared to that for labour productivity and, especially, per capita GDP. Finally, the presence of non normal residuals does not compromise the robustness of OLS results; in fact, ML estimates for spatial error and spatial lag models generate almost identical findings.

Although most of the literature is focused on productivity effects, some studies have also examined the employment enhancing impact of innovation and knowledge (for a recent contribution see Petit and Soete, 2001). They mainly refer to the Schumpeterian view of capitalist development by stressing the structural implications of technological breakthroughs such as the emergence of new industries, goods and services leading to the creation of new jobs.

Table 6 – OLS regressions for the rate of change of the occupation ratio 1995-2002

	Specification 1		Specification 2	
	Coefficient	Standard Err.	Coefficient	Standard Err.
Ln Occupation ratio	-0.156**	0.029	-0.166**	0.030
Share of adults with tertiary education	0.382**	0.069		
Composite indicator of knowledge base			0.015**	0.003
Ln Population density	0.009**	0.003	0.009**	0.003
Adjusted R^2	0.274		0.249	
		P-value		P-value
Jarque-Bera test on residuals' normality	25.2**	0.00	10.4**	0.00
Reset test for omitted variables	1.07	0.36	0.58	0.63
Koenker-Bassett test for heteroskedasticity	1.89	0.60	2.50	0.48
Breusch-Pagan test for heteroskedasticity	6.10	0.20	4.08	0.25
LM test for spatial error dependence	0.04	0.85	0.27	0.61
LM test for spatial lag	0.10	0.76	0.55	0.46

** = significant at a 5% level of confidence; * = significant at a 10% level of confidence.

Needless to say that, along with other important factors, the structural changes driven by the recent ICT revolution contribute to explain the US employment expansion in the early 1990s and the EU employment resurgence during the second part of the decade (Matteucci and Sterlacchini, 2003). Our results concerned with the growth of occupation ratio across EU developed regions support such a view and, in addition, suggest that the regions with the highest level of human capital have been able to reap greater benefits from the new growth opportunities of the last decade.

6. Concluding remarks

The recent growth patterns of the EU developed regions have been significantly affected by their innovation and knowledge base and, especially, by the intensities of R&D

expenditures and tertiary education. These findings indicate that the growth enhancing policies of the Lisbon strategy are not the products of wishful thinking but are based on a sound and robust empirical evidence, arising also in the European context. Unfortunately, according to the assessment of the European Commission (Kok, 2004; European Commission, 2005), the progress made in pursuing the Lisbon strategy is far from being satisfactory and the recent low-profile agreement on the EC budget for the period 2007-13 puts such a strategy in further jeopardy.

Having saying that, we are aware that mere additional efforts in terms of innovation, knowledge and education are not a panacea for all the European diseases.

First of all, they need to be coupled with a broad set of policies and institutional changes such as, for instance, a favourable fiscal treatment of intangible investments, more advanced regulatory frameworks for the provision of new products and services, new work practices ascribing greater responsibilities to educated and skilled workers. These policies, affecting the way in which firms and individuals operate, can raise the returns from these kinds of investment. Secondly, there is no guarantee that the EU25 regions or countries with lower income level will benefit from the above investments to the same extent of the more advanced areas. Our results refer to regions that have already reached a relatively high threshold of development while the existing evidence concerned with less developed areas or countries is more controversial (see section 2). However, as far as the laggard areas of the EU are able to catch up, it is likely that an increasing knowledge base, no matter its location, will enhance the economic growth of the whole Europe.

Further insights can be drawn from other specific results of our analysis. We found, for instance, that the determinants of regional growth are different when looking at labour productivity or employment. In the first case, only the intensity of R&D appears significant and the regions with a wider manufacturing base are able to grow faster. In the second, a broadly defined innovation capability (albeit particularly associated with higher education) appears effective and additional growth advantages are displayed by urban regions. These different paces seem to replicate the dualistic patterns of growth recorded, during the last years, by the EU manufacturing and services: the growth of labour productivity, in fact, has been particularly strong in manufacturing (which, at the same time, has reduced employment) while the employment growth has been concentrated in business services (which, at the same time, do not have shown substantial productivity improvements). Due to the mounting importance of services, this has reduced the overall rate of productivity growth in the EU (cf. section 3). Thus, the productivity increase in service activities other than that related to telecommunication and IT (already characterised by good performances) should be put on the top of the EU policy agenda. Clearly, to maintain an adequate growth of per capita GDP, this should not be achieved at the expenses of employment (as it happened during the early 1990s). How to implement, also at regional level, productivity enhancing policies without generating job losses is obviously not easy since it requires a remarkable growth of output. An inescapable condition for this goal is an environment favourable to innovation, knowledge and high-tech entrepreneurship.

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Appendix A.1 – List of the EU developed regions considered in the present study by country

COUNTRY (number of regions)	NUTSII	NAME
AUSTRIA (8)		
	AT12	Niederösterreich
	AT13	Wien
	AT21	Kärnten
	AT22	Steiermark
	AT31	Oberösterreich
	AT32	Salzburg
	AT33	Tirol
	AT34	Vorarlberg
BELGIUM (9)		
	BE21	Antwerpen
	BE22	Limburg
	BE23	Oost-Vlaanderen
	BE24	Vlaams-Brabant
	BE25	.West-Vlaanderen
	BE31	Brabant Wallon
	BE33	Liège
	BE34	Luxembourg
	BE35	Namur
GERMANY (29)		
	DE11	Stuttgart
	DE12	Karlsruhe
	DE13	Freiburg
	DE14	Tübingen
	DE21	Oberbayern
	DE22	Niederbayern
	DE23	Oberpfalz
	DE24	Oberfranken
	DE25	Mittelfranken
	DE26	Unterfranken
	DE27	Schwaben
	DE50	Bremen
	DE60	Hamburg
	DE71	Darmstadt
	DE72	Gießen
	DE73	Kassel
	DE91	Braunschweig
	DE92	Hannover
	DE94	Weser-Ems
	DEA1	Düsseldorf
	DEA2	Köln
	DEA3	Münster
	DEA4	Detmold
	DEA5	Arnsberg
	DEB1	Koblenz
	DEB2	Trier
	DEB3	Rheinhessen-Pfalz
	DEC0	Saarland
	DEF0	Schleswig-Holstein
SPAIN (11)		
	ES13	Cantabria
	ES21	País Vasco
	ES22	Comunidad Foral de Navarra
	ES23	La Rioja

	ES24	Aragón
	ES30	Comunidad de Madrid
	ES41	Castilla y León
	ES51	Cataluña
	ES52	Comunidad Valenciana
	ES53	Illes Balears
	ES70	Canarias
FINLAND (4)		
	FI13	Itä-Suomi
	FI18	Etelä-Suomi
	FI19	Länsi-Suomi
	FI1A	Pohjois-Suomi
FRANCE (22)		
	FR10	Île de France
	FR21	Champagne-Ardenne
	FR22	Picardie
	FR23	Haute-Normandie
	FR24	Centre
	FR25	Basse-Normandie
	FR26	Bourgogne
	FR30	Nord - Pas-de-Calais
	FR41	Lorraine
	FR42	Alsace
	FR43	Franche-Comté
	FR51	Pays de la Loire
	FR52	Bretagne
	FR53	Poitou-Charentes
	FR61	Aquitaine
	FR62	Midi-Pyrénées
	FR63	Limousin
	FR71	Rhône-Alpes
	FR72	Auvergne
	FR81	Languedoc-Roussillon
	FR82	Provence-Alpes-Côte d'Azur
	FR83	Corse
ITALY (15)		
	ITC1	Piemonte
	ITC2	Valle d'Aosta
	ITC3	Liguria
	ITC4	Lombardia
	ITD1+2	Province Autonome di Bolzano e Trento
	ITD3	Veneto
	ITD4	Friuli-Venezia Giulia
	ITD5	Emilia-Romagna
	ITE1	Toscana
	ITE2	Umbria
	ITE3	Marche
	ITE4	Lazio
	ITF1	Abruzzo
	ITF2	Molise
	ITG2	Sardegna
NETHERLANDS (12)		
	NL11	Groningen
	NL12	Friesland
	NL13	Drenthe
	NL21	Overijssel
	NL22	Gelderland
	NL23	Flevoland
	NL31	Utrecht

	NL32	Noord-Holland
	NL33	Zuid-Holland
	NL34	Zeeland
	NL41	Noord-Brabant
	NL42	Limburg
SWEDEN (8)		
	SE01	Stockholm
	SE02	Östra Mellansverige
	SE04	Sydsverige
	SE06	Norra Mellansverige
	SE07	Mellersta Norrland
	SE08	Övre Norrland
	SE09	Småland med öarna
	SE0A	Västsverige
UNITED KINGDOM (32)		
	UKC1	Tees Valley and Durham
	UKC2	Northumberland and Tyne and Wear
	UKD1	Cumbria
	UKD2	Cheshire
	UKD3	Greater Manchester
	UKD4	Lancashire
	UKD5	Merseyside
	UKE1	East Riding and North Lincolnshire
	UKE2	North Yorkshire
	UKE3	South Yorkshire
	UKE4	West Yorkshire
	UKF1	Derbyshire and Nottinghamshire
	UKF2	Leicestershire, Rutland and Northamptonshire
	UKF3	Lincolnshire
	UKG1	Herefordshire, Worcestershire and Warwicks
	UKG2	Shropshire and Staffordshire
	UKG3	West Midlands
	UKH1	East Anglia
	UKH2	Bedfordshire and Hertfordshire
	UKH3	Essex
	UKI2	Outer London
	UKJ1	Berkshire, Buckinghamshire and Oxfordshire
	UKJ2	Surrey, East and West Sussex
	UKJ3	Hampshire and Isle of Wight
	UKJ4	Kent
	UKK1	Gloucestershire, Wiltshire and North Somerset
	UKK4	Devon
	UKL2	East Wales
	UKM1	North Eastern Scotland
	UKM2	Eastern Scotland
	UKM3	South Western Scotland
	UKN0	Northern Ireland

Appendix A.2 – Definition of variables, data sources and computations

POPULATION DENSITY: Population (thousands) / Surface (square kilometres). Year: 1995. Source: Eurostat. Level: NUTSII.

SHARE OF MANUFACTURING EMPLOYMENT: Employment in Manufacturing (NACE Rev. 1.1 code D) / Total employment. Year: 1995. Source: Eurostat. Level: NUTSII.

SHARE OF BUSINESS SERVICES EMPLOYMENT: Employment in Business Services (NACE Rev. 1.1 codes G, H, I, J and K) / Total employment. Year: 1995. Source: Eurostat. Level: NUTSII apart from Germany where NUTSI data were available. The shares to German NUTSII regions are imputed according to the differences in terms of population density.

R&D EXPENDITURES ON GVA: Percentage of total intramural R&D expenditure on Gross Value Added. Year: 1995 (with the exclusion of Austrian regions for which only 1999 data are available). Source: Eurostat. Level: NUTSII apart from UK (NUTSI), Belgium (NUTS0) and Sweden (NUTS0). In these cases, the R&D intensities are imputed to NUTSII regions according to the differences in terms of EPO applications per million inhabitants.

EPO APPLICATIONS PER MILLION INHABITANTS: Total patent applications to the European Patent Office/ Population in millions. Year: 1995. Source: Eurostat. Level: NUTSII.

SHARE OF EMPLOYMENT IN HIGH-TECH MANUFACTURING: Employment in high-tech manufacturing (NACE Rev. 1.1 codes 30, 32 and 33) / Total employment. Year: 1995. Source: Eurostat. Level: NUTSII. In some cases, NUTSI (in a few cases NUTS0) figures are imputed to NUTSII regions or, in place of the 1995 employment shares, the averages of the following years are used The above adjustments were necessary for all the NUTSII regions of Finland and the UK, some belonging to Belgium, Spain and Sweden and a few located in France, Germany and the Netherlands.

SHARE OF EMPLOYMENT IN HIGH-TECH SERVICES: Employment in high technology and knowledge-intensive services (NACE Rev. 1.1 codes: 64, 72 and 73) / Total employment. Year: 1995. Source: Eurostat. Level: NUTSII.

SHARE OF ADULTS WITH TERTIARY EDUCATION: Population aged 25-64 with tertiary education (ISCE97 codes 5 and 6) / Total population aged 25-64. Year: 1999. Source: Eurostat. Level: NUTSII.