LINKING INNOVATION AND KNOWLEDGE TO REGIONAL ECONOMIC PERFORMANCES: SIMILARITIES AND DIFFERENCES AMONG EU DEVELOPED REGIONS*

Alessandro Sterlacchini
Faculty of Economics
Polytechnic University of Marche
Piazzale Martelli, 8 - 60121 Ancona, Italy
Phone: +390712201091. Fax: +390712207199.
E-mail: a.sterlacchini@univpm.it

Abstract: This paper examines how the recent economic performances of European developed regions (i.e. those with a GDP per capita greater than 75% of the EU25 average) have been affected by their innovation and knowledge base. A regression analysis for both the level and the rate of growth of per capita GDP is performed by using as a main explanatory variable a composite indicator extracted from regional data on R&D, innovation and education. Controlling for other explanatory factors, the above relationship is allowed to vary across countries. The results show that the composite indicator of innovation and knowledge is strongly and similarly associated across regions with the level of GDP. Instead, its influence on the GDP growth, though positive, is less significant and remarkable regional differences arise. In particular, while the regions of Northern and Central Europe record a substantial impact of innovation and knowledge on their economic growth, the results for those located in Southern Europe are disappointing. The policy implications of this finding are discussed.

Keywords: Regional economic performances; innovation and knowledge.

JEL Codes: O18, O33, R11.

*Paper prepared for the XXVII Conferenza Italiana di Scienze Regionali, Pisa, 12-14 ottobre 2006. This work is an extension of a broader study on "Policy guidelines for regions falling under the new regional competitiveness and employment objective for the 2007-2013 period" carried out on behalf of the European Commission, DG Regional Policy. I am grateful to Massimo Florio (scientific responsible of the study) and Jordi Torrebadella and Hugo Poelman (officials of the DG Regio) for their valuable advice and support and to Roberto Esposti and Francesco Venturini for their suggestions. The adopted methodology and the derived conclusions are my own and do not reflect those expressed in the above mentioned study and, a fortiori, those of the European Commission.

1. Introduction

Among the reasons of the unsatisfactory economic performances of the EU during the second half of the 1990s and the early 2000s, a great emphasis has been put on its weak innovation and knowledge base, especially when compared to that of the US. Indeed, this was the main rationale of the Lisbon strategy aimed at transforming Europe in "the most competitive and dynamic knowledge-based economy in the world". In order to assess the potential benefits of this strategy, this paper examines some recent data concerned with European regions. Since the overall weakness of the EU is accompanied by remarkable regional differences in terms of R&D, patenting and higher education, our aim is to test whether these disparities are significantly associated with regional economic performances.

The analysis refers to 151 NUTSII developed regions of the former EU15 where "developed" means with a level of per capita GDP equal or above 75% of the EU25 average. This geographical restriction can be justified by both a policy and an analytical motivation. First, the above mentioned regions are included in the new "competitiveness and employment objective" of the EU regional policy for the period 2007-13 and, according to the EC guidelines (European Commission, 2004), they should be the main carriers of the Lisbon strategy. Secondly, the less developed regions of the EU have not yet reached a minimum threshold of innovation and knowledge activities so that one cannot expect that additional investments in these fields will generate for them, at least in the medium term, substantial economic benefits.

With respect to economic performances we employ both the level of per capita GDP in 2000-02 and its growth rate over the period 1995-2002. As a main explanatory variable of them we use a composite indicator of innovation and knowledge which refers to the years 1995-96 and is obtained from a comprehensive set of measures: the intensity of R&D expenditures and EPO applications, the employment shares in high-tech manufacturing and services, the share of adults with tertiary education, and the percentage of firm turnover due to new products. The above relationship is controlled for the population density of the regions (a proxy for agglomeration economies) and, when the economic growth is considered, for their initial level of GDP; moreover, the economic impact of innovation and knowledge is allowed to vary across countries.

The results of a regression analysis show that the regional level of per capita GDP is strongly associated with the composite indicator of innovation and knowledge and that there are not significant differences among EU countries even when the population density is taken into account. On the contrary, the impact on the regional growth of GDP is less significant and, most importantly, there are some countries - mainly located in Southern Europe (Austria, France, Italy and Spain) – in which the recent patterns of regional growth have not been affected by innovation and knowledge

capabilities. From a policy perspective, the latter finding suggests that innovation policies based on quantitative targets – such as those proposed by the Lisbon strategy – cannot guarantee by themselves a substantial increase of the EU economic growth: for such a goal, they have to be included into broader policy frameworks, tailored on the specific features of the different national and regional innovation systems of Europe and more focussed upon the mechanisms facilitating the economic exploitation of new ideas.

The paper is organised as follows. Section 2 reviews the main backgrounds of the present study whose aim and geographical scope is presented in section 3. Sections 4 describes how the composite indicator of innovation and knowledge is obtained and distributed across countries and regions. Section 5 illustrates the two dependent variables of regional economic performance while section 6 presents the regression results. Section 7 concludes with some policy considerations.

2. Backgrounds of the study

In contrast with the standard neoclassical framework, endogenous growth models contend that, in the 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; Verspagen, 1991; Fagerberg and Verspagen, 2002), 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 sub-optimal, so that there is no guarantee 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 (see for a survey, European Commission, 2005) and similar findings have emerged from recent regional studies (see below). The increasing attention to the regional dimension of economic growth is due, among other reasons, to the fact that, even when countries converge, the differences within them appear

persistent[1]. In spite of its ongoing economic integration, this seems the case of the EU during the last two decades (Fagerberg and Verspagen, 1996; Gardiner et al., 2004).

In the explanation of these enduring growth differentials among regions, the importance of innovation and knowledge has been increasingly recognised. By considering 106 European regions, Cappellen et al. (1999) show that 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[2]. 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. Mora et al. (2005) find that the initial regional specialisation in high-tech services affects positively and significantly the change of per capita GDP in 108 EU regions during the period 1985-2000. Badinger and Tondl (2003) examine 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 exerts a significant impact on regional growth and the same occurs to the intensity of patent application per employee.

Another strand of literature, focussed on innovation only, has examined the regional distributions of patents and R&D expenditures and the spatial correlation among the two measures. 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 patent/R&D elasticity close to unity also after controlling for spatial spillovers which are found to be remarkable but strongly localised. Similar results are attained by Moreno-Serrano et al. (2004) 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 regions but this occurs mainly within countries so that innovation or knowledge spillovers appear significantly constrained by national borders[3].

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[1] In this connection, the endogenous growth theory and the new economic geography display an interesting convergence. 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 pointing to increasing regional specialisation and concentration of economic activities and, then, no necessary convergence.

[2] A result confirmed by Cappellen et al. (2003) for a more recent period.

[3] 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.

To synthesise, both the uneven regional distribution of innovative activities and the presence of localised spillovers point to the key role played by the regional dimension[4]. A further argument of support relies on the mounting importance of knowledge, especially in its tacit component. As stressed by Asheim and Gertler (2005) among others, tacit knowledge, which is naturally fostered by geographical proximity, is becoming crucial to be a "successful" region, not only in terms of production and absorption of innovations but also with respect to the learning ability of local organisations. The latter is obviously influenced by the extent and quality of local interactions between government, business and education. In this connection, the conceptual passage from national (Lundvall,1992; Nelson,1993) to regional systems of innovation (Howells, 2002; Asheim and Gertler, 2005) should be viewed as an important advancement, both for analytical and policy purposes.

Regional innovation systems are differentiated by a broad range of institutional, structural and technological features and, above all, by their inter-relationships[5] so that, across regions, an identical stock or flow of innovation and knowledge does not guarantee equal improvements of economic performances. As Oughton et al. (2002) point out in the light of the European evidence, traditional innovation policies based on purely quantitative targets (such as the intensity of R&D expenditures) may not reduce and, actually, might increase regional disparities.

Thus, contrary to the assumptions of endogenous growth models, a significant relationship between knowledge and economic growth cannot be taken for granted. Acs et al. (2004) contend that, between the two spheres, a filtering mechanism is needed and that such a role is played by entrepreneurship capital: the ability of a country (or a region) to convert public knowledge into "useful" economic knowledge relies on its availability of would-be and effective entrepreneurs which is fostered by a socio-economic environment favourable to new business activities. Audretsch and Keilbach (2006) test the above hypothesis across 440 German counties and find that their GDP growth is significantly and equally affected by the regional R&D intensity and a measure of entrepreneurship capital.

[4] As stressed by Oughton et al. (2002, p. 99) regional data on innovative activities "[…] suggest that the variations across regions within nation states are greater than variations across nation states providing strong empirical evidence in favour of extending the analysis of national systems of innovations to the regional level". Detailed evidence on the prevailing role of within country variations is provided in section 4 for a set of innovation and knowledge indicators.

[5] By using this kind of information, Todtling and Trippl (2005) distinguish among peripheral, "old" industrial and metropolitan regions and identify different sets of innovation policies specific to their idiosyncratic features.

3. Aim and geographical scope

This paper employs a comprehensive set of innovation and knowledge indicators as determinants of the recent economic performances of European NUTSII regions. The latter are measured by the level of per capita GDP over the years 2000-02 and the growth of real GDP per capita over the period 1995-2002 while innovation variables refer to the initial years. The reference period, shaped by the ICT revolution and the so called "knowledge economy", is particularly suitable for testing whether the economic impact of innovation and knowledge variables has been substantial also for the EU regions characterised by a relatively high level of development. We then consider the NUTSII regions of Europe which 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.
There are two main reasons for focussing on developed regions only.
First, in the new regulation of the EU regional policy for the period 2007-13 (see European Commission, 2004) the regions with the above mentioned level of GDP per capita will be eligible to a new "competitiveness and employment objective" while the remaining low-income regions to a "convergence objective" (which will be in place of the current "Objective 1"). For the former group of regions, the EC guidelines identify " innovation & knowledge" as one of the key policy areas, also with a view to provide a further contribution to the attainment of the Lisbon goals. As a consequence, to assess whether this strategy is likely to produce the expected outcomes, an inspection to the recent performances of the relatively developed areas of the EU is useful. In this sense, it can be said that our empirical analysis is "policy oriented".
Secondly, within the broad geographical area composed by the European developed regions a sufficient knowledge base already exists so that, in contrast with low income regions, it is likely that the economic impact of innovation, knowledge and education is already substantial and could increase further if sustained by adequate policy measures. As reported in the previous section, some studies (Cappellen et al., 1999; Oughton et al., 2002) have shown that R&D efforts and policies have not been effective in raising the economic performances of the less developed areas of the EU.

Rodgrìguez-Pose (2001) provides further arguments and evidence in this respect: the amount of R&D activities and highly educated people in most lagging regions of the EU is still too small and does not reach the minimum threshold to be effective. To attain such a threshold is crucial as far as there are increasing returns from R&D activities as well as agglomeration economies in the spatial distribution of research centres and highly qualified workforce; moreover, with a limited amount of

human capital and R&D expenditures even the possibility of absorbing external knowledge and innovations can be precluded (Nelson and Phelps, 1966; Cohen and Levinthal, 1989).
Obviously, to concentrate the attention on the advanced areas of the EU is an analytical choice and, as such, it does not imply that the less developed regions should be left behind (on the contrary, they will continue to receive the bulk of regional development funds) but that to speed-up their process of convergence a broader and more variegate mix of policies is needed[6].

INSERT MAP 1 AROUND HERE

Since our focus is on regional rather than country differences, the European countries containing only one or two NUTSII regions eligible to the new competitiveness objective of the EU regional policy are not taken into account. Thus, five countries of the former EU15 are excluded: Denmark (1 region corresponding to the whole country), Greece (2 regions), Ireland (2), Luxembourg (1) and Portugal (2). The same applies to four New Member States containing only one developed region (Czech Republic, Cyprus, Hungary and Slovakia). Moreover, other four regions with abnormal indicators of economic performances are excluded. Specifically, the big capital cities of Brussels and Inner London coincide with two NUTSII regions with a per capita GDP more than double with respect to the average of the EU developed regions. On the other hand, the German region corresponding to the city of Berlin records a GDP per capita 20% lower than the reference average coupled with a negative rate of GDP growth over the period 1995-2002. Finally, another peculiar case is that of Åland in Finland, a small highland of only 26 thousands inhabitants recording a GDP per capita 50% higher than the above mentioned average (along with an excellent GDP growth rate). To avoid the possible biases due to the inclusion of relevant outliers, these four regions are not included in our empirical analysis. Thus, at the end, our study refers to 151 regions. Map 1 illustrates their geographical location in the EU15 space while the complete list of them is provided in appendix A.1.

4. The composite indicator of innovation and knowledge

For the purposes of our study we collected six indicators of the regional innovation and knowledge base, all included in the *European Innovation Scoreboard* (European Commission, 2006). Since our aim is to use these measures as explanatory variables of the regional growth of per

[6] As stressed by Rodgrìguez-Pose (2001, p. 293), the economic growth of lagging European areas could be simply fostered by factors that have little to do with R&D, patenting and so on.

capita GDP over the period 1995-2002 and its regional level during 2000-02, the following indicators refer, with only one exception, to the years 1995 or 1996:

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;
6) share of turnover due to products that are new to the firm, a variable obtained from the second Community Innovation Survey (CIS2) and referring to the year 1996; contrary to the previous variables, this indicator is provided as a value re-scaled across all the EU15 NUTSII regions (ranging from 0 – ascribed to the region with the lowest share – to 100[7]).

Apart from the last measure which derives from a specific study carried out for the EU regions (see European Commission, 2003), all the other variables are taken from the regional statistics provided by Eurostat (see Appendix A.2 for technical and computational details). 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; finally, the sixth variable is the only measure of innovation output considered in the present study and can be taken as a proxy of the regional capability to assimilate innovations which are not necessarily produced in the local context . 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 have been no attempts to considered all of them together either to shape the innovation capabilities or explain the regional economic performances across Europe.

[7] The region with the lowest share of turnover attributable to new-to-the-firm products was Åland in Finland (a region excluded from our analysis) while that with the highest share was Braunschweig in Germany. See European Commission (2003, Annex Table F: Re-scaled European indicator values).

Table 1 – Indicators of innovation and knowledge across 151 EU developed regions

	No. of NUTSII regions	R&D expenditures on GVA		Ln EPO application per million inhabitants		Share of employment in high-tech manufacturing	
		Mean	Stand. Dev.	Mean	Stand. Dev.	Mean	Stand. Dev.
Austria	8	1.491	0.923	4.622	0.325	1.717	0.639
Belgium	9	1.710	1.142	4.383	0.655	1.246	0.650
Germany	29	1.952	1.350	5.081	0.573	1.944	0.861
Spain	11	0.686	0.415	2.205	0.958	0.702	0.409
Finland	4	3.048	1.390	4.858	0.621	2.075	0.992
France	22	1.267	0.822	4.041	0.671	1.418	0.768
Italy	15	0.829	0.514	3.587	0.923	1.214	0.529
Netherlands	12	1.751	0.746	4.568	0.413	1.410	0.964
Sweden	8	2.476	1.661	5.090	0.444	1.703	0.676
UK	33	1.936	1.307	4.261	0.561	1.805	0.843
Total	151	1.647	1.199	4.280	0.971	1.568	0.830
Between country dispersion			20%		59%		19%
Within country dispersion			80%		41%		81%

	Share of employment in high-tech services		Share of adults with tertiary education		Share of turnover due to products new to the firm (*)		Composite indicator of innovation & knowledge	
	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
Austria	2.304	0.566	19.511	2.010	46.250	9.794	-0.107	0.510
Belgium	3.054	1.042	31.723	5.745	19.111	1.054	0.141	0.706
Germany	2.824	0.513	22.781	3.099	59.069	22.290	0.547	0.846
Spain	1.743	0.878	27.858	6.043	36.727	21.804	-1.224	0.874
Finland	3.604	1.275	24.823	2.349	29.375	10.144	0.824	1.058
France	3.084	0.899	20.675	4.117	23.636	11.919	-0.370	0.787
Italy	2.374	0.837	12.912	1.770	36.067	22.607	-1.015	0.721
Netherlands	2.991	0.937	24.424	5.168	34.583	8.836	0.103	0.501
Sweden	4.009	1.208	26.589	4.696	40.375	9.516	0.887	1.088
UK	3.278	1.116	26.151	4.096	31.364	4.872	0.271	0.909
Total	2.920	1.022	23.346	6.037	37.156	19.169	0.000	1.000
Between country dispersion		25%		57%		42%		37%
Within country dispersion		74%		43%		58%		63%

(*) Value re-scaled across all the NUTSII regions of the EU15 (range 0-100).

Table 1 shows that, in line with the findings of other recent studies for the EU regions (Oughton et al., 2002; Frenz and Oughton, 2005), the regional dispersion of the R&D intensity is mainly due to within country differences (accounting for 80% of the total variance). The same conclusion arises for the employment share in high-tech manufacturing and, albeit to a lower extent, for the share of

turnover due to new products[8]. The intensity of EPO applications and the share of adults with tertiary education across regions are instead significantly influenced by country effects: respectively, 59% and 57% of their total variance is due to between country dispersion.
All the selected indicators are significantly correlated – albeit not to the same extent - across the 151 European regions under examination, so that it is possible and advisable to compute a composite or synthetic indicator of them. For this purpose we run a factor analysis to identify what components capture the maximum possible variance among the original variables. From this analysis only one important factor emerges (where "important" means with an eigenvalue greater than one).

Table 2 - Factor analysis for innovation and knowledge indicators

	Basic variables	Variables expressed as deviations from country means
Factor weight	2.814	2.916
Percentage of total correlation explained	46.908	48.594
Factor correlation coefficients:		
R&D expenditures on GVA	0.871	0.843
Ln EPO application per million inhabitants	0.808	0.786
Share of employment in high-tech manufacturing	0.639	0.511
Share of employment in high-tech services	0.682	0.638
Share of adults with tertiary education	0.593	0.813
Share of turnover due to products new to the firm	0.422	0.508

The first column of table 2 shows that this factor is quite informative accounting for 47 per cent of the total correlation among the original indicators; moreover, it appears strongly associated with the intensities of R&D and EPO applications while the correlation with the share of innovative turnover is much lower. On the basis of these results, a factor score (synthesising the information contained in the six basic variables) can be attached to each region and taken as a composite indicator of innovation and knowledge. The country means of this composite indicator are reported in the last column of the bottom part of table 1 and confirm the well known "technological" divide between Northern and Southern European countries: positive scores[9] arise for the former (which are, in decreasing order, Sweden, Finland, Germany, UK, Belgium, and the Netherlands) while the latter

[8] It must be reminded that for this indicator the mean values reported in table 1 do not refer to the original shares of turnover due to new products but are re-scaled across all the European regions. Thus, for instance, the mean of 19.1 attached to Belgian regions indicates that, on average, their share of innovative turnover amounts to 19% of that recorded by the best NUTSII region of the EU15. Moreover, the relatively low standard deviations arising for Belgium and UK are due to the fact that, for these two countries, CIS2 data are available only for NUTSI regions.

[9] The mean of the scores arising from the factor analysis is, by definition, equal to zero so that the positive values identify the regions and, then, the countries with above average innovation and knowledge performances.

record negative scores (Spain, Italy, France, and Austria). Moreover, the decomposition of variance shows that between country differences explain a substantial share (37%) of the regional dispersion.

According to the above findings and since our aim is that of emphasising idiosyncratic regional differences, the country effects should be removed from our data. Accordingly, the regional variables of innovation and knowledge can be expressed as deviations from national un-weighted means, where "national" stands for all the developed regions belonging to each country (cf. the first column of table 1).

The second column of table 2 reports the results of the factor analysis applied to the six variables computed as deviations from country means. Once again, only one relevant factor emerges which, however, is now particularly correlated with the intensity of R&D and the share of adults with tertiary education, while the role of EPO applications is reduced as compared to the previous results. Moreover, along with the share of innovative turnover, also the employment share in high-tech manufacturing plays a secondary role. In conclusion, by removing country effects, the composite indicator of regional innovation and knowledge that can be computed from the scores of the factor analysis is mainly shaped by within country differences in terms of R&D and higher education.

Table 3 illustrates the distribution of this composite indicator by showing, for each country, the minimum and maximum values (with the corresponding regions) and the interval among them. There are remarkable regional differences within countries, no matter their average performance in terms of innovation and knowledge. Less technology-oriented countries contain some regions that score largely above the national mean (which is centred, by construction, around zero): a notorious example is that of Ile de France but also in Spain and Italy the interval between the best and worst region is substantial. Strong regional differences are also displayed by the more technology-oriented countries and this is particularly the case of UK, Sweden and Germany.

In all the countries in which they are included (i.e. apart from Belgium, Germany and the UK), the regions hosting the country capital attain the highest scores, confirming that highly urbanised or metropolitan areas act as strong centres of attraction for (private and public) R&D activities, advanced business services and highly educated workers. As a consequence, to avoid a spurious correlation between innovation and knowledge variables and economic performances, it is highly advisable to control for the role played by agglomeration economies which can be proxied by the density of population.

Table 3 – Composite indicator of innovation and knowledge*

	Number of NUTSII regions	Minimum value (region)	Maximum value (region)	Interval
Austria	8	-0.570 (Salzburg)	1.381 (Wien)	1.950
Belgium	9	-0.978 (Limburg)	1.760 (Brabant Wallon)	2.315
Germany	29	-1.636 (Weser-Ems)	2.370 (Oberbayern)	4.005
Spain	11	-1.532 (Illes Balears)	2.252 (Comunitad de Madrid)	3.784
Finland	4	-1.648 (Itä-Suomi)	1.324 (Etelä-Suomi)	2.972
France	22	-1.924 (Corse)	3.194 (Île de France)	5.118
Italy	15	-1.521 (Sardegna)	1.794 (Lazio)	3.315
Netherlands	12	-1.334 (Zeeland)	0.881 (Noord-Brabant)	2.215
Sweden	8	-1.582 (Småland med öarna)	2.783 (Stockholm)	4.366
UK	33	-1.515 (South Yorkshire)	3.168 (Berkshire, Buckinghamshire, Oxfordshire)	4.683

*= Computed on the basis of the scores arising from the factor analysis for the innovation and knowledge indicators expressed as deviations from national means (cf. second column of table 2).

5. The indicators of regional economic performances

The economic performance variables used in this study are the log of GDP per capita in PPS (Purchasing Power Standards) averaged over the years 2000-02 and the rate of growth of per capita GDP at constant prices during the period 1995-2002.

As mentioned in section 3, the level of per capita GDP represents the crucial variable used by the EC to distinguish between “developed” and “less developed” regions. Moreover, it can be taken as a broad measure of the regional competitiveness reflecting the cumulative outcome of past growth performance (Gardiner et al., 2004; Frenz and Oughton, 2005). As depicted by table 5, in spite of having a level of GDP per capita equal or above 75 per cent of the EU25 average, the 151 developed regions considered in this study are characterised by significant differences which, moreover, are marginally influenced by country effects. In fact, 87% of the total variance is

explained by the regional (within countries) dispersion. The countries recording a regional dispersion significantly above the average are Finland, Germany, Italy and Austria.

For the second, dynamic measure of economic performance we compute GDP per capita at constant (1995) prices for each NUTSII region according to the sectoral composition of its economy. For this purpose, we take the 6 macro branches of the NACE classification[10] 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 current prices; finally, the resulting regional values at constant price for each branch are summed-up. The growth rate of real GDP per capita over the period 1995-2002 is expressed as the log difference between the initial and final year.

Table 4 – Indicators of economic performance across 151 EU developed regions

	No. of NUTSII regions	Ln per capita GDP in PPS 2000-02		ΔLn per capita GDP at constant prices 1995-2002	
		Mean	Stand. Dev.	Mean	Stand. Dev.
Austria	8	10.136	0.179	0.152	0.023
Belgium	9	9.947	0.174	0.141	0.045
Germany	29	10.057	0.180	0.081	0.037
Spain	11	9.938	0.126	0.187	0.040
Finland	4	9.945	0.198	0.219	0.047
France	22	9.942	0.148	0.157	0.027
Italy	15	10.084	0.180	0.108	0.035
Netherlands	12	10.064	0.175	0.142	0.042
Sweden	8	10.025	0.157	0.155	0.052
UK	33	9.976	0.165	0.168	0.064
Total	151	10.010	0.173	0.141	0.057
Between country dispersion			13%		41%
Within country dispersion			87%		59%

Sources: for the level of GDP: Eurostat; for the growth of GDP: own computations from Eurostat data.

[10] 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 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).

Table 4 shows that, in contrast with the final level of per capita GDP, its growth rate is significantly affected by country differences as displayed by the fact that only 59% of the total variance is due to within country dispersion.

The final level and the growth rate of per capita GDP could be positively correlated as far as the richest (poorest) regions have grown faster (slower). However, this is not the case, since the coefficient of simple correlation between the two variables is very low (0.09) and not statistical significant. This low correlation could be due, among other factors, to the different role played by country effects which is much more pronounced in the growth rather than the level of per capita GDP. Since our aim is to stress regional differences, as done for the innovation and knowledge indicators in the previous section, the two measures of economic performance have been transformed into deviations from country means (again, only the developed regions of each country are considered). Computed in this way, the level and growth of per capita GDP are significantly correlated although with a not particularly strong coefficient (0.35).

6. The impact of innovation and knowledge on regional economic performances

In this section a regression analysis is carried out across EU developed regions whose dependent variables are the two indicators of economic performance described in the previous section – level and growth of per capita GDP - which are assumed to be mainly explained by the composite indicator of innovation and knowledge computed in section 4. As argued at the end of the same section, the above relationships must be controlled for the structural features of the regions and, in this respect, the population density – being a proxy for agglomeration economies - should play a crucial role. It must be added that, to control for other structural characteristics of the regions, additional explanatory variables were used[11]; they are not displayed because did not exert a significant impact on economic performances.

The nature of available data allows one to run a cross-sectional regression only[12] so that the issues of regional heterogeneity and endogeneity between dependent and independent variables cannot be properly addressed. In any case, the fact that the dependent variables are, respectively, the level of GDP per capita in 2000-02 and its growth rate over the period 1995-2002 while the innovation and knowledge variable refers to the beginning of the period (1995-96) alleviates the problem of

[11] Namely, the employment share in total manufacturing (useful to identify “industrial” regions) and the employment share in total business services. The former was always not significant while the latter did not provide additional explanatory power when inserted together with the population density.

[12] A panel analysis was precluded by the lack of complete annual series (from 1995 on) for most of the innovation and knowledge variables.

endogeneity. Similarly, by adding the population density as a control variable, an important source of regional heterogeneity is taken into account.

6.1 The impact on the level of GDP per capita

The equation to be estimated for the level of per capita GDP expressed in natural logs and averaged over the years 2000-02 is:

$$LnPCGDP_{00\text{-}02} = \alpha_1 + \alpha_2\, INKNOW_{95\text{-}96} + \alpha_3\, LnPOPDENS_{95} + \varepsilon \qquad [1]$$

INKNOW denotes the composite indicator of innovation and knowledge relative to the years 1995-96 (cf. section 4), the population density in natural logs refers to 1995 and ε is the error term. To be free from country effects, all the variables are computed as deviations from national means.
To test the stability of the innovation parameter (α_2) across EU countries, an alternative specification that shall be used is:

$$LnPCGDP_{00\text{-}02} = \alpha_1 + \Sigma_j\, \alpha_{2j}\, (INKNOW_{95\text{-}96} * COUNTRY_j) + \alpha_3\, LnPOPDENS_{95} + u \qquad [2]$$

where the *INKNOW* is interacted with *j* country dummies (with *j*=1, …,10).

Table 5 – OLS regression results for the log level of per capita GDP

	Specification 1		Specification 2		Specification 3		Specification 4	
	Coeff.	St. Err.	Coeff.	St. Err.	Coeff.	St. Err.	Coeff.	St. Err.
Constant	-0.015	0.010	-0.015	0.010	-0.015	0.010	-0.014	0.009
INKNOW	0.108	0.010**			0.093	0.010**		
LnPOPDENS					0.050	0.011**	0.055	0.012**
INKNOW*Austria			0.202	0.078**			0.079	0.078
INKNOW*Belgium			0.119	0.043**			0.099	0.041**
INKNOW*Germany			0.091	0.022**			0.086	0.021**
INKNOW*Spain			0.062	0.031**			0.048	0.029
INKNOW*Finland			0.147	0.057**			0.120	0.053**
INKNOW*France			0.118	0.026**			0.093	0.025**
INKNOW*Italy			0.105	0.036**			0.075	0.034*
INKNOW*Netherland			0.162	0.053**			0.124	0.050**
INKNOW*Sweden			0.102	0.034**			0.055	0.034
INKNOW*UK			0.119	0.020**			0.120	0.019**
Adjusted R^2	0.443		0.433		0.508		0.501	
F test for the equality of INKNOW parameters[(a)]			0.70 (0.708)				0.76 (0.656)	

*= significant at 0.05; **=significant at 0.01; (a)= P-value in brackets.

Table 5 presents four regression specifications estimated by means of OLS. The first uses as explanatory variable only the composite indicator of innovation and knowledge. The second, instead, includes ten variables obtained by interacting the innovation indicator with country dummies. The third specification adds the log of population density as a control variable while the fourth also includes the ten interaction variables. When applicable, a test for the equality of interaction parameters is presented[13].

In the first specification, as indicated by the adjusted R squared, the innovation variable turns out to be highly significant in explaining the GDP level of the EU developed regions. By introducing country interaction variables (specification 2) the impact of the innovation and knowledge base is not significantly different among countries as indicated by the F test (which accept the hypothesis of equality among the innovation parameters).

The results slightly change when also the log of population density is included in the regression. The third specification suggests that, thanks to agglomeration economies, the most urbanised regions record higher levels of per capita GDP; the inclusion of population density reduces the size of the innovation coefficient which, however, remains substantial and very significant. When the innovation parameter is allowed to vary among countries (specification 4), the estimated coefficients seem more different than in the previous regression; moreover, controlling for population density, in three countries – namely, Austria, Spain and Sweden – the impact of innovation and knowledge on per capita GDP is not statistically significant. Notwithstanding, from a strict statistical point of view, the F test indicates that the innovation parameters should be considered equal across the EU countries considered.

To sum up, it can be said that when the current level of per capita GDP is taken into account, the developed regions of the EU record a similar and very significant impact of their past intensity of innovation and knowledge activities. However, the above conclusion simply describe the current situation while, from a policy perspective, it is important to assess whether additional efforts in the fields of R&D, innovation and higher education are likely to affect significantly the economic growth of European regions. For this purpose, we now turn to the analysis of the GDP per capita growth.

[13] Along with the usual test for heteroskedasticity, which does not affect our estimates for the GDP levels, two Lagrange Multiplier (LM) tests for spatial error and spatial lag dependence were performed (cf. Anselin, 1988; see, for an application, Acs et al., 2002). 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. In all the regressions reported in table 6, both tests – performed by means of a row-normalised binary contiguity matrix for the 151 regions - accept the null hypothesis of no spatial correlation. It must be pointed out that this finding is mainly due to the use of variables expressed as deviations from country means which, by definition, reduces the spatial correlation among the regions belonging to the same country. Both the Breush-Pagan test for heteroskedasticity and the LM tests for spatial error and dependence are available from the author upon request.

6.2 The impact on the growth of GDP per capita

For the growth of per capita GDP at constant (1995) prices and expressed as the long difference of natural logs over the period 1995-2002, the estimated equation is the following:

$$\Delta LnPCGDP_{95\text{-}02} = \beta_1 + \beta_2\, INKNOW_{95\text{-}96} + \beta_3\, LnPCGDP_{95} + \beta_4\, LnPOPDENS_{95} + \varepsilon \qquad [3]$$

Looking at its right hand side, equation [3] is identical to [1] apart form the fact that here the initial (1995) level of the log of per capita GDP is added as a further explanatory variable: the sign and significance of its coefficient (β_3) is important to detect whether the regions with a lower level of GDP at the beginning of the period were able to catch up, i.e. grow faster than the leading regions. As for the level of GDP, a further specification of equation [3] shall be used by allowing the *INKNOW* parameters to vary across countries.

Table 6 – OLS regression results for the growth of per capita GDP

	Specification 1		Specification 2		Specification 3		Specification 4	
	Coeff.	St. Err.(b)	Coeff.	St. Err.(b)	Coeff.	St. Err.	Coeff.	St. Err.
Constant	0.001	0.003	0.001	0.003	0.001	0.003	0.001	0.003
INKNOW	0.019	0.004**			0.017	0.004**		
$LnPCGDP_{95}$	-0.044	0.027	-0.035	0.031	-0.064	0.027**	-0.058	0.026**
LnPOPDENS					0.011	0.004**	0.015	0.004**
INKNOW*Austria			-0.004	0.012			-0.033	0.025
INKNOW*Belgium			0.035	0.009**			0.031	0.013**
INKNOW*Germany			0.014	0.007*			0.015	0.007**
INKNOW*Spain			0.015	0.009			0.013	0.009
INKNOW*Finland			0.037	0.004**			0.032	0.017*
INKNOW*France			-0.004	0.007			-0.008	0.008
INKNOW*Italy			0.005	0.011			-0.002	0.011
INKNOW*Netherland			0.050	0.012**			0.042	0.016**
INKNOW*Sweden			0.022	0.010**			0.011	0.011
INKNOW*UK			0.029	0.010**			0.032	0.006**
Adjusted R^2	0.130		0.194		0.167		0.259	
F test for the equality of INKNOW parameters(a)			7.50** (0.000)				3.03** (0.002)	

*= significant at 0.05; **=significant at 0.01; (a)= P-value in brackets; (b)=robust to heteroskedasticity.

Table 6 presents the OLS results of the same specifications used in the previous analysis, with or without controlling for population density and with or without interaction variables.

By neglecting population density (specifications 1 and 2), the presence of heteroskedasticity was detected so that robust standard errors were applied. The parameter of the initial level of GDP is negative but not statistically significant so that neither a convergence nor a divergence across the EU developed regions can be detected. The innovation and knowledge indicator is the only significant variable which affects positively the GDP growth: however, as indicated by the adjusted R squared, its explanatory power is much lower than that obtained for the GDP level. Moreover, when the innovation coefficient is allowed to vary across countries (specification 2) relevant differences emerge. For four countries – Austria, Spain, Italy and France – the parameter is not significantly different from zero and the F test refuse the hypothesis of equality across countries.
By including the population density in the regression (specification 3), the size of the innovation parameter is slightly reduced and a significant negative coefficient of the initial level of GDP arises suggesting that a process of catching up has been at work. It must be stressed that the size of the estimated coefficient is very small (-0.06) but this can be justified by the relatively short period of time considered and by the fact that the examined regions already record a relatively high level of per capita GDP. By interacting the innovation variable with country dummies (specification 4) the presence of significant differences across countries is confirmed. The EU countries characterised by a non significant innovation parameter are now five out of ten, since Sweden joins the four already mentioned countries of Southern Europe.
The result for Sweden is surprising but can be explained by the fact that the region of Stockholm is largely above all the other Swedish regions, either in terms of innovation and GDP per capita growth; being the most urbanised region, agglomeration economies - proxied by the population density - emerge as the most significant explanatory variable outperforming that related to innovation and knowledge.
Apart from Sweden, for the regions of the countries located in north and central Europe - which, according to the descriptive analysis of section 4, can be defined as "highly innovative"- the relationship between innovation and knowledge and economic growth is positive and highly significant while the results are disappointing for the developed regions belonging to the "low innovative countries" of Southern Europe. Once again, it should be stressed that we are dealing with *developed* regions only: as a consequence, the above finding is not affected by the laggard regions located in the southern parts of Spain and Italy (which, in fact, are excluded from our analysis). The point is that the recent growth differentials among the developed regions of Austria, France, Spain and Italy does not seem affected by their different endowments of innovation and knowledge (cf. section 4). These unequal regional performances among EU countries should be taken into account

in order to design national and regional innovation policies that could be effective in raising the growth and employment prospect of Europe.

7. Concluding remarks

This paper has shown that the recent economic performances of the EU developed regions have been positively and significantly affected by their innovation and knowledge base, as measured by a comprehensive set of indicators. Thus, the growth enhancing policies grouped under the "Lisbon strategy" label are supported by our empirical analysis. However, having said that, the second relevant message is that a mere additional effort in terms of innovation, knowledge and education does not guarantee equal growth opportunities among EU countries and regions.

Although the analysis has been confined to the most developed regions of the EU, it has been shown that, while there are strong similarities in the relationship between innovation and knowledge and the level of per capita GDP, significant differences emerge when looking at the effects on the GDP per capita growth.

More specifically, we found that the impact of innovation and knowledge on GDP growth is substantial and highly significant for the regions of the north and central European countries characterised by a higher average intensity of innovation and knowledge (Belgium, Finland, Germany, the Netherlands, Sweden and the UK) while disappointing results arise for the regions of southern Europe (Austria, France, Italy and Spain) recording, on average, low innovative capabilities. It must be stressed, however, that the unsatisfactory performance of the latter countries cannot be ascribed to a generalised low level of innovative activities: as illustrated in section 4 (see, in particular, table 3), also within Southern European countries there are remarkable differences across developed regions in terms of R&D, innovation and higher education. Moreover, since we use variables expressed as deviations from national means, our results are not influenced by country effects.

Thus, the fact that Southern European regions do not benefit from their innovation and knowledge base to the same extent of the regions located in Northern Europe is quite a robust finding suggesting that, albeit the innovation potential remains an important driver of regional competitiveness, its effectiveness cannot be taken for granted.

As a general policy implication it can be said that to convert innovation capabilities and knowledge endowments into higher rates of economic growth, traditional public supports for R&D and higher education need to be accompanied by other specific measures, tailored on the different features of the national and regional innovation systems and more focussed on the inter-relationships between

the different local actors (government, education and business). To put it another way, innovation and knowledge policies based on purely quantitative targets – such as those proposed by the Lisbon strategy – cannot guarantee by themselves a substantial increase of the EU economic growth: for such a goal, they have to be included into broader policy frameworks, in which a greater emphasis should be put on the mechanisms that can foster the economic exploitation of new ideas, especially (though not only) those produced in the local context.

In this connection, a crucial role should be played by entrepreneurship capital, that is the socio-economic attitude towards new business activities, especially in high-tech manufacturing and services. This kind of entrepreneurship can be sustained by different policy measures focussed upon, for instance, the availability of financial resources for high-tech start-ups and spin-offs from universities and R&D laboratories, the presence of effective channels of technology transfer from research centres to business firms, and the design of regulatory frameworks more favourable to the introduction of new products and services. In this way, the relationship between innovation and knowledge and economic growth could be strengthened also for the European countries and regions in which, at present, investing in R&D, knowledge and education is less rewarding than expected.

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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 (33)		
	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
	UKK2	Dorset and Somerset
	UKK4	Devon
	UKL2	East Wales
	UKM1	North Eastern Scotland
	UKM2	Eastern Scotland
	UKM3	South Western Scotland
	UKN0	Northern Ireland

Appendix A.2 – Innovation and knowledge variables: definition, data sources and computations

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. 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.

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.

SHARE OF TURNOVER DUE TO PRODUCTS NEW TO THE FIRM: Year: 1996. Source European Commission (2003) which reports regional data taken from the second Community Innovation Survey; values are re-scaled in a range going from 0 (ascribed to the region with the lowest share of innovative turnover, Åland in Finland) to 100 (attributed to the region with the highest share, Braunschweig in Germany). Level: NUTSII. In the cases of Belgium and UK NUTSI values are imputed to NUTSII regions.

Map 1 - EU-15 developed regions considered in the present study