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The Determinants of Regional Growth: an Empirical Analysis

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ABSTRACT

The paper analyses the growth process of European Functional Urban Regions (FURs) during the period 1979-1990. The first part describes a theoretical model that guides the empirical analysis and that pays particular attention to the role of human capital, research activity and spillovers of technological knowledge. The main prediction of this model are then tested using OLS on a database of 122 major European FURs.

1 Introduction

The renewed attention to theoretical issues of economic growth over the past decade has been accompanied by a growing body of empirical analyses aimed, in particular, at confirming the existence of a process of convergence across national and regional economies. A substantial part of this body of empirical literature is made up of cross-sectional and panel data regression analyses that focus on the behaviour of a representative economy and make the implicit assumption that each economy is characterised by a steady-state growth path along which the economy is moving. However, although developed within the framework of the traditional neoclassical model of growth, cross-sectional and panel data regression analyses of convergence do not make it possible to test the validity of this theory against alternative and conflicting ones (Romer 1993, 1994; Fagerberg 1994; Cheshire and Carbonaro 1995; see also Barro and Sala-i-Martin 1995, Sala-i-Martin 1996). Indeed, their typical finding that economic systems are converging at a stable rate of 2 per cent per year (Barro 1991; Barro and Sala-i-Martin 1991, 1992, and 1995; Holtz-Eakin 1992, Armstrong 1995a and b; Sala-i-Martin 1996; among the others), is consistent with traditional neoclassical theory. However, this result could be equally consistent, for example, with 'evolutionary' or 'endogenous growth' theories. Hence, it does not confirm any of these theories and other sources of empirical evidence on the determinants of economic growth need to be utilised in trying to evaluate the relative merits of the different theoretical approaches. Several findings (Lucas 1988; Barro and Sala-i-Martin 1995; Pavitt and Soete 1982; Fagerberg 1987, 1988; Acs *et al*. 1992, 1994; Feldman 1994, Audertsch and Feldman 1996; Coe *et al*. 1997; among the others) suggest that the study of economic growth cannot abstract from the study of technological change and its determinants. For this purpose, cross-sectional regressions can still provide a valuable contribution, provided that attention is shifted away from the task of producing an unbiased estimation of the speed of convergence.

Within the traditional neoclassical model, technological change is interpreted as a purely exogenous phenomenon and thus no economic explanation of its evolution is put forward. By contrast, the 'evolutionary approach' has developed a framework in which technological change is explained by the action of economic agents. Much of the theoretical work within the evolutionary tradition has relied primarily on appreciative theory, that is on less abstract, more descriptive modelling. In response, recent 'endogenous growth' contributions have tried to codify some of the fundamental elements of the evolutionary view within the formal modelling tradition of mainstream economics. As a result, although differing profoundly in many ways, both frameworks interpret technological progress as either the by-product of other economic activities or the intentional result of research efforts carried out by profit seeking agents and therefore consider human capital and innovation as fundamental elements in the explanation of the process of economic growth.

One of the aspects that has not received sufficient attention from endogenous growth theorists is represented by the relationship between technological progress, knowledge spillovers and space. Fagerberg emphasises that "appreciative theorising often describes technology as organisationally embedded, tacit, cumulative in character, influenced by the interaction between firms and their environments, and geographically localised" (Fagerberg 1994, page 1170). Tacit knowledge, in particular, being the non-written personal heritage of individuals or groups is naturally concentrated in space. Moreover, because of its personal nature, tacit knowledge spills over space essentially through direct, face-to-face, contacts. It seems therefore important to analyse the geographical dimension of these spillovers explicitly. This is a feature of knowledge creation and transmission that has been entirely neglected in formal theories of endogenous growth.

The empirical analysis on the role of Research and Development (R&D) activities in regional growth presented here is based on a theoretical model developed elsewhere (Magrini 1997, 1998b), the main elements of which will be briefly recalled in the following section. Section 3 contains the empirical results for a data set of 122 major European Functional Urban Regions[1] (FURs) over the period 1979-1990; Section 4 concludes.

2 A Model of Regional Growth: Basic Features and Findings

The main aim of the theoretical model developed in Magrini (1997, 1998b) is to describe the role of formal research organisations - firms' R&D laboratories, government laboratories, universities, etc. - in shaping the spatial distribution of wealth within a two-region economic system. The model, which builds on the existing literature on endogenous growth and, in particular, on the work of Romer (1990a and b), Rivera-Batiz and Romer (1991a and b) and Rivera-Batiz and Xie (1993), presents three main features. Firstly, economic growth is endogenous and driven by the research activity of profit-seeking agents. Secondly, an explicit role in regional production structures is assigned to human capital. In particular, this factor of production is considered as the crucial input in the research sector. Thirdly, knowledge spillovers across space are an essential feature of research activity aimed at designing and developing new products.

The model presents a stable equilibrium characterised by permanent differences in per capita income levels. By resorting to a definition of research activities that recognises the important role played by spillovers of both tacit and abstract knowledge, the explanation suggested is that income disparities owe their existence to a process of regional specialisation between ‘knowledge creating’ and ‘knowledge applying’ regions. The ability to innovate within a regional economy depends on the interaction between the macro-economic system and the different factors shaping its Regional Innovation System (RIS). The result is the development of a location-specific ability to innovate which is referred to as the regional technological competence in research. Those regions which are better able to innovate through the development of a superior technological competence in research will be characterised by a relative specialisation in research activities and thus become ‘knowledge creating’ regions. Since research activities tend to make a more intensive use of human capital than manufacturing activities, the process of relative concentration of research in one location leads to a parallel relative concentration of human capital. Moreover, since wages for human capital tend to be higher than wages for unskilled labour, the relative concentration of human capital in one region implies that the average level of per capita income in this ‘knowledge creating’ regions will be higher than that in ‘manufacturing’ regions.

The model also offers a possible interpretation of the effects of the process of European integration on the disparities in per capita income. Indeed, a process of integration similar to the one that has characterised the recent European history, by determining a reduction in the cost of the physical distance, fosters the rate at which the European economic system grows in the long-run. At the same time, however, given that the reduction in the cost of distance has been achieved primarily through a reduction of the travel time between locations with little improvements in the degree of cultural and institutional homogeneity of the system, and given the high level of cultural-institutional heterogeneity characterising the European system, the price to pay may be represented by an increase in regional differentials. In such a situation, even though integration may reduce existing gaps in regional levels of technological competence in research, disparities in per capita income are likely to widen. In other words, the integration process may determine the emergence of a new steady-state equilibrium characterised by a further concentration of research activities in the regions which already were relatively more specialised in research. During the transition towards this new equilibrium per capita income growth rates differ across regions. While the adjustment takes place through the reallocation of unskilled labour and human capital, average per capita income in the more innovative, relatively more research-intensive region grows at a faster rate than in the other region.

The fundamental equation of the model describes the activity of each regional research sector. Consider an economic system made up of two regions, i and j, and in which the cost of moving from region one region to the other is equal to d_{ij}. The flow of new knowledge -i.e. the number of new designs- created in region i at any point in time is given by:

$$\dot{A}_i = \delta_i Hr_i \, Hr_i^{\phi} \left(Hr_j \, d_{ij}^{-1/\beta_{ij}} \right) A \qquad (1)$$

where Hr_i is the level of human capital employed in the research sector of region i, and δ_i represents the level of technological competence characteristic of the research sector located in region i. A is the number of intermediate inputs existing in the system and the overall level of abstract knowledge created so far and available to all researcher due to a-spatial spillovers of knowledge. As far as the spatial spillovers of technological tacit knowledge are concerned, Hr_i^{ϕ} reflects the size of the intra-regional spillovers whilst the term $Hr_j \, d_{ij}^{-1/\beta_{ij}}$ represents the extent of the inter-regional spillovers of tacit knowledge that benefit the research effort in region i and originate from the interaction with the research sector located in region j. These are a function of the level of human capital existing in the other region, Hr_j, weighted by the cost of the physical distance, d_{ij}, and a measure of the potential technological benefit from interaction, β_{ij}. On the one hand, as these spillovers result primarily from the physical interaction between researchers, their size is inversely related to (the cost of) physical distance. On the other hand, the 'catch-up' argument (Gerschenkron 1962; Abramovitz 1986) emphasises the potential benefit that can be enjoyed by technologically less advanced economies from the interaction with economies closer to the technological frontier due to the possibility of imitating technologies already developed elsewhere. It is assumed that the potential technological benefit accruing to researchers located in one region from the interaction with the researchers of the technologically more advanced region is an increasing function of the relative local technological competencies in research $\delta_{\text{tech.leader}} / \delta_{\text{other region}}$, and a decreasing function of the cost of the physical distance. The measure of the potential technological benefit accruing to region i from the interaction with region j could then be represented by:

$$\beta_{ij} = 1 + \frac{\ln\left(\dfrac{\delta_{\text{technological leader}}}{\delta_i} \right)}{\ln d_{ij}} \qquad (2)$$

where

$$\delta_{\text{technological leader}} = \begin{cases} \delta_i & if \quad \delta_i > \delta_j \\ \delta_j & if \quad \delta_i < \delta_j \end{cases} .$$

A crucial element of this description of the reseach effort is the parameter δ, the level of 'local technological competence in research', a concept introduced to account for location-specific tacit knowledge. In particular, it is defined as the ability to perform research characterising the RIS and allows for spatially bounded spillovers of knowledge arising from researchers' interaction. In turn, the RIS is the local network of public and private institutions supporting the initiation, modification and diffusion of new technologies (Freeman, 1987; Nelson and Rosenberg, 1993; Patel and Pavitt, 1994). Among the factors that constitute the RIS, it is possible to emphasise the role played by: the size and quality of the education system, the availability of technical, financial and networking services, the quantity and quality of space available for innovative activities, the structure of the local industrial sector, and both the system-wide and local macro-economic setting.

3 The Variables of the Empirical Model

The aim of the present section is to provide a simple test for the model's predictions. In particular, the growth process of the 122 major European FURs is studied in terms of its fundamental determinants. The period ranging from 1979 to 1990 conforms to two fundament requirements. Firstly, it is long enough to allow for the cyclical movements around the growth trend. Secondly, this is a period in which the European system has undergone important steps in its process of economic integration.

The dependent variable is the growth rate of per capita GDP in each FUR. The formula for the growth rate is the traditional logarithmic transformation of the ratio of regional per capita GDP at the two extremes of the period of analysis:

$$\text{GROWTH}_i = \frac{1}{11} \ln\left(\frac{y_{i,1990}}{y_{i,1979}}\right).$$

The fundamental independent variables of the empirical model relate to the activity of research performed in the regions. Indeed, on the basis of the theoretical analysis summarised above, the regions which are relatively specialised in research activities are expected to grow faster than region specialised in manufacturing activities. According to equation 1, however, it is not only the level of research activity carried out within one region that matters but also the level of knowledge spillovers which benefit the region. Whilst a-spatial spillovers, accruing to all regions in the same way, are not of interest when the relative performance of the regional economies is concerned, the other forms of spillovers are essentially spatially asymmetric and must be taken into account. An attempt is therefore made here to estimate the total effect of research activity on the growth performance of the region by considering both intra- and inter-regional spillovers of tacit knowledge. Ideally, this would require data for the level of employment in research activities in all the regions at the beginning of the period of analysis as well as data for technological and physical distances. Unfortunately, however, such data are not easily available and it has been necessary to resort to proxies. In particular, the level of regional research activities is here measured by the number of R&D laboratories located in the region at the beginning of the period and belonging to corporations which appeared in the Fortune top 500 lists. The data on the laboratories and their location has been collected on the basis of the *Directory of the European Research Centres* published in 1982. To represent relative concentration in research activities within the region, the number of R&D laboratories has been expressed per unit population. As pointed out by Cheshire and Carbonaro (1995 and 1996), who employ similar data for a more recent year, this is only a crude measure of the theoretically appropriate variable. It seems however able to provide a general indication on the role of the relative specialisation in research and on the extent of the spatial spillovers of knowledge.

To obtain an estimate of the parameter ϕ measuring the strength of the intra-regional spillovers, the R&D variable has been divided by the area of the region. As for inter-regional spillovers, the initial step has been the calculation of two matrices of time distances (expressed in minutes) between each pair of FURs. The first matrix reports time distance by road between FURs, whilst the second matrix reports the shortest time distance when a choice between airplane and road is available. Given the importance of air transport infrastructure for regions with a stronger commitment to research-intensive activities emphasised by many empirical studies of European urban regions (see, for instance, Andersson *et al*. 1990; Batten 1995), this second matrix has then been used in the estimation of inter-regional spillovers of knowledge. A proxy for the technological distance between pairs of FURs, β_{ij}, has then been calculated on the basis of equation 2, where the relative levels of technological competence in research have been estimated using data on regional technological creativity for the early 1980s derived by Åke Andersson and reported by Batten (1995).

To sum up, a first set of variables is used in the empirical analysis to account for the role of research activity and spatial spillovers of tacit knowledge. More details on these variables are reported in Table 1. The first of this variables, labelled R&D, simply reflects the relative concentration of research without allowing for spatial spillovers. The other variables, R&DS1 to R&DS7, consider both types of spatial effects and allow for different sizes of the distance range over which inter-regional spillovers are calculated. The *a priori* expectation is that, whilst all variables should be positively related with per capita GDP growth, those allowing for spatial spillovers should result statistically more significant and improve the overall performance of the model. The statistical significance of these variables, together with the measure of fit of the resulting models, will then be used to identify the distance range over which the inter-regional spillovers appear to be the strongest.

Table 1 Research and Development Variables

Variable	Spatial Spillovers	Distance Threshold
R&D	No	-
R&DS1	Yes	90 minutes
R&DS2	Yes	110 minutes
R&DS3	Yes	115 minutes
R&DS4	Yes	120 minutes
R&DS5	Yes	125 minutes
R&DS6	Yes	130 minutes
R&DS7	Yes	150 minutes

A second set of variables has been introduced in the empirical analysis in order to reflect the local factors shaping the RIS which in turn determine the regional level of technological competence in research, δ, and, most importantly, its likely evolution. Although not all these factors can be explicitly considered here due to data availability problems, it seems nonetheless possible to take into account the most relevant ones.

Universities are on the one hand producers of education and therefore influence the quality of the human capital available to firms. On the other hand, they also engage in research activities and produce knowledge. Universities are therefore an essential feature of the RIS and their influence on the evolution of regional technological competence in research must be accounted for. This is done by considering the number of academic staff employed in universities, higher and further education institutions in the academic year 1976-1977.[2] Clearly, this variable is expected to play a positive role in the economic performance of the region.

The growth prospects of a regional economy are also influenced by the structure of the local industrial sector. The theoretical model indicates that the concentration of manufacturing activities is detrimental for economic growth: it hampers the ability of the existing regional research sector both to develop a superior technological competence in research and to attract other researchers. Clearly, not all manufacturing activities have the same negative role. The variables COAL and PORT are intended to account for those industries which are likely to play a particularly negative influence on the growth prospects of the local economies or, in other words, aim to identify “old industrial regions suffering from industrial decline and employment loss” (Objective 2 regions). As pointed out by Cheshire and Carbonaro, the presence of coal mining should adversely affect local growth prospects for a considerable period of time even after this industry has ceased to account for a substantial share of employment. Consequently, the influence of the coal industry is allowed for through a dummy variable related to the coincidence of the area of the FUR with a coalfield as defined in the Oxford Regional Economic Atlas (1971).

The second variable reflects the size of the port industry, as measured by the amount of freight handled in 1978. On the one hand, dramatic developments in transport technology and, particularly, the introduction of containerisation and roll-on roll-off ferries have greatly reduced the attractiveness of port locations for processing activities. This shock therefore should have negatively affected all ports according to their size during the period under analysis. On the other hand, however, the transformation in the industry is likely to have lead to a re-organisation of the traffic flows and, therefore, to an increase in the degree of competition among existing ports. Large ports, thanks to their economies of scale, might have hence taken advantage of the process of re-organisation and increased their share of traffic over total flows at the expenses of smaller ports. As a result, the relation between port size and growth of per capita income in the region could be quadratic rather than linear.

Another relevant feature of the local industrial structure concerns the relative importance of service sector due to the role played by the variety of business services in providing firms with market, financial and commercial knowledge. This factor is measured as the percentage share of employment in service activities over employment in services and manufacturing in 1980, and is expected to be positively related to per capita GDP growth.

An interesting issue related to the local industrial structure concerns the question whether local ability to innovate is promoted by industrial specialisation, thanks to intra-industry spillovers, or rather by industrial diversity and inter-industry spillovers. The underlying theoretical model adopted here does not provide any indication of the relative importance of these two possibilities, but rather leaves the question open to the empirical investigation. The degree of specialisation of the regional economies is then measured on the basis of data on employment for 9 industrial NACE sectors, and ranges between 0 and 1, these two extremes indicating respectively specialisation and diversity in the regional industrial structures.[3]

The variable AGR is the share of employment in agriculture in 1975, in the wider NUTS2 region. This variable therefore focuses on "Objective 5b" and, at least partially, "Objective 1 regions". Similarly to Cheshire and Carbonaro (1995 and 1996), it is argued that the relation between FUR growth in per capita GDP and specialisation in agriculture in the NUTS2 region should be quadratic. Indeed, economic growth in FURs surrounded by regions relatively specialised in agriculture should be relatively slow because these FURs appear unable to attract research activities or other human capital rich activities whilst, at the same time, rural-urban migrations of unskilled workers from the countryside are likely to lead to population increasing faster than output and falling average levels of human capital. On the other hand, however, FURs located in densely urbanised regions would certainly suffer from congestion and other environmentally related problems and therefore could find it difficult to attract human capital.

A second variable that, more directly, considers the quantity and quality of the local supply of space suitable for research activities is represented by the density of the population in the FUR area in 1981. The level of density could be considered as a proxy for the land rent. At the same time, urban areas have witnessed a rapid increase in traffic levels that in many cases has led to acute congestion problems. In both cases, population density, measured by the number of habitants per squared kilometre, is expected to be negatively associated with growth.

The variable labelled SDG represents the sum of the difference between the growth rate of a FUR and the growth rates in FURs within a 150 minutes radius. In particular, the variable is calculated as

$$\mathrm{SDG}_i = \sum_j \left(\frac{\frac{\dot{y}_i}{y_i} - \frac{\dot{y}_j}{y_j}}{d_{ij}} \right)$$

where d_{ij} represents the road distance between regions. Moreover, to avoid problems of definitional correlation with the dependent variable, the growth rates are calculated over the period 1979-1985. This variable is introduced in the analysis in order to take into account how spatial adjustment between neighbouring FURs takes place. As explained by Cheshire (1979), adjacent local labour markets tend to interact primarily through adjustment of commuting patterns (see also Evans and Richardson 1981; Burridge and Gordon 1981; Gordon and

Lamont 1982; Gordon 1985). As a consequence a more rapid growth of per capita GDP in one FUR would attract additional in-commuters from surrounding FURs. The effect of such mechanism is twofold. The first of these effects is essentially statistical since the increase in in-commuters affects measured per capita GDP: output, which is measured at workplaces, varies, but resident population does not. The second effect concerns the level of human capital and productivity of the workers employed in the FUR. Indeed, these additional in-commuters are relatively long distance commuters who tend to have higher human capital and productivity than short distance commuters. As a consequence, the flow of in-commuters induced by the differential in growth rates is likely to increase the average level of human capital in the recipient FUR which, in turn, can have dynamic implications through the intra-regional spillovers of knowledge of the research sector. Because of the combination of both effects, a positive relationship between the growth rate of a FUR and the sum of the differential growth with adjacent FURs is expected.

The variable NFGROWTH reflects the influence of the macro-economic system. National macroeconomic policies, education policies, national culture, legal and social institutions all shape the local technological competence in research and its evolution over time. In particular, this variable is calculated as the growth rate of per capita GDP in the part of the nation that remains outside of the major FURs. At a sub-national level, empirical analyses have often stressed the specificity of the southern regions of Spain.[4] For instance, in their analysis of the Spanish Provinces, Mas *et al*. (1995) find that growth prospects for the southern agricultural Provinces of Spain are significantly worse than those for northern and eastern part of the country. As a consequence, a dummy variable for the south of Spain is introduced in the model.[5]

4 The Results

The empirical model can therefore be summarised as follows:

$$\frac{1}{11}\ln\left(\frac{y_{i,1990}}{y_{i,1979}}\right)=\alpha_0+\alpha\mathrm{E}_{i,1979}+\varepsilon_{i,1990} \qquad (3)$$

where E_{1979} is the vector of explanatory variables just described. The results of the OLS cross-sectional estimation of these equations are reported in Table 2. The first version of the model (reported in the first column) makes use of the variable on research activity without considering spatial spillover effects, whilst these effects are instead allowed for in all the other estimated versions.

Table 2 The Determinants of per capita GDP Growth in the FURs

	1	2	3	4	5	6	7	8
Constant	0.00718	0.00692	0.00705	0.00743	0.00725	0.00690	0.00713	0.00736
	(0.52)	(0.50)	(0.51)	(0.54)	(0.53)	(0.50)	(0.52)	(0.53)
R&D	0.00011	-	-	-	-	-	-	-
	(2.74)							
R&DS1	-	6.69e-5	-	-	-	-	-	-
		(2.81)						
R&DS2	-	-	6.02e-5	-	-	-	-	-
			(2.90)					
R&DS3	-	-	-	5.92e-5	-	-	-	-
				(3.01)				
R&DS4	-	-	-	-	5.65e-5	-	-	-
					(3.00)			
R&DS5	-	-	-	-	-	5.19e-5	-	-
						(3.00)		
R&DS6	-	-	-	-	-	-	4.86e-5	-
							(2.98)	
R&DS7	-	-	-	-	-	-	-	4.34e-5
								(2.95)
University	3.81e-7	4.24e-7	4.23e-7	4.23e-7	4.24e-7	4.17e-7	4.09e-7	4.15e-7
	(2.22)	(2.47)	(2.47)	(2.48)	(2.48)	(2.44)	(2.40)	(2.43)
Coal	-0.00296	-0.00331	-0.00339	-0.00336	-0.00336	-0.00336	-0.00339	-0.00338
	(-2.31)	(-2.57)	(-2.63)	(-2.62)	(-2.62)	(-2.62)	(-2.64)	(-2.63)
Port	-9.74e-5	-9.35e-5	-9.54e-5	-9.54e-5	-9.64e-5	-9.75e-5	-9.96e-5	-9.69e-5
	(-2.45)	(-2.37)	(-2.42)	(-2.43)	(-2.45)	(-2.47)	(-2.52)	(-2.46)
$Port^2$	3.94e-7	3.80e-7	3.89e-7	3.91e-7	3.94e-7	3.97e-7	4.04e-7	3.93e-7
	(2.20)	(2.13)	(2.18)	(2.20)	(2.22)	(2.23)	(2.26)	(2.21)
Service	0.01742	0.01726	0.01684	0.01630	0.01655	0.01710	0.01717	0.01682
	(2.21)	(2.19)	(2.14)	(2.07)	(2.11)	(2.18)	(2.19)	(2.14)
Specialisation	-0.03957	-0.04063	-0.03917	-0.03907	-0.03942	-0.03960	-0.04015	-0.04026
	(-2.53)	(-2.62)	(-2.52)	(-2.52)	(-2.54)	(-2.56)	(-2.60)	(-2.60)
Agriculture	8.99e-4	9.26e-4	9.46e-4	9.55e-4	9.58e-4	9.54e-4	9.50e-4	9.49e-4
	(4.01)	(4.09)	(4.16)	(4.21)	(4.21)	(4.20)	(4.19)	(4.18)
$Agriculture^2$	-3.35e-5	-3.43e-5	-3.48e-5	-3.50e-5	-3.51e-5	-3.50e-5	-3.50e-5	-3.50e-5
	(-5.28)	(-5.38)	(-5.44)	(-5.48)	(-5.49)	(-5.48)	(-5.47)	(-5.47)
Density	-0.00936	-0.00952	-0.00957	-0.00954	-0.00957	-0.00960	-0.00963	-0.00959
	(-3.99)	(-4.06)	(-4.09)	(-4.09)	(-4.10)	(-4.12)	(-4.12)	(-4.11)
SDG	0.19645	0.20122	0.20366	0.20424	0.20538	0.20554	0.20437	0.20251
	(4.93)	(5.04)	(5.10)	(5.13)	(5.15)	(5.15)	(5.13)	(5.09)
NFGrowth	1.02707	1.03278	1.03051	1.02832	1.02922	1.03037	1.02888	1.02855
	(6.92)	(6.98)	(6.98)	(6.98)	(6.99)	(6.99)	(6.98)	(6.97)
DSE	-0.00936	-0.00952	-0.00957	-0.00954	-0.00957	-0.00960	-0.00963	-0.00959
	(-3.99)	(-4.06)	(-4.09)	(-4.09)	(-4.10)	(-4.12)	(-4.12)	(-4.11)
$\overline{R}^2$	0.5812	0.5826	0.5844	0.5866	0.5865	0.5865	0.5860	0.5855

Note: t-ratios are reported within parentheses

The results appear rather robust in all versions. The $\overline{R}^2$ values range between 0.58 and 0.59, a satisfactory level for a large cross sectional data set. All the expectations on the signs of the coefficients are met, and all coefficients are generally highly significant.

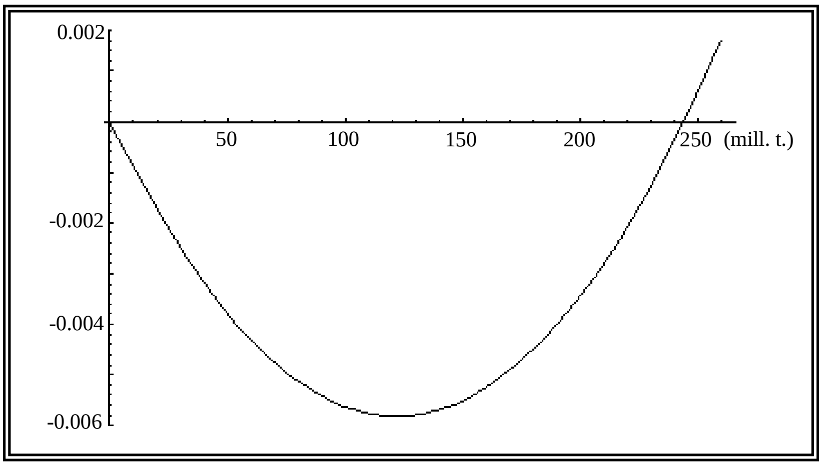
The first noticeable result is that all the coefficients for the variables aimed at reflecting the role of R&D activities on per capita GDP growth not only have the expected positive sign but are also highly statistically significant. With all the caveats concerning the measurement of this activity expressed in the previous section, this appears nonetheless a rather encouraging result.

The comparison between the results on the R&D variables for the different models allows to gain some insights on the role of the spatial knowledge spillovers. Indeed, it is possible to note that the inclusion of the spillovers in the R&D variable determines a generalised improvement in the regression results. Both the $\overline{R}^2$ values and the level of statistical significance of the coefficients for research activities are generally enhanced when these spatial effects are accounted for. At the same time, the statistical significance of the other variable closely related to innovation activity, the number of university staff, is also substantially improved by the inclusion of these effects. All these results could therefore be interpreted as supporting the view that spatial spillovers of knowledge are an important feature of innovation activities. Concentrating on those versions of the model that allow for these effects (columns 2-8), it is possible to analyse how the strength of interaction between research sectors of neighbouring FURs is affected by space. As explained in the previous section, these variables are calculated considering different distance ranges for the inter-regional spillovers. The distance ranges considered here vary from a minimum of 90 minutes to a maximum of 150 minutes. The best version of the model, both in terms of the regression $\overline{R}^2$ and of the *t*-ratios for the 'research activity' and the 'university' variables, corresponds to the R&DS3 variable (column 4), which allows for interaction between regional research sectors located within a range of 115 minutes. In other words, the strength of the inter-regional interaction between researchers appears to reach its strongest level when the researchers are within 115 minutes travelling time. Including the possibility of inter-regional spillover effects for time distances of more than 115 minutes reduces the significance of the variable.

Given these results, in what follows attention will be concentrated on the fourth version of the model. The coefficient for the index of specialisation of the local industrial structure is negative and significant at the 1% level. This suggests that, during the period covered by the analysis, those regions that at the beginning of this period were characterised by a higher degree of specialisation in their industrial structures have grown faster, other things being equal. With regard to the nature of the intra-regional spillovers, this result suggests that, in aggregate terms, intra-industry dynamic externalities have been more effective than inter-regional dynamic externalities in stimulating per capita GDP growth.

The role of port activities on regional growth according to the estimated coefficients is described in Figure 1.

Figure 1 The Role of Port Activities



As argued in the previous section, it is possible that the relation between port size and regional growth is quadratic, and the regression results seem to support this view. However, a closer look at the figure shows that the minimum point of the curve is reached for an amount of trade just exceeding 120 million tonnes. The only port that at that time was handling more than 100 million tonnes was the port of Rotterdam (with 259 million tonnes), whilst the second port in terms of goods handled was Marseille with 93 million tonnes. It is therefore likely that the functional form of the influence of port activities on regional growth is heavily influenced by the observation for Rotterdam. To check for this possibility, two further regressions are run in which the variable for port activity excludes Rotterdam. In the first of these regression the functional form for the influence of port activity of regional growth is linear; a quadratic form is instead considered in the second regression. The results of these regressions, together with the results of the best version of the previous set of regressions (version 4), are reported in Table 3.

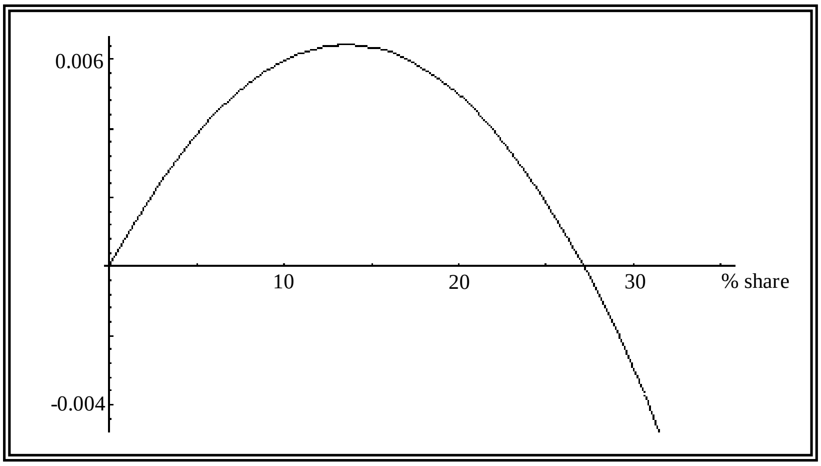
Table 3 The Influence of Port Activities

	4	9	10
Constant	0.00743	0.00851	0.00823
	(0.54)	(0.62)	(0.60)
R&DS3	5.92e-5	5.72e-5	5.76e-5
	(3.01)	(2.91)	(2.97)
University	4.23e-7	4.16e-7	4.16e-7
	(2.48)	(2.46)	(2.47)
Coal	-0.00336	-0.00340	-0.00340
	(-2.62)	(-2.66)	(-2.67)
Port	-9.54e-5	-	-
	(-2.43)		
$Port^2$	3.91e-7	-	-
	(2.20)		
Port2	-	-6.15e-4	-7.30e-4
		(-0.82)	(-2.47)
$Port2^2$	-	-1.78e-5	-
		(-0.17)	
Service	0.01630	0.01649	0.01658
	(2.07)	(2.12)	(2.15)
Specialisation	-0.03907	-0.03979	-0.03967
	(-2.52)	(-2.59)	(-2.59)
Agriculture	9.55e-4	9.43e-4	9.44e-4
	(4.21)	(4.19)	(4.22)
$Agriculture^2$	-3.50e-5	-3.48e-5	-3.48e-5
	(-5.48)	(-5.49)	(-5.51)
Density	-0.00954	-0.00942	-0.00947
	(-4.09)	(-4.02)	(-4.09)
SDG	0.20424	0.20356	0.20343
	(5.13)	(5.14)	(5.16)
NFGrowth	1.02832	1.01503	1.01784
	(6.98)	(6.90)	(6.99)
DSE	-0.00954	-0.00942	-0.00947
	(-4.09)	(-4.02)	(-4.09)
$\overline{R}^2$	0.5866	0.5873	0.5910

These results seem to confirm the impression that the quadratic form is in fact due to the very high leverage on the observation for Rotterdam. The coefficients for "Port2" and "$Port2^2$", the variables on port activity which exclude the observation for Rotterdam, are both statistically non significant, thus rejecting the hypothesis of a quadratic form for the influence of the other European ports on regional growth. On the contrary, when the relation between port activity and growth is assumed to be linear (version 10), the coefficient is negative and highly significant. In other words, it seems possible to conclude that, generally speaking, port activity has a negative influence on the growth prospects of a region. The most noticeable exception is represented by Rotterdam. The explanation of these results may be outcome of successful port re-structuring in Rotterdam or might be the outcome of other factors specific to the Rotterdam FUR.

As for the role of agriculture, the results of the regression confirm the expectation of a quadratic relationship with regional growth. This relationship, which is represented in Figure 2, is stable to changes in the port variable. For both version 4 and 10, the curve representing the influence of the share of employment in agriculture, reaches its maximum for a value of 13.6. Differently to the previous case, almost one sixth of the observations in the database have a value exceeding the maximum.

Figure 2 The Role of the Share of Employment in Agriculture



Finally, a set of diagnostics have been performed on version 4 and version 9 of the model. The first test being performed is the Kiefer-Salmon test for the normality of the residuals. Heteroscedasticity is tested with two different diagnostics, the Breusch-Pagan (BP) Lagrange Multiplier test and the Koenker-Bassett (KB) test. However, following the testing procedure in *SpaceStat* (see Anselin 1994) only one test against heteroscedasticity is actually carried out depending on the results of the normality test. When the errors are non-normal (for a probability level of 0.01) the KB test is preferred to the BP test. The Ramsey's RESET test is then used to check the functional form. Finally, four separate diagnostic statistics for spatial dependence are produced: Moran's I statistic, Burridge's Lagrange multiplier test, Kelejian and Robinson's test for *spatial error*, and Anselin's test for *spatial lag* (for details see Anselin 1988 and 1994). In each case the tests are based upon both distance matrices used in the derivation of the variables of the model. All diagnostics excluded the presence of specification problems with either of the two preferred versions of the model.

5 Conclusions

The results of the regression analyses lend some support to the main predictions of the theoretical model sketched in Section 2. These results can be summarised as follows. Firstly, research activities appear to play an important role in the process of regional growth. Indeed, the coefficients for the variables measuring regional research efforts are always positive and highly significant. Secondly, by considering different specifications of the spatial interaction between researchers, it has been possible to find evidence supporting the existence of spatial spillovers of knowledge. The effects of inter-regional spillovers of knowledge are maximised if interactions are assumed to extend to a distance determined by about 2 hours travelling time. Thirdly, several factors affecting the regional growth rate of per capita GDP by shaping the local level of technological competence in research have been identified. One of these factors appears to be the existence of universities. These contribute to the regional research effort both directly, in their role of centres of research, and indirectly, as that part of the regional infrastructure that provides new human capital. Data limitations do not allow these effects to be analysed separately. Nonetheless, the empirical analysis suggests the conclusion that one or both of these effects have a significant positive impact on regional growth. Finally, another interesting outcome concerns the controversy on the relative importance of intra-industry and inter-industry dynamic spillovers in promoting growth. An index of the degree of sectoral specialisation of regional industrial specialisation has been used to shed light on this largely debated issue. The results indicate that, during the period 1979-1990, European regions characterised by a higher degree of sectoral specialisation have grown faster than regions with a more diverse industrial structure. In other words, intra-regional dynamic spillovers appear to have been more successful than inter-regional dynamic spillovers in fostering regional economic growth.

Finally, a note of caution derives from the fact that data limitations have, in some instances, lead to the use of raw measures of the variables indicated by the theoretical model. In particular, this appears to be the case for the variable related to the research activity. Although the lack of spatially disaggregated data on employment in research has forced to adopt a crude measure of the research activity, this measure appears nonetheless appropriate in order to provide a first indication of the influence of research activities on regional growth.

Notes

[1] The present analysis adopts the set of functional regions derived by Hall and Hay (1980). Each of these regions, termed Functional Urban Regions (FURs), is derived from a two-step procedure. Firstly, a core is defined by identifying an urban centre with 20,000 jobs or more, and adding all those contiguous surrounding areas -at the lowest level of disaggregation available- which have a density of 12.35 jobs per hectare or greater. Secondly, to each core are added all those contiguous administrative areas from which more workers commuted to the core in question than to any other core. As argued by Cheshire and Hay (1980), Cheshire and Carbonaro (1996), Cheshire, Furtado and Magrini (1996) and Magrini (1998a), because of the very nature of regional economic disparities, any empirical study on the subject must take space into consideration and opt for a definition of region centred on the spatial sphere of socio-economic influence of any basic unit. Since the functional links between spatial units are limited by space, functional regions take explicit account of the distance factor and appear therefore as a suitable choice.

[2] The sources of data on academic employment are the *International Handbook of Universities*, (7th edition; London: The Macmillan Press, 1978) by The International Association of Universities; the *Commonwealth University Yearbook 1979*, (55th edition; London: The Association of Commonwealth Universities, 1978) by the Association of Commonwealth Universities; and *The World of Learning 1978-1979*, (29th edition; London: Europa Publications, 1978). Moreover, due to the different national education systems, it has been necessary to identify comparable institutions on the basis of the *International Guide to Qualifications in Education*, (2nd edition; London: Mansell Publishing, 1990) by the British Council.

[3] The index of specialisation is calculated on the basis of data on employment for 9 industrial NACE classes. In particular, the employment in each regional sector is expressed as a percentage of the total industrial employment in the region. After having ranked the sectors by size, the index of regional specialisation is calculated as the ratio between the average percentage of employment for the smallest four regional sectors, over the average percentage of employment in the largest four ones. The index, therefore, ranges between 0 and 1, these two extremes indicating respectively specialisation and diversity in the regional industrial structures. The data on employment 1980 are derived from the REGIO Databank (Eurostat). In the case of Greece and Portugal this source has been complemented by the respective national statistical offices. For the breakdown of the sectors see Magrini 1998b.

[4] A dummy variable for the Italian Mezzogiorno has also been introduced in the model. However, the inclusion of this variable has always proven to add no explanatory power to the model.

[5] The FURs included in this variable are Alicante, Cordoba, Granada, Malaga, Murcia, and Sevilla.

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