Structural and Spatial Aspects of Regional Inequality in Spain

by

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Abstract:

In this paper we examine differences in Spain's regional economies and how these differences might be taken into account in designing policies to reduce regional inequality. Toward this end, we first set out a basic model of regional economic growth and develop time series corresponding to the theoretical variables of this model. We estimate from these series the model's parameters in the case of each of the regions of Spain to analyze structural differences in the nature of the economic growth processes at work. Making use of an approximation employed in projection methods, we also compute spatial gradients of growth rates for the regions of Spain to examine how these rates are changing through time as one moves across space relative to a reference location.

1. Introduction

Spain is the European country in which disparities in regional income per capita have increased the most over the last twenty years. While neoclassical economic growth theory would lead us to expect that decreasing returns in reproducible factors would eliminate regional disparities through equalization of capital/labor ratios, there has been no apparent relationship between the development gap and the speed at which Spanish regions are catching up, except in the regions of Melilla and Baleares. Extremadura, for instance, has been the poorest region for more than twenty years and its per capita income has never exceeded 70% of the national average. On the other hand, per capita incomes in La Rioja, Aragon, Madrid and Cataluña have exceeded the national average by a wide margin (Neven and Gouyette, 1995; Fayolle and Lecuyer, 2000). From considerations of equity as well as politics, unequal regional development is unacceptable. It is especially so since the successive enlargements of the European Community/European Union (EU) have made regional disparities so obvious that current programs of the European Commission to reduce them account for as much as one-third of the EU budget. Since the beginning of its membership in 1986, Spain has received more regional development funds (in absolute value) than any other country with, respectively, one quarter and one half of all structural and cohesion funds. Between 1989 and 1999 Spain received 66.6 billion euros in funds. (See Table 1 for an accounting of structural funds received by Spanish regions over this period of time.)

Figure 1 : The Regions of Spain

Table 1: Allocation of Structural Funds per Region and per Year (in million euros)

	1989	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
Total Spain	644	592	1318	1526	1532	1051	2528	2636	2190	2960	3023
Galicia	68	84	98	284	271	208	475	561	528	331	725
Asturias	76	26	175	66	56	72	178	154	176	164	143
Cantabria	7	19	23	12	31	43	46	77	152	89	111
Pais Vasco	38	37	84	90	160	50	125	184	54	358	29
Navarra	6	6	16	24	32	9	41	60	49	36	19
La Rioja	2	1	11	11	8	5	12	13	12	17	29
Aragon	53	39	53	70	88	24	78	90	95	105	121
Madrid	22	12	56	35	59	22	63	54	32	138	131
Castilla y Leon	106	142	187	225	246	131	422	368	262	447	590
Castilla-la Mancha	124	113	188	236	81	125	297	207	294	121	468
Extremadura	48	34	117	113	219	133	199	202	106	264	252
Cataluna	30	62	158	166	133	79	140	299	218	514	140
Comunidad Valenciana	64	17	152	194	148	150	452	367	212	376	265
Baleares	3	1	9	8	20	2	14	21	7	21	34
Andalucia	244	330	369	535	339	515	757	504	890	422	1259
Murcia	27	35	66	51	43	59	117	122	60	120	256

Source : Banco de España (2001), "Financial Accounts of the Spanish Economy 1995-2001", table III.3.4 and Banco de España (1998), "Financial Accounts of the Spanish Economy 1989-1998", table V.2.23

Why have regional development funds not been more helpful in reducing inequalities among the Spanish regions? Several explanations have been advanced in the literature. One explanation is that the agglomeration forces at work may be so powerful that giving a small advantage to a poor region will not alter the stability of the mechanism (Krugman, 1991; Faini, 1983). A second is that in Spain the most important part of EU funds (40%) has been used to finance new transportation infrastructures, its gap in infrastructure endowments with other EU members being even larger than in per capita incomes. However, transportation infrastructures can lead to agglomeration of firms in the richer area when they are built between regions of different levels of development. As a result, transportation infrastructure investments may not lead to reduction in spatial inequities (Martin, 1999; Vickerman *et al.*, 1999; Venables and Gasiorek, 1999). A third explanation is that rich regions are able through leveraging to triple or quadruple the amount of regional funds allocated by the Commission in the financing of a particular project (Fayolle and Lecuyer, 2000; Dall'erba, 2003). As a result, the total amount of investment in some rich regions may be much higher than in poor regions, which are hard put to match the targeted amount of regional funds.

There are good reasons to believe that regional funds might have been better spent in promoting education, research, and labor mobility in the attempt to reduce regional disparities. While such objects of expenditure do receive modest support from the EU, we may well wonder whether their effect on regional growth has been underestimated and the effect of transportation infrastructures overestimated.

Another possible explanation for divergence in regional economic performance may be physical differences in locations, as Parker (2000) and a long line of predecessors, who have emphasized differences in resource endowments, have suggested. Although Parker's analysis has focused more upon the spatial correlation of performance measures of economies that share the same latitude and political system than upon the correlation (or lack thereof) of performance measures of economies of regions that are physically proximate, the physical differences in rich and poor regions of the same country may be important. In spite of a recent surge in scholarship on convergence and divergence in regional economic performance the etiology of regional inequality and its reduction remains somewhat of a black box.

In this paper we do not attempt to test any of the above mentioned possible explanations of why regional inequality in Spain has persisted; nor do we supply an alternative general causal account. Rather, we take a closer look at some of the differences in Spain's regional economies and explore how these differences might be taken into account in designing policies to reduce regional inequality. Toward this end, we first elaborate a basic model of regional economic growth and develop time series corresponding to the theoretical variables of this model. We estimate from these time series the model's parameters in the case of each of the regions of Spain to examine structural differences in the nature of the economic growth processes at work. Making use of an approximation employed in solving functional equations by projection methods, we also use these data to compute spatial gradients of growth rates for the regions of Spain to examine how these rates are changing as one moves relative to a reference location.

The paper's second section sets out the regional growth model, describes the development of the time series data and the estimation of the model, and presents and discusses the parameter estimates for the regional economies. The third section introduces the notion of spatial gradients of regional growth rates, discusses the computation of these gradients, and offers comparisons across the regions. The paper concludes with a brief summary of our findings and their implications.

2. Model, Data, and Estimation

As our point of departure we assume that for any region *l* in a nation of *R* regions there is an underlying technological relationship between gross regional product, Y_l, human capital, HC_l, physical capital, K_l, labor, L_l, and energy, N_l, all of which we consider in real *per capita* terms. Each of these variables is taken to be a function of time, *t*, and two dimensions of space, x_1 and x_2. That is, $Y_l(x_1,x_2,t)$, $HC_l(x_1,x_2,t)$, $K_l(x_1,x_2,t)$, $L_l(x_1,x_2,t)$, and $N_l(x_1,x_2,t)$. Suppressing arguments in space and time, the relationship between these variables is assumed to take the form of a generalized constant-elasticity-of-substitution (or CES) production function,

$$Y_l = g_l[f_l VA_l^{-r_l} + (1-f_l)N_l^{-r_l}]^{-k_l/r_l}\text{, where } g_l, f_l, r_l, k_l \geq 0, \qquad (1)$$

where *VA* is a value-added aggregator function of the form

$$VA_l = a_l HC_l^{b_{1l}} K_l^{b_{2l}} N_l^{b_{3l}}\text{, where } \sum_n b_{nl} = 1.0\text{, and } a_l, b_{1l}, b_{2l}, b_{3l} \geq 0.$$

The technology manifests decreasing, constant, or increasing returns to scale, as the returns-to-scale parameter k is less than, equal to, or greater than 1.0.[1] All other parameters have standard interpretations: g and a are efficiency parameters, f is the factor intensity parameter for the upper-level CES function, r is the substitution parameter, where $s = 1/(1+r)$ is the elasticity of substitution, and $b_1 - b_3$ are the input-intensity (and also output-elasticity) parameters in the value-added aggregator function. (See Ferguson, 1969.) We assume that all value-added output elasticities are non-negative. While acknowledging disagreement in the recent literature concerning the direction of causality of

[1]On this specification, see Henderson and Quandt (1980). In previous work we have employed a functional form similar to the Solow growth model allowing for the possibility of increasing returns to scale (Donaghy and Dall'Erba, 2003). We compare below our present findings with those obtained previously.

increases in rates of growth of output and energy use, and whether declining use of energy per capita might be associated with increasing output per capita (Cleveland *et al.*, 2000), we maintain the non-negativity hypothesis. Logarithmic differentiation of equation (1) with respect to time yields a growth model of the following form:

$$\begin{aligned}\frac{\dot{Y}_l}{Y_l} &= g_l^{-r_l/k_l} k_l f_l Y_l^{r_l/k_l} VA_l^{-r_l} \left(b_{l1}\frac{\dot{HC}_l}{HC_l} + b_{2l}\frac{\dot{K}_l}{K_l} + b_{3l}\frac{\dot{L}_l}{L_l}\right) \\ &+ g_l^{-r_l/k_l} k_l (1-f_l) Y_l^{r_l/k_l} N_l^{-r_l}\frac{\dot{N}_l}{N_l}.\end{aligned} \tag{2}$$

We wish to consider the relationship characterized by equation (2) in the case of the 16 regions of Spain, exclusive of the remote islands of Canarias and Ceuta y Mellila. To do so, appropriate time series must be obtained or constructed. The length of the time series is limited by the fewest available observations on any one of the variables in equation (1). Per capita gross regional product, Y_l, on which there are observations from 1980 through 1999, has the fewest. Observations on Y_l were obtained from the 2001 Eurostat database *NewCronos Regio*, the official database used by the European Commission for its evaluation of regional policy. Annual observations on per capita regional capital stocks, K_l, were constructed by the 'perpetual inventory method' from observations on the gross formation of fixed capital published by Cambridge Econometrics and observations on capital consumption published at the national level in *International Financial Statistics*, regional allocations of which were made proportional to gross fixed capital investment levels. Observations on Y_l and K_l are in 1990 euros per capita. Observations on the labor-force participation rate, L_l, were also obtained from Cambridge Econometrics. Observations on final energy consumption per inhabitant, expressed in tons petrol equivalent, were taken from the World Bank's World Development indicators database. However, since data on energy use exist only at the national level, the energy consumption of each region is imputed from its share in national electricity consumption taken from the *Regio* database, for which the values of missing observations were interpolated. Observations on a principal components index of human capital, *HC,* were developed from time series in two databases.[2] The first attribute included was 'expenditures in research and development per capita.' These expenditures are believed to promote regional growth by favoring innovation and growth in the region itself or by facilitating imitation of more advanced technologies already in use elsewhere (Cohen and Levinthal, 1989). Data on R&D expenditures per capita were taken from the *Regio* database; missing observations for several years were interpolated. The other attributes included in the human capital index are per capita counts of population members who have achieved three different education levels corresponding to junior high school, high school, and university. These data were provided by the Spanish National Institute of Statistics (Instituto Nacional de Estadística or INE) and were forecasted for the two final years using an autoregressive (or moving average) process of forecasting time series data. We therefore follow the applications of Mankiw, Romer and Weil (1990) and Lucas (1988), who provide strong arguments for the essential role of investment in human capital in the growth process. On their view, education facilitates innovation and diffusion of knowledge, which increases aggregate growth and reduces regional inequalities. For these reasons the educational attainment of workers is supposed to have a positive effect on growth. But, as Rodríguez-Pose (1996) has observed in the case of Spain, even if the level of education has increased over the recent decades, regional differences in human capital of the labor force remain great. The following table presents the means and standard deviations of the regional time series we employ in our study.

[2] Based on the scree plot, the principal component analysis shows that only the first component is significant and explains 83.9% of the variation of the data. The second and other components explain 10% or less of the variation and thus are not included in the analysis.

Table 2- Means and Standard Deviations of the Variables (in logs)

	GRP	Human capital	Energy	Capital stock	Labor force
Galicia	8.92909 0.11669	2.62202 0.80459	7.83158 0.15358	10.81973 0.11428	-0.87174 0.02123
Asturias	9.13458 0.08658	3.19666 0.54436	8.27220 0.10833	11.32518 0.09024	-0.98149 0.02204
Cantabria	9.16292 0.10619	3.15065 0.65547	8.10338 0.10758	10.93208 0.10303	-1.00168 0.04218
Pais Vasco	9.34743 0.11646	4.18297 0.60178	8.22055 0.08443	11.21541 0.12194	-0.94327 0.07355
Navarra	9.36641 0.13898	3.76738 0.70834	8.02979 0.13356	10.93134 0.12475	-0.94929 0.03989
La Rioja	9.31579 0.10760	2.02180 1.39783	7.58254 0.19660	11.20625 0.10653	-0.99349 0.04944
Aragon	9.25054 0.15847	3.47746 0.58666	7.95319 0.14049	10.81873 0.14269	-0.97900 0.05110
Madrid	9.35650 0.18185	4.95027 0.41603	7.51961 0.17995	10.60260 0.17100	-0.98409 0.08371
Castilla-y-Leon	9.08307 0.12479	3.04641 0.77759	7.51056 0.15207	10.83783 0.11991	-1.00029 0.04085
Castilla-La-Mancha	8.95799 0.15681	2.00263 1.04674	7.58466 0.18147	10.59568 0.12360	-1.06029 0.04355
Extremadura	8.73795 0.16979	2.35166 0.59121	6.69958 0.26916	10.11638 0.16283	-1.04930 0.04828
Cataluña	9.33622 0.17623	3.94741 0.65681	7.91569 0.16105	10.80991 0.15033	-0.91273 0.07461
Communidad Valenciana	9.14661 0.13268	2.96048 0.82832	7.60487 0.17705	10.67531 0.12392	-0.94872 0.06155
Baleares	9.42151 0.13943	2.28375 0.58555	7.62267 0.21311	10.72212 0.14442	-0.93834 0.07165
Andalucia	8.87270 0.12382	2.95856 0.64591	7.32132 0.17196	10.41323 0.10818	-1.07869 0.08720
Murcia	9.05366 0.13704	3.04201 0.61167	7.50776 0.14450	10.50077 0.11858	-1.01031 0.07248

From the summary statistics in Table 2, it is apparent that the richest regions of Spain in per capita terms are, in addition to Madrid and Baleares, the Northern regions of Pais Vasco, Navarra, La Rioja, and Cataluña. While the mean *per capita* gross regional product of some of these regions over 1980-1999 may be higher than that of Madrid or Cataluña, the latter regions now enjoy the highest per capita incomes by far. (Figure 2 depicts the mean *per capita* gross regional products and the mean growth rates in the same for 1980-1999.)

[Insert Figure 2 here]

This geographical distribution of income is also reflected in the distribution of regional human capital levels. There are two notable exceptions, however; the mean levels of human capital per capita of the rich regions of Baleares and La Rioja are lower than that of the poor region Extremadura. This might be explained by the fact that the economies of the former regions are based on labor-intensive industries, such as furniture and textiles production and tourism, while the economy of the latter is based on agriculture (wine production). The Northern regions are the best endowed with per capita stocks of physical capital (both private and public), while Extremadura is the least well endowed. Bearing in mind that the figures given in Table 2 for labor-force participation are in logarithms, so that the least negative numbers indicate the regions with the highest participation rates, it is apparent that the northern regions enjoy the highest employment rates while the southern regions and Castilla-La-Mancha and Castilla-y-Leon have the lowest. Regional levels of per capita energy consumption track per capita income levels, as the Northern regions are the highest consumers and Extremadura, which has little industry, consumes the least. Extremadura's regional production specializes in wine, olive oil, and cereals. Although, almost all of the energy consumed in Madrid is produced by its neighbors, this region is not the most important consumer of energy, perhaps because of its small size and concentrated development results in energy cost savings in transportation.

In most empirical studies of regional income convergence, regions are treated as isolated entities; geographical location and potential interregional linkages are not explicitly taken into account. Only recently has the role of spatial effects--upon estimates of parameters and their standard errors--been considered through the use of formal tools of spatial analysis and spatial econometrics. Examples of studies of European regions that make use of these tools include Fingleton (1999 and 2001), Baumont et al. (2001), and Bivand and Brunstad (2002). The thesis that informs these studies is that forces driving location and agglomeration processes and hence uneven regional development, such as productivity, transportation infrastructure, knowledge and technology spillovers, factor mobility, and local competition, have explicit geographical components. Donaghy (2001) and Donaghy and Plotnikova (2003) exposit and demonstrate an alternative approach to the estimation of spatial dynamic structural models that controls for the effects on estimation and inference of spatial dependence in data. In the research here reported we do not take either of these approaches for several reasons. We do not maintain as an underlying hypothesis that there is a *common structural model* shared by all the regional economies of Spain, whose common parameter values cannot be properly estimated, nor hypotheses about parameter values validly tested, without taking explicit account of spatial dependencies. Moreover, the short length of available time series and the number of regions involved render problematic the implementation of the approach for estimating structural spatial dynamic models set out by Donaghy (2001). Hence we estimate individual equations for the 16 regions of Spain *as if* they were autonomous.[3]

We have estimated the continuous-time regional growth model from the discrete-time series by the continuous-time econometric methods of Wymer (1993 and 1997) and obtained the quasi-FIML estimates of the parameters and their asymptotic standard errors presented in Table 3. We have imposed bounds upon the estimates of the input intensity parameters in the value-added aggregator function within the following ranges historically observed (reported) for industrial economies:

$$0.0 \leq b_{1l} \leq 0.10, \quad 0.10 \leq b_{2l} \leq 0.75, \text{ and } 0.10 \leq b_{31} \leq 0.90.$$

A necessary condition for the estimates of g_l and f_l to be economically meaningful is that they be non-negative. All such estimates obtained were non-negative without binding values.

[3]Hence we proceed as Barro and Sala-I-Martin (1995) have done in analyzing growth in the regions of Europe and the United States.

Table 3: Quasi-FIML Estimates of the Parameters and Their Asymptotic Standard Errors, and In-Sample Root-Mean-Square Errors (RMSEs) of Y_l

Region	b_{1l}	b_{2l}	b_{3l}	f_l	k_l	g_l	a_l	r_l	s_l	In-Sample RMSEs
Galicia	0.06432* (0.05457)	0.60987 (0.00037)	0.32579 (0.05429)	0.19775 (0.10960)	1.93099 (0.00458)	7.83720 (0.19748)	1.17869 (0.02864)	1.13761 (0.01667)	0.43147 (0.00310)	0.015032
Asturias	0.07946 (0.00100)	0.60537 (0.00009)	0.31515 (0.00108)	0.94010 (0.00598)	1.25696 (0.00059)	0.27938 (0.00059)	1.12382 (0.01374)	1.02021 (0.00227)	0.49499 (0.00055)	0.013087
Cantabria	0.09551 (0.00204)	0.51877 (0.00035)	0.38571 (0.00213)	0.10104 (0.00322)	1.26753 (0.00005)	0.27938 (0.00059)	8.16077 (0.21011)	1.25852 (0.00013)	0.44276 (0.00002)	0.017344
Pais Vasco	0.07026 (0.00034)	0.71431 (0.00017)	0.21541 (0.00035)	0.96973 (0.00016)	1.33057 (0.00030)	5.22591 (0.00602)	14.2746 (0.00066)	0.78854 (0.00051)	0.55911 (0.00015)	0.009756
Navarra	0.00992 (0.00162)	0.60517 (0.00107)	0.38490 (0.00252)	0.80748 (0.00412)	1.30590 (0.00027)	0.66967 (0.00574)	2.96360 (0.04222)	0.99920 (0.01763)	0.50019 (0.00441)	0.018934
La Rioja	0.09852 (0.00001)	0.55955 (0.00037)	0.34192 (0.00037)	0.97398 (0.00003)	1.49613 (0.05706)	1.07313 (0.31277)	9.31911 (0.07034)	1.09085 (0.04222)	0.47827 (0.00965)	0.016794
Aragon	0.09997 (0.00004)	0.74160 (0.00062)	0.15842 (0.00061)	0.97951 (0.00018)	1.18464 (0.00042)	0.66967 (0.00332)	1.09755 (0.00037)	1.15981 (0.00049)	0.46300 (0.00010)	0.013265
Madrid	0.09982 (0.00001)	0.63095 (0.00427)	0.26921 (0.00425)	0.92072 (0.00001)	1.24305 (0.01641)	1.04985 (0.01626)	6.39000 (0.00826)	0.93880 (0.03841)	0.51578 (0.01021)	0.007858
Castilla-y-Leon	0.04655 (0.00324)	0.60670 (0.00001)	0.34673 (0.00324)	0.67331 (0.00874)	1.34150 (0.00079)	1.06117 (0.00034)	5.38691 (0.00770)	1.13983 (0.00030)	0.45169 (0.00006)	0.010223
Castilla-La-Mancha	0.09999 (0.00003)	0.62752 (0.01503)	0.27248 (0.01506)	0.97980 (0.00002)	1.67305 (0.10515)	1.06685 (0.04914)	1.14395 (0.01626)	1.21389 (0.04433)	0.45169 (0.00904)	0.015442
Extremadura	0.07716 (0.00003)	0.58500 (0.00010)	0.33783 (0.00011)	0.96591 (0.00092)	1.48009 (0.00116)	0.95803 (0.00027)	2.77865 (0.07238)	1.06496 (0.00083)	0.48427 (0.00019)	0.020831
Cataluña	0.09527 (0.00001)	0.56794 (0.00249)	0.33677 (0.00249)	0.33753 (0.00448)	1.56677 (0.00391)	0.98770 (0.00972)	1.00139 (0.00001)	1.06687 (0.01072)	0.48382 (0.00251)	0.008281
Communidad Valenciana	0.00719 (0.00018)	0.60614 (0.00003)	0.38665 (0.00018)	0.96035 (0.00007)	1.00276 (0.00018)	1.00642 (0.00018)	8.28962 (0.00736)	0.99952 (0.00011)	0.50011 (0.00002)	0.013271
Baleares	0.09985 (0.00003)	0.57028 (0.06492)	0.32986 (0.06490)	0.97597 (0.00247)	2.03904 (0.43881)	2.00719* (1.34215)	1.15377 (0.01873)	1. 56824 (0.33356)	0.38937 (0.05057)	0.019384
Andalucia	0.09987 (0.00047)	0.40404 (0.03693)	0.49608 (0.03676)	0.97597 (0.00247)	2.80832 (0.16561)	0.78744 (0.01511)	1.17666 (0.00538)	1.76593 (0.05135)	0.36154 (0.00671)	0.011277
Murcia	0.07102 (0.00994)	0.64149 (0.00355)	0.28747 (0.01301)	0.84331 (0.02050)	1.40710 (0.01004)	0.42362 (0.02067)	1.20050 (0.00980)	1.18819 (0.01915)	0.45699 (0.00399)	0.017615

Note: Estimates of the asymptotic standard errors of the parameters are in brackets.
*Denotes that the parameter is not statistically discernible from zero at conventional levels of significance.

The estimated equations all fit the data very well. Since the variables are measured in natural logarithms, the standard deviations of the errors in the estimates of the dependent variable, or root mean-square errors (RMSEs), are in proportionate terms. The largest RMSE, for Extremadura, is only 0.021. Standard tests for autocorrelation and heteroskedasticity in the residuals (Durbin-Watson, Goldfeld-Quandt, and Breusch-Pagan) indicate that the hypotheses of uncorrelated and homoskedastic residuals cannot be rejected at conventional levels of significance. Of course, given the highly non-linear formulation of the model and the nature of the estimator, whatever linear association may exist between the ‘explanatory variables’ does not present a problem for obtaining unbiased estimates or drawing appropriate statistical inferences. Of the 128 parameters estimated (not including estimates of the elasticity of substitution, which were derived), all but two are discernible from zero at conventional levels of significance.

Considering now the estimates of the parameters of the upper-level CES function, what is immediately striking is the riect and robust evidence of increasing returns to scale in production in all regions during the study period; estimates of k_l range from 1.003 for Communidaad Valenciana to 2.808 for in Andalucia. While the estimate of k_l for Baleares, the most well-to-do region, in terms of per capita gross regional product, is the second largest at 2.04, and the analogous estimates for Cataluña and La Rioja are, respectively, the fifth and sixth largest at 1.567 and 1.496, we can nonetheless observe that the four least well-to-do regions--Andalucia, Castilla-La-Mancha, Extremadura, and Galicia--are among the seven regions with the largest estimated returns to scale. This suggests that investments of regional funds in the latter regions, *ceteris paribus*, should lead to greater proportional increases in gross regional product per capita per unit of expenditure. What is perhaps a more important implication is that since we do not observe decreasing returns to scale in reproducible factors of production, it is not reasonable to expect that disparities in regional *per capita* incomes are likely to be reduced through equalizations of capital-labor ratios. This suggests a role for regional policy if reduction in disparities is a public goal.

Also evident is that estimates of the substitution parameter r_l suggest that the elasticity of substitution--of energy inputs for value added in aggregate output--ranges in value, somewhat narrowly, between approximately 0.362 for Andalucia to 0.559 for Pais Vasco, a range generally observed for industrialized economies in the late 20th century (Bruno and Sachs, 1985). While Baleares is again the exception to the rule, the elasticity of substitution is generally smaller for poorer regions, indicating relatively greater difficulty in making adjustments to changes in the ratio of the value-added price index to the energy price index. Considering only the parameters of the upper-level CES function, there are evident similarities between the northern industrial regions of Navara, La Rioja, and Aragon. Estimates of the input intensity parameters in the CES function, f_l, suggest that in Galicia, Cantabria, and Cataluña, energy is used more intensively in production than in the other regions.

At the level of the value-added aggregator, we find structural similarities between the northern regions of Galicia, Asturias, and La Rioja, and between the neighboring regions of Cantabria and Pais Vasco. Generally speaking and excepting the case of Andalucia, the estimates of the input intensity (output elasticity) parameters suggest that regional production is intensive in physical capital and that further investment with regional funds in such capital will result in the greatest growth in output per capita.

We should note that the estimates of b_{1l} were at or close to their upper bound in the case of five regions--Aragon, Madrid, Castilla-La-Mancha, Baleares, and Andalucia--indicating that the output elasticity of human capital is likely to be larger than estimated. (In future estimation work this bound should be relaxed.) The regional estimates of b_{1l} and f_l together suggest that investment in human capital will have the greatest impact on gross regional product per capita in the poorer regions of Andalucia, Extremadura, and Murcia, but less so in Galicia and in Communidad Valenciana. Also benefiting from such investment would be the wealthier regions of Aragon, Asturias, Madrid, Pais Vasco, and La Rioja.

In Donaghy and Dall’Erba (2003) we employed an augmented version of the growth model of Solow (1956) but allowed for the possibility of increasing returns to scale.[4] For the same data employed in the present study, we obtained estimates of the input intensity parameters that suggested structural similarities between the northwestern regions of Galicia and Asturias, between the northern regions of Cantabria, Pais Vasco, Navarra, La Rioja, and Castilla-y-Leon, and between the eastern regions of Cataluña and Communidad Valenciana. While, as discussed above, some of these patterns found in the estimates obtained in the earlier study are borne out by the estimates obtained with the growth model based on the generalized CES function, some are decidedly not. And even as Akaike Information Criterion tests suggest that the additional structure and parameterization of the generalized CES function are not warranted to explain the variation in the regional growth rates, we deem that the additional information obtained from estimates of the more general model provides adequate justification for its implementation.

While the differences in parameter estimates obtained for the 16 regions suggest, among other things, which factors contribute most to growth in which regions and what kinds of investments of regional funds are most likely to be most effective in reducing inequalities in per capita income, we can probe more deeply into the nature of inequality by considering how regional growth rates of the variables in equation (2) vary as one moves across space. Thus we turn to the construction and examination of spatial gradients of regional growth rates.

3. Spatial Gradients

Equation (2) can be differentiated twice partially with respect to the two dimensions in space, yielding a somewhat unwieldy expression characterizing the relationship between the

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[4]The model estimated was the following:

$\frac{\dot{Y}_l}{Y_l} = l_l + e_l \frac{\dot{HC}_l}{HC_l} + b_{1l} \frac{\dot{K}_l}{K_l} + b_{2l} \frac{\dot{L}_l}{L_l} + b_{3l} \frac{\dot{N}_l}{N_l}$, where $\sum_n b_{nl} = 1.0$, and

$a_l, l_l, e_l, b_{1l}, b_{2l}, b_{3l} \geq 0$.

spatial gradients of the growth rates in equation (2). Since we would make no further use of this expression we do not provide it here. Each of these gradients may be interpreted as *the marginal change in the rate of growth of the relevant variable with an increase in distance from a reference point in the two dimensions of space.* To compute such gradients, we need first to express the variables for which growth rates are computed as explicit functions of time and space. This we can do by employing a technique used in solving functional equations by projection methods (Judd, 1998). In a projection method approach we are not looking for functions that solve the original problem exactly but rather functions that provide serviceable approximations. From the Weierstrass theorem, we know that any differentiable function, no matter how non-linear, can be approximated as closely as we like by a large sum of polynomial terms. Of course, for computational purposes, the number of terms must be finite. Hence, in the first step we choose as a candidate solution basis a set of finite polynomial approximations of our five variables. Their form and conditions are similar to those presented for the *per capita* stock of physical capital for some region *l*:

$$\hat{K}_l(x_{1l}, x_{2l}, t) = K_0(x_{1l}, x_{2l}) + \sum_{i=1}^{m}\sum_{j=1}^{n} a_{ij}(t) x_{1l}{}^{i} x_{2l}{}^{j} \quad . \tag{3}$$

In equation (3), x_{1l} and x_{2l} are spatial coordinates of location *l* (a centroid in the case of a region), $K_0(x_{1l}, x_{2l},)$ is the value of the physical capital stock at time $t=0$, and the $a_{ij}(t)$ are time-varying coefficients. Since $\hat{K}_l$ must satisfy the initial-value condition, $\hat{K}_l(x_{1l}, x_{2l}, t) = K_0(x_{1l}, x_{2l})$, at t=0, the further condition upon the time-varying coefficients of the approximation, $\sum_{i=1}^{m}\sum_{j=1}^{n} a_{ij}(t_0) x_{1l}{}^{i} x_{2l}{}^{j} = 0$, must also be satisfied. Defining a new variable

$$\tilde{K}_l(x_{1l}, x_{2l}, t) = K_l(x_{1l}, x_{2l}, t) - K_0(x_{1l}, x_{2l}), \tag{4}$$

equation (3) can be rewritten in matrix notation, for all regions $l=1, 2, \ldots, R$ at time *t* as

$$\mathbf{D}^{\tilde{\mathbf{K}}} = \mathbf{X_1 A X'_2}, \tag{5}$$

in which $\mathbf{D}^{\tilde{\mathbf{K}}}$ is an *RxR* diagonal matrix on whose principal diagonal are the deviations of the regional capital stocks from their initial levels, $\tilde{K}_l(x_{1l}, x_{2l}, t)$, $\mathbf{X_1}$ is an *Rxm* matrix of the *m* powers of *R* distance measurements in one dimension of space corresponding to *R* regions, $\mathbf{X_2}$ is an *Rxn* matrix of the *n* powers of the *R* distance measurements in the second dimension of space corresponding to the *R* regions, and **A** is an *mxn* matrix of the time-varying coefficients $a_{ij}(t)$. A solution for **A** at each point in time $t \neq t_0$ is given by

$$\mathbf{A} = (\mathbf{X_1}'\mathbf{X_1})^{-1}\mathbf{X_1}'\mathbf{D}^{\tilde{\mathbf{K}}}\mathbf{X_2}(\mathbf{X_2}'\mathbf{X_2})^{-1}. \tag{6}$$

The second step in the projection method of solving functional equations is to choose a degree of approximation for the polynomials. This choice will be dictated in part by considerations of feasibility and adequacy of the solution's accuracy. In the case of spatial dynamic models, data availability will also play a role. We follow Judd (1998), who found that *n*=10 works well for applications of projection methods in solving macroeconomic growth models. Hence, in the present case, we have set *m=n=10*.

Making use of the elements of the matrix of time-varying coefficients, **A**, one can derive an approximation for the growth rate, $\dot{K}_l / K_l$, at spatial coordinates x_{l1}, x_{l2} as

$$\frac{\dot{K}_l}{K_l} \approx \sum_{i=1}^{m}\sum_{j=1}^{n} \dot{a}_{ij} x_{l1}{}^{i} x_{l2}{}^{j} \,/\, \hat{K}_l, \tag{7}$$

and an approximation of the spatial gradient of this growth rate can be computed as

$$\frac{\partial \dot{K}_l / K_l}{\partial x_{l1} \partial x_{l2}} \approx [\sum_{i=1}^{m}\sum_{j=1}^{n} ij\dot{a}_{ij} x_{l1}{}^{i-1} x_{l2}{}^{j-1} \hat{K}_l - \sum_{i=1}^{m}\sum_{j=1}^{n} \dot{a}_{ij} x_{l1}{}^{i} x_{l2}{}^{j} (\frac{\partial^2 K_{l0}}{\partial x_{l1}\partial x_{l2}} - \sum_{i=1}^{m}\sum_{j=1}^{n} ij a_{ij} x_{l1}{}^{i-1} x_{l2}{}^{j-1})] / \hat{K}_l{}^2 . \tag{8}$$

The spatial gradients of the growth rates in equation (2) have been computed for all 16 regions and are presented in Appendix A. The coordinates used in forming the polynomial expansions for the approximations of the variables and their growth rates are those corresponding to the centroids of each region, relative to the coordinates of Barcelona, and are also given in Appendix A.

We should first observe that, in view of the fact that the coordinates of the centroids of the regions are given relative to the longitudinal and latitudinal coordinates of Barcelona, the values of the gradients indicate marginal changes in rates of change computed for small movements to the northeast. (Conversely, reversing sign gives marginal changes for southwest movements and a 'rectangle rule' can be used to infer the nature of changes for movements in other directions.)

Considering first the gradients for the rate of change in GRP per capita (in Table A of Appendix A), it is immediately obvious that the relative size of the gradients is very small. There is moreover a fair amount of variability in value and cyclicality in the gradients for all regions. While we found (as noted in the previous section) that Galicia and Asturias were structurally similar, the computed gradients for these regions differ in sign. And while the gradients in income per capita for Pais Vasco, Navarra, and La Rioja seem to be in step over time, those of other members of the northern constellation, Cantabria and Castilla-y-Leon, are not. (These observations seem to suggest that in subsequent work it might be better to compute gradients relative to regional poles instead of a single point.) Over the sample period, rates of change in income per capita in the poorest regions of Andalucia and Extremadura don't increase with a shift toward the northeast. This rate of change does increase in Baleares, however, with a shift to the southwest. Mean values of the spatial gradients of rates of change in gross regional products for the periods before and after 1989 are mapped in Figure 3.

[Insert Figure 3 here.]

Considering next the gradients for the rate of change in human capital per capita (in Table B of Appendix A), patterns similar to those observed for the three regional constellations identified in the previous section are apparent, with the exception of La Rioja breaking ranks with Pais Vasco and Navarra. Also emerging are patterns of substantial volatility in gradients for Galicia and La Rioja. Interestingly, the rate of change for Madrid, which had one of the highest output elasticities of human capital per capita and the highest mean value of the variable, seems least affected by a shift to the northeast.

In the spatial gradients computed for the rate of change in the stock of physical capital per capita (in Table D of Appendix A) there is the greatest monotonicity and least cyclicality observed. Over the sample period, the gradients faced as one moves northeast from centroids in Pais Vasco, Navarra, and Rioja are again similar, as are those for Madrid and Castilla-La-Mancha. One can reasonably infer from this that the hyperplane of spatial gradients for the per capita rate of physical capital formation is fairly flat.

We encounter the roughest 'terrain' in the spatial gradients of the rate of change in the labor force per capita (in Table E of Appendix A). The patterns for the regional constellations are again consistent, but the size and volatility of the gradients for Galicia, Asturias, and Extremadura are extraordinary. There also appear to be spikes in gradient values in 1980/81, 1985-1987, 1989-1991, and 1994/95. It would be instructive to determine what events in industrial labor relations may have corresponded to these periods.

The spatial gradients for the rate of change in energy use per capita (in Table C of Appendix A) are, like those for income per capita, small and variable. The patterns for the regional constellations again emerge, but others are difficult to discern.

4. Conclusions

In the foregoing we have elaborated, estimated and analyzed a basic model for characterizing how rates of growth in fundamental economic variables are related at the regional level in Spain. We have found that within the stylized setting of this model, and within the constraints of its maintained hypotheses, there is considerable variety in the economic structure of Spanish regions, even as there are constellations of similar regions. Most importantly, we have found strong evidence of increasing returns to scale in production in all regions. This suggests that regional disparities in income *per capita* are not likely to be reduced by equalization of capital-output ratios and that there is a role for regional policy to play in reducing disparities. We have pursued the structural analysis further in examining how regional rates of growth in income per capita, and factors in which explanations of changes in the former are sought, vary over space. Thus far we have only a fragmented picture of why regional inequalities persist and, although there are a number of candidate explanations, there is no consensus in regional economics as to the etiology of inequalities. In Donaghy and Dall'Erba (2003), however, we have sketched a state-space modeling approach for examining how these rates co-vary when a general causal theory is not well enough developed to inform our investigation. In the latter we have also shown how structural differences between regional growth processes can be taken into account in designing policies to minimize regional inequality in income per capita.

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Appendix A - Spatial Gradients

Table A – Spatial gradients of the rate of change in GRP per capita

	80/81	81/82	82/83	83/84	84/85	85/86	86/87	87/88	88/89	89/90	90/91	91/92	92/93	93/94	94/95	95/96	96/97	97/98	98/99
Galicia	1.41E-03	2.77E-03	2.11E-05	1.61E-03	-1.6E-02	6.84E-03	4.53E-03	1.33E-02	6.17E-03	2.01E-03	4.10E-03	7.13E-04	-1.0E-03	6.88E-03	5.68E-03	2.84E-03	8.09E-03	8.58E-03	5.53E-03
Asturias	4.41E-04	-5.1E-04	1.91E-03	-6.5E-03	-3.5E-07	2.15E-03	-1.6E-03	-4.7E-03	1.98E-04	-7.4E-04	-1.6E-03	-5.4E-04	3.53E-04	-4.2E-03	1.20E-03	-2.8E-04	-1.6E-03	-1.7E-03	-1.9E-03
Cantabria	-3.4E-04	1.58E-04	3.43E-04	2.56E-04	-1.1E-03	-6.0E-04	-8.9E-04	-3.5E-04	-8.1E-04	-7.9E-05	-4.1E-05	-1.8E-04	2.32E-04	1.60E-04	-9.5E-05	-1.5E-04	-2.8E-04	-6.1E-04	2.37E-04
Pais Vasco	8.73E-04	-8.9E-04	4.84E-04	6.42E-04	1.21E-04	2.98E-07	5.32E-04	7.32E-04	1.04E-03	4.09E-04	6.95E-04	-7.6E-05	-5.2E-04	6.33E-04	2.06E-04	5.28E-05	1.44E-03	1.11E-03	7.77E-04
Navarra	7.05E-04	-7.3E-04	3.44E-04	-1.1E-04	2.71E-04	2.84E-04	5.45E-04	1.75E-04	1.00E-03	4.37E-05	3.85E-04	-4.5E-05	-3.9E-04	2.64E-04	2.87E-04	5.18E-05	8.78E-04	7.32E-04	2.39E-04
La Rioja	8.35E-04	-8.5E-04	4.43E-04	4.51E-04	2.17E-04	8.23E-05	5.51E-04	6.06E-04	1.04E-03	3.48E-04	6.17E-04	-6.2E-05	-4.9E-04	5.08E-04	2.19E-04	5.73E-05	1.31E-03	1.03E-03	6.37E-04
Aragon	-2.6E-04	3.05E-04	-1.7E-04	-3.6E-04	-7.2E-04	7.50E-05	-1.7E-04	-4.0E-04	-2.2E-04	-6.4E-04	-2.2E-04	2.98E-05	2.08E-04	1.86E-04	1.22E-04	-1.9E-05	-6.3E-04	-5.4E-04	-4.2E-04
Madrid	-1.1E-04	1.51E-05	2.24E-04	3.68E-04	-6.9E-04	-4.0E-04	-4.5E-04	-1.1E-05	-3.8E-04	1.78E-05	8.53E-05	-1.0E-04	7.06E-05	2.54E-04	-5.8E-05	-8.1E-05	3.04E-05	-1.9E-04	2.82E-04
Castilla-y-Leon	-5.5E-04	3.14E-04	4.10E-04	-6.6E-04	-1.0E-03	-3.9E-04	-1.1E-03	-1.1E-03	-1.0E-03	-3.1E-04	-4.2E-04	-2.1E-04	3.84E-04	-4.9E-04	-4.3E-05	-2.1E-04	-8.8E-04	-1.1E-03	-2.3E-04
Castilla-La-Mancha	4.02E-04	-4.3E-04	3.32E-04	7.47E-04	-3.4E-04	-2.7E-04	6.73E-05	5.52E-04	3.34E-04	2.79E-04	4.70E-04	-7.7E-05	-2.4E-04	5.91E-04	4.80E-05	-2.9E-06	8.50E-04	5.49E-04	6.43E-04
Extremadura	8.7E-04	-7.5E-04	2.06E-03	-6.8E-03	8.65E-05	2.63E-03	-1.3E-03	-4.5E-03	8.24E-04	-6.2E-04	-1.4E-03	-5.1E-04	1.62E-04	-4.3E-03	1.51E-03	-1.7E-04	-1.0E-03	-1.2E-03	-1.8E-03
Cataluña	-9.1E-05	1.33E-04	1.50E-04	1.90E-04	1.19E-04	7.14E-04	8.50E-04	9.85E-04	7.53E-04	4.49E-04	3.46E-04	5.91E-05	-2.5E-04	3.98E-04	3.24E-04	1.93E-04	6.10E-04	5.51E-04	4.41E-04
Communidad Valenciana	-5.1E-04	5.8E-04	-2.8E-04	-2.3E-04	-9.3E-04	-4.1E-05	-3.5E-04	-3.8E-04	-5.6E-04	-6.7E-04	-3.1E-04	5.05E-05	3.46E-04	2.03E-04	3.69E-05	-3.2E-05	-9.1E-04	-8.0E-04	-4.7E-04
Baleares	-6.3E-04	-9.4E-04	-9.6E-04	-1.1E-03	1.05E-03	1.81E-04	-1.2E-03	-1.1E-03	-3.9E-04	-1.1E-03	-7.9E-04	-1.9E-04	1.45E-04	6.75E-05	-8.7E-05	-8.7E-05	-1.5E-03	-4.8E-04	-4.2E-04
Andalucia	-3.9E-04	2.24E-04	3.22E-04	-7.1E-04	-6.6E-04	-1.9E-04	-8.9E-04	-9.9E-04	-7.4E-04	-3.1E-04	-3.9E-04	-1.3E-04	3.14E-04	-5.2E-04	1.18E-05	-1.6E-04	-7.4E-04	-8.8E-04	-3.1E-04
Murcia	4.42E-04	-4.6E-04	2.13E-04	-1.2E-04	1.46E-04	2.04E-04	3.46E-04	6.45E-05	6.42E-04	-1.2E-05	2.22E-04	-2.8E-05	-2.4E-04	1.65E-04	1.93E-04	3.08E-05	5.25E-04	4.42E-04	1.13E-04

Table B – Spatial gradients of the rate of change in human capital per capita

	80/81	81/82	82/83	83/84	84/85	85/86	86/87	87/88	88/89	89/90	90/91	91/92	92/93	93/94	94/95	95/96	96/97	97/98	98/99
Galicia	6.9985	50.9294	9.2195	24.5000	49.4647	52.8093	39.7177	66.9354	58.0022	54.0245	60.5608	106.2539	-38.9226	-34.4758	77.3787	8.5445	21.2432	11.8735	16.2978
Asturias	1.6438	-3.7125	0.2442	-1.1747	-3.1808	-2.5597	-2.5134	-7.7863	0.1872	-6.1329	-1.8384	-5.8412	3.9360	-7.0050	9.7752	-7.6094	-1.7843	-3.7043	-0.7219
Cantabria	-0.2746	-0.2300	0.1706	0.0326	-0.2683	-0.4457	-0.2436	2.3109	-0.3935	-4.1668	-2.6239	0.0514	4.6057	-0.9567	-9.8487	0.9190	-2.3556	0.2014	3.2261
Pais Vasco	0.3259	1.6631	0.4502	0.8981	1.6907	1.6692	1.3923	3.3781	4.5887	2.7009	3.1209	0.7098	1.3232	-1.2156	-1.3245	1.4079	-0.5270	2.6176	1.2751
Navarra	0.4126	1.6566	0.4977	0.9308	1.7376	1.7735	1.4577	2.0769	6.4856	5.2139	3.6646	-0.5220	1.3277	-2.1746	1.2394	0.8310	-0.6079	2.7298	1.3388
La Rioja	9.5383	42.1157	11.9956	23.2222	38.7941	33.5826	25.4717	53.0956	52.8326	23.0948	23.0262	2.9944	9.3673	-10.6144	1.0096	7.8031	-1.9968	12.9145	5.1411
Aragon	-0.3861	-1.1299	-0.2605	-0.5731	-1.1172	-1.0672	-0.8818	-3.8724	-1.1178	2.1668	-2.1001	-2.7006	0.3639	-0.3289	1.3254	-1.2573	-0.1668	-0.8475	-0.1462
Madrid	-0.0121	0.0601	0.0280	0.0398	0.0589	0.0493	0.0532	0.4016	0.0992	-0.1528	0.0585	0.0356	0.4345	-0.0755	-0.9092	0.1716	-0.1851	0.2937	0.2342
Castilla-y-Leon	-0.4073	-2.5631	-0.1852	-1.0508	-2.5121	-2.5498	-1.9999	-2.3981	-3.9433	-5.9903	-3.0290	-3.0035	3.9078	-0.6511	-6.2446	-1.6218	-2.0472	-0.0352	-0.5098
Castilla-La-Mancha	1.5632	10.8351	3.1028	6.1811	10.4443	9.0679	7.3174	18.2780	14.1309	4.7438	7.6508	2.8591	6.3042	-3.8762	-6.2539	4.9171	-1.4138	7.7572	3.3501
Extremadura	3.0291	-3.8479	0.7523	-0.8833	-2.9986	-1.9327	-2.3221	-10.0272	5.4583	-4.7110	0.5957	-5.6452	4.1159	-12.3975	19.5986	-11.4992	-2.2536	-4.3953	-0.2795
Cataluña	0.1655	0.9613	0.0553	0.3899	0.8693	1.0126	0.7026	1.9289	0.7926	1.6212	0.7809	0.4200	-0.4532	-0.2952	0.4413	0.4751	0.1792	0.9203	0.2154
Communidad Valenciana	-1.2723	-3.7545	-0.9670	-1.9750	-3.7787	-3.6748	-3.0062	-9.7849	-6.6045	1.3604	-6.5905	-5.5289	0.4493	0.6314	1.7889	-2.7969	-0.1076	-2.6874	-0.9953
Baleares	0.1902	-7.0221	-0.7240	-3.0224	-6.7246	-6.2434	-5.2737	9.6727	-9.4823	-5.1134	-13.1199	1.0172	4.8393	-6.9846	-13.3558	-9.3472	-4.9842	-8.7524	1.4291
Andalucia	-0.1695	-1.6346	-0.1311	-0.6645	-1.6423	-1.7421	-1.4733	-1.9438	-4.4132	-5.5015	-3.8187	-2.4829	1.2152	0.7909	-4.2998	-1.8126	-0.8718	-1.5112	0.3761
Murcia	0.3337	1.3446	0.4098	0.7611	1.4324	1.4850	1.2233	1.4019	5.2904	5.2466	2.6324	1.2576	0.2561	-1.9890	1.2182	0.6960	-0.0533	2.2440	1.8743

Table C – Spatial gradients of the rate of change in energy consumption per capita

	80/81	81/82	82/83	83/84	84/85	85/86	86/87	87/88	88/89	89/90	90/91	91/92	92/93	93/94	94/95	95/96	96/97	97/98	98/99
Galicia	5.96E-04	-2.0E-02	1.06E-03	4.77E-03	7.00E-03	1.16E-02	8.91E-03	6.98E-04	1.01E-01	-4.0E-03	2.17E-02	1.64E-02	-2.2E-02	3.44E-02	-4.8E-02	6.48E-02	1.04E-02	2.13E-02	9.69E-03
Asturias	1.25E-03	7.66E-04	-2.7E-03	-3.3E-03	-2.7E-03	-6.0E-04	-3.6E-03	-6.2E-03	-1.3E-02	-1.4E-03	-5.7E-03	-4.6E-03	1.81E-03	-6.1E-03	3.59E-03	-1.9E-02	-3.4E-03	-5.4E-03	-3.6E-03
Cantabria	-1.7E-03	4.01E-05	-2.6E-04	-3.2E-04	-3.8E-04	-6.3E-04	-3.7E-04	2.50E-03	-1.9E-04	-6.0E-03	-3.5E-04	-2.5E-04	2.98E-04	8.75E-04	-1.9E-04	2.66E-03	-2.7E-03	-4.1E-04	-3.0E-04
Pais Vasco	-4.0E-05	-2.7E-03	4.16E-04	8.41E-04	1.34E-03	1.02E-03	1.34E-03	6.49E-03	6.45E-03	-4.0E-03	2.30E-03	1.65E-03	-2.9E-03	9.11E-04	-8.4E-04	8.68E-03	2.59E-03	2.93E-03	1.31E-03
Navarra	-5.2E-06	-1.8E-03	1.51E-05	3.24E-04	8.12E-04	8.19E-04	7.25E-04	4.53E-03	3.30E-03	-1.8E-03	1.24E-03	7.88E-04	-2.5E-03	2.73E-04	2.64E-04	3.84E-03	2.32E-03	1.89E-03	7.04E-04
La Rioja	1.71E-04	-4.1E-03	7.45E-04	1.58E-03	2.62E-03	2.10E-03	2.58E-03	1.24E-02	1.22E-02	-6.7E-03	4.39E-03	3.13E-03	-5.7E-03	1.43E-03	-1.3E-03	1.58E-02	5.59E-03	5.69E-03	2.53E-03
Aragon	-1.4E-03	6.31E-04	-6.1E-04	-8.2E-04	-1.1E-03	-8.2E-04	-1.0E-03	-2.1E-03	-4.1E-03	4.82E-04	-1.6E-03	-1.2E-03	9.72E-04	8.99E-04	8.81E-04	-4.8E-03	-2.7E-03	-1.7E-03	-9.9E-04
Madrid	-2.2E-03	-5.2E-04	-9.1E-05	-2.1E-05	-1.2E-05	-5.0E-04	5.70E-05	5.14E-03	2.33E-03	-8.8E-03	4.19E-04	3.28E-04	-4.4E-04	1.70E-03	-7.3E-04	6.74E-03	-2.7E-03	4.97E-04	6.93E-05
Castilla-y-Leon	-2.7E-03	1.38E-03	-1.3E-03	-1.7E-03	-2.0E-03	-1.8E-03	-2.1E-03	-3.3E-04	-7.5E-03	-8.4E-03	-3.3E-03	-2.5E-03	2.40E-03	-5.1E-04	1.48E-03	-5.1E-03	-6.7E-03	-3.6E-03	-2.2E-03
Castilla-La-Mancha	-8.4E-04	-1.9E-03	4.51E-04	8.51E-04	1.23E-03	7.01E-04	1.30E-03	7.33E-03	7.00E-03	-6.3E-03	2.35E-03	1.74E-03	-2.5E-03	1.66E-03	-1.3E-03	1.06E-02	1.27E-03	2.86E-03	1.30E-03
Extremadura	6.93E-03	4.30E-04	-9.9E-03	-1.1E-02	-8.7E-03	-2.4E-04	-1.2E-02	-2.1E-02	-4.0E-02	-3.0E-03	-1.9E-02	-1.5E-02	3.52E-03	-2.2E-02	1.14E-02	-6.8E-02	-8.1E-03	-1.7E-02	-1.2E-02
Cataluña	1.85E-03	-1.4E-03	5.57E-04	-04	6.55E-04	1.60E-03	1.10E-03	4.21E-03	4.66E-03	8.61E-04	2.04E-03	1.49E-03	-2.2E-03	2.82E-03	-5.3E-03	6.24E-03	3.03E-03	2.36E-03	1.18E-03
Communidad Valenciana	-2.2E-03	1.62E-03	-8.7E-04	-1.3E-03	-1.9E-03	-1.5E-03	-1.8E-03	-4.6E-03	-6.9E-03	9.98E-04	-2.8E-03	-2.1E-03	2.39E-03	1.63E-03	8.69E-04	-7.9E-03	-5.1E-03	-3.2E-03	-1.7E-03
Baleares	-1.2E-03	1.93E-03	-3.0E-03	-3.9E-03	-4.1E-03	-2.5E-03	-4.5E-03	-1.3E-02	-1.4E-02	-4.0E-03	-5.1E-03	-3.8E-03	5.23E-03	-4.6E-03	1.19E-02	-1.1E-02	-9.3E-03	-6.9E-03	-3.9E-03
Andalucia	-1.7E-03	1.20E-03	-1.1E-03	-1.5E-03	-1.7E-03	-1.4E-03	-1.9E-03	-1.3E-03	-6.9E-03	-5.4E-03	-3.0E-03	-2.3E-03	2.08E-03	-1.2E-03	1.95E-03	-6.2E-03	-5.0E-03	-3.3E-03	-1.9E-03
Murcia	-1.2E-04	-1.3E-03	-6.8E-05	1.52E-04	5.20E-04	5.70E-04	4.48E-04	3.33E-03	2.09E-03	-1.2E-03	8.01E-04	4.80E-04	-1.9E-03	2.42E-04	3.68E-04	2.43E-03	1.64E-03	1.33E-03	4.60E-04

Table D – Spatial gradients of the rate of change in the stock of physical capital per capita

	80/81	81/82	82/83	83/84	84/85	85/86	86/87	87/88	88/89	89/90	90/91	91/92	92/93	93/94	94/95	95/96	96/97	97/98	98/99
Galicia	2.86E-04	3.20E-04	3.28E-04	3.39E-04	5.12E-04	7.42E-04	4.26E-04	4.52E-04	4.69E-04	4.70E-04	5.01E-04	5.45E-04	5.76E-04	1.04E-03	5.52E-04	5.55E-04	5.55E-04	4.91E-04	4.70E-04
Asturias	1.01E-04	-9.1E-05	-8.5E-05	-1.0E-04	-9.1E-05	1.77E-05	-1.0E-04	-1.1E-04	-1.0E-04	-1.1E-04	-1.1E-04	-1.2E-04	-1.2E-04	-4.6E-04	-1.1E-04	-1.1E-04	-1.1E-04	-1.0E-04	-1.0E-04
Cantabria	-1.2E-04	-2.7E-05	-2.6E-05	-2.5E-05	-3.6E-05	-5.2E-05	-3.6E-05	-3.6E-05	-3.8E-05	-3.9E-05	-4.0E-05	-4.0E-05	-4.0E-05	2.37E-06	-2.9E-05	-2.9E-05	-3.0E-05	-2.5E-05	-3.3E-05
Pais Vasco	2.04E-05	4.38E-05	4.52E-05	4.93E-05	8.89E-05	6.88E-05	6.08E-05	6.27E-05	6.60E-05	6.61E-05	7.11E-05	7.75E-05	8.21E-05	6.07E-05	8.53E-05	8.56E-05	8.69E-05	7.65E-05	6.08E-05
Navarra	3.58E-05	3.45E-05	3.55E-05	3.59E-05	7.31E-05	7.27E-05	4.92E-05	4.96E-05	5.42E-05	5.28E-05	5.63E-05	6.10E-05	6.40E-05	1.75E-05	6.67E-05	6.78E-05	6.82E-05	5.99E-05	4.81E-05
La Rioja	2.62E-05	3.79E-05	3.91E-05	4.21E-05	7.74E-05	6.29E-05	5.30E-05	5.44E-05	5.76E-05	5.75E-05	6.17E-05	6.71E-05	7.10E-05	4.33E-05	7.32E-05	7.37E-05	7.47E-05	6.56E-05	5.25E-05
Aragon	-7.7E-05	-2.5E-05	-2.6E-05	-2.9E-05	-5.6E-05	-3.6E-05	-3.9E-05	-3.9E-05	-4.0E-05	-4.3E-05	-4.6E-05	-4.9E-05	-5.2E-05	2.12E-05	-4.7E-05	-4.6E-05	-4.7E-05	-4.1E-05	-3.4E-05
Madrid	-1.1E-04	-1.3E-05	-1.2E-05	-9.3E-06	-1.2E-05	-3.7E-05	-1.7E-05	-1.6E-05	-1.8E-05	-1.8E-05	-1.8E-05	-1.6E-05	-1.5E-05	3.93E-05	-4.5E-06	-4.4E-06	-4.6E-06	-2.7E-06	-1.3E-05
Castilla-y-Leon	-1.1E-04	-5.7E-05	-5.5E-05	-6.0E-05	-8.1E-	-05-05	-7.3E-05	-7.5E-05	-7.8E-05	-7.9E-05	-8.3E-05	-8.7E-05	-9.0E-05	-1.0E-04	-7.8E-05	-7.8E-05	-8.0E-05	-6.9E-05	-7.2E-05
Castilla-La-Mancha	-3.1E-05	2.91E-05	3.03E-05	3.52E-05	6.01E-05	3.28E-05	3.95E-05	4.18E-05	4.31E-05	4.34E-05	4.73E-05	5.27E-05	5.65E-05	7.75E-05	6.19E-05	6.21E-05	6.31E-05	5.60E-05	4.17E-05
Extremadura	3.15E-04	-1.7E-04	-1.6E-04	-2.0E-04	-1.4E-04	1.14E-04	-1.8E-04	-2.0E-04	-1.9E-04	-1.9E-04	-2.1E-04	-2.2E-04	-2.3E-04	-1.0E-03	-2.1E-04	-2.0E-04	-2.1E-04	-1.9E-04	-2.0E-04
Cataluña	1.37E-04	6.23E-05	6.36E-05	6.60E-05	6.04E-05	1.15E-04	6.81E-05	7.18E-05	7.57E-05	7.74E-05	8.19E-05	8.62E-05	8.92E-05	6.77E-05	9.21E-05	9.08E-05	9.26E-05	8.06E-05	7.59E-05
Communidad Valenciana	-1.0E-04	-3.7E-05	-3.9E-05	-4.2E-05	-8.4E-05	-6.4E-05	-5.7E-05	-5.8E-	-6.0E-05	-6.3E-05	-6.8E-05	-7.2E-05	-7.6E-05	3.48E-05	-7.1E-05	-7.0E-05	-7.2E-05	-6.3E-05	-5.1E-05
Baleares	-4.9E-05	-1.3E-04	-1.3E-04	-1.5E-04	-1.6E-04	-8.9E-05	-1.4E-04	-1.4E-04	-1.4E-04	-1.5E-04	-1.6E-04	-1.7E-04	-1.7E-04	4.90E-05	-1.5E-04	-1.4E-04	-1.5E-04	-1.3E-04	-1.1E-04
Andalucia	-8.6E-05	-5.6E-05	-5.4E-05	-6.0E-05	-7.9E-05	-6.4E-05	-7.1E-05	-7.4E-05	-7.7E-05	-7.8E-05	-8.2E-05	-8.6E-05	-8.9E-05	-1.1E-04	-7.9E-05	-7.9E-05	-8.2E-05	-7.1E-05	-7.2E-05
Murcia	2.07E-05	2.19E-05	2.26E-05	2.25E-05	4.70E-05	4.92E-05	3.17E-05	3.19E-05	3.53E-05	3.42E-05	3.64E-05	3.96E-05	4.16E-05	1.05E-05	4.39E-05	4.48E-05	4.49E-05	3.95E-05	3.16E-05

Table E – Spatial gradients of the rate of change in the labor force per capita

	80/81	81/82	82/83	83/84	84/85	85/86	86/87	87/88	88/89	89/90	90/91	91/92	92/93	93/94	94/95	95/96	96/97	97/98	98/99
Galicia	-30.9723	-28.7031	-28.8217	-28.9159	-8.3982	-21.1483	-25.2917	9.3831	27.5158	-61.4105	-35.2187	28.2903	-24.0908	31.5672	-69.3015	13.6999	-27.5051	-20.2075	-22.6232
Asturias	48.3894	14.2454	14.2380	14.3618	16.7185	41.2651	-64.8401	4.6481	5.1672	-20.8298	10.5518	9.9916	-40.9624	-19.6504	37.7118	-17.9303	7.4590	-7.0998	6.1125
Cantabria	-14.0211	-1.5052	-1.4888	-1.4987	-2.3628	-7.1252	15.7169	9.9874	4.9825	-3.1605	0.1422	-7.6554	-0.1365	8.0115	-3.2685	-20.8839	-1.8290	-12.0097	-1.7051
Pais Vasco	-3.2907	1.1281	1.1041	0.9816	8.3919	2.2284	10.7536	13.3475	15.6765	-9.2501	20.3818	-8.1419	-4.3092	9.8273	16.0075	-9.6402	15.9110	-16.5317	2.0348
Navarra	3.6020	3.7898	3.7614	3.6874	8.3504	7.2845	-10.4046	3.8927	11.6279	-9.5620	15.1702	-2.7213	-11.5393	4.8599	15.1483	-2.2245	16.1982	-6.7608	2.6382
La Rioja	-0.7329	1.6919	1.6676	1.5609	8.2411	3.6953	5.7722	10.7415	13.9014	-8.6995	18.7436	-6.3473	-5.3979	7.7700	15.7210	-6.8178	15.2016	-13.6691	2.1965
Aragon	-3.3709	2.3199	2.3111	2.3231	-0.3868	0.5918	-19.0736	-7.0781	2.1249	-5.3237	-3.6841	0.0185	-10.8653	3.4896	-2.7983	-1.3172	5.2540	5.0175	-0.2786
Madrid	-10.8208	-1.3885	-1.3796	-1.4023	-1.1903	-5.6982	13.4771	8.0129	4.7241	-2.5334	1.8054	-6.1588	0.7606	6.7884	-1.6185	-14.4146	-0.0472	-9.6057	-1.1498
Castilla-y-Leon	-5.9187	0.5021	0.5190	0.5497	-1.6752	-1.6700	3.1402	5.8954	1.7104	-2.8558	-2.4514	-3.7480	-4.1839	2.6071	-1.3743	-17.4274	-3.0810	-6.8801	-0.9269
Castilla-La-Mancha	-6.7584	-0.7394	-0.7437	-0.8014	2.0692	-2.7071	11.9320	8.3457	7.4101	-3.8188	7.8306	-5.7994	0.2740	6.7942	4.1049	-9.0648	5.1211	-10.1744	0.0208
Extremadura	35.6509	9.7117	9.6980	9.7686	12.8014	29.5993	-46.3073	3.1643	4.7321	-15.8112	9.2085	7.4932	-28.1780	-13.3819	27.0541	-9.5105	6.3267	-5.0844	4.3087
Cataluña	8.6639	0.6885	0.6732	0.6573	0.2824	14.8658	15.3639	4.0213	1.8133	7.9751	0.3494	-3.0777	3.9372	5.4852	6.1186	-2.9430	7.0122	1.0280	2.5507
Communidad Valenciana	-5.1843	0.9855	0.9848	1.0124	-2.8457	-1.9515	-14.2436	-7.4145	-0.6931	-2.6478	-7.6542	0.0466	-6.9738	3.0138	-7.1853	-1.4176	0.8904	6.1757	-1.0963
Baleares	6.7543	-0.5069	-0.4914	-0.4095	-3.4376	11.5016	-27.4783	-27.3087	-16.1002	4.7349	-10.3932	33.3746	-23.0211	-6.4459	-14.2437	-11.3183	-8.8706	-9.8095	-3.0576
Andalucia	-1.9241	0.8530	0.8637	0.8907	-0.6848	0.3680	-0.6633	3.3058	0.7628	-2.0745	-1.6398	-1.7235	-3.8204	0.6216	0.0430	-10.7834	-1.9537	-3.7430	-0.3795
Murcia	1.8486	2.1238	2.1086	2.0728	4.2387	3.8798	-6.8230	1.3797	5.8911	-5.0815	7.3206	-1.1875	-6.5735	2.4698	7.5062	-1.0211		-2.8463	1.3316

Spatial Coordinates of the Regional Centroids
(Relative to Barcelona)[5]

Regions	**Latitude** (x_1)	**Longitude** (x_2)
Galicia	1.034123	0.163022
Asturias	1.045606	0.341767
Cantabria	1.042240	0.493431
Pais Vasco	1.038154	0.608973
Navarra	1.029602	0.689551
La Rioja	1.021664	0.624170
Aragon	0.999983	0.764333
Madrid	0.979209	0.508603
Castilla-y-Leon	1.006662	0.457983
Castilla-la-Mancha	0.958667	0.561937
Extremadura	0.947470	0.321111
Cataluña	1.007358	0.965349
Communidad Valenciana	0.950027	0.787710
Baleares	0.957162	1.061550
Andalucia	0.902821	0.445906
Murcia	0.919762	0.699186

[5] Calculations of the coordinates have been made with Arcview 3.2 by ESRI.