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Infrastructure and growth in the European regions

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Abstract:

Since 1988, public capital investment has been a major instrument of regional policy in the EU, and will continue as such during the current programming / program period. Over the last decade a great number of studies have been conducted to investigate the relationship between infrastructure and development and growth. But, owing to lack of data, few of these deal with the regions of the community. In this paper we analyse the impact of public capital on the development and growth of the EU regions, using the different statistical resources for the period 1970-1994. We introduce infrastructure indexes, along with other variables that may condition the level of regional development, into a convergence equation. This approach allows us to compare our results with those obtained by other authors who have studied the convergence process among European regions.

Infrastructure and growth in the European regions

1. Introduction

Over the past decade various investigations have addressed the impact of public capital on economic development. However, the possibility that the stock of public capital could be among the significant variables in the private sector production function is something which had already been considered by Arrow and Kurz (1970) and Grossman and Lucas (1974), being later contrasted by Mera (1973) for the Japanese regions and Ratner (1983) for the USA. The key argument to support the inclusion of public capital in the production function is that it increases the productivity of private factors, and that both sources of capital are complementary. An increase in public investment, therefore, brings about an increase in the marginal product of private capital thereby providing an inducement to private investment.

Among other factors that have motivated renewed interest in public capital among economists, we could mention the following. Firstly, studies by Aschauer (1989) and Munnell (1990) estimate production functions in which the elasticity of the product with respect to public capital is surprisingly high. The notion that the decreasing growth rate in the productivity of private factors, apparent since the early seventies, could, in part, be due to a reduction in public investment seemed to hold some truth.

In addition, concern for regional development, which grew with the formation of the European Union, and increasing integration within the Union, has given rise to a great number of studies which analyse the stock of public capital and its influence on the level of national or regional development. One study with widespread impact at the European level was that carried out by Biehl *et al* (1986).

However, a great number of subsequent studies have, since then, cast doubt on what is known as the "Aschauer effect", at least as far as the estimated degree of elasticity is concerned. The possible effect on these early findings of such econometric problems as reverse causation**,** the possible omission of variables correlated with public investment or the presence of tendencies in the series estimated, have inspired researchers to concentrate on estimation by panel data, for entire countries as well as for regions. Findings by Holtz-Eakin (1994), Evans and Karras (1994), García-Milá *et al*

(1996) show how, when regional or time specific variables are controlled using estimations with fixed or random effects, the estimated elasticities are considerably smaller and in some cases completely cancelled out.

Many economists, however, continue to believe that infrastructure plays an essential role as a driving force for development. Indeed studies such as that of the EEC (1993), carried out to identify the determining factors in the location of businesses, point to infrastructure endowment as one of the most important factors when it comes to deciding where to locate a business.

Another very productive line of investigation pursued in the last decade sought to detect any possible neo-classical convergence among countries and regions. This was not motivated purely out of academic interest, but because the issue is one that affects the main reason given to justify the existence of regional policy: the fact that market forces and economic integration may not necessarily succeed in reducing inequality in per capita income. Given that the budget allocated to European structural policy has increased considerably since 1989, it is more important than ever to justify its existence. Most of the empirical studies (see for example, Armstrong 1995, Sala-i-Martín 1996, Rodríguez-Pose 1997, López-Bazo *et al* 1999) reveal a slight tendency towards regional convergence, but at such a minimal rate (around 1%) that it would take over 50 years to reduce income differences even by half. Meanwhile, the community's own regional policy may have had some positive influence on the process. Some authors report that investigations into convergence among the countries and regions of the European Union provide no definite conclusion as to whether the existing process is one of divergence or convergence. They claim, therefore, that the issue needing to be addressed is how regions setting out from fairly similar positions, can then register different rates of development.

The present study aims to contribute to this literature, by testing the influence of endowment and investment in infrastructure on the process of development and convergence in the regions of the EU.

The content is arranged in three parts. The second of these gives a brief description of the study directed by Biehl. This then serves as the starting point in the subsequent section for our analysis of the influence of infrastructure and other factors that combine to determine productive capacity and convergence in the European regions. Finally, there is a summary of our main conclusions.

2. Infrastructure and development in the regions of the EU

Investigations into the role of infrastructure in development, growth and convergence in the European regions are very few in number because of the scarcity of homogeneous statistical data. One of the widest read and most influential was carried out by the research group directed by Dieter Biehl, the results of which were published in 1986 in a final report under the title “The contribution of infrastructure to regional development”.

One of the main contributions made by Biehl *et al* (1986) is their regional development potential approach. The potential to which they refer is measured in terms of a particular type of resource, different from the traditional type of productive resources (private capital and labour). These resources are named as the potentiality factors (PF henceforth), the main ones being natural resources, the region's location, the size and structure of its settlements, the sectorial structure of the region's economy and its stock of public capital. This last factor is distinct from the rest in that it is a capital good, supplies a series of services and is the result of an investment process from the outset of its economic life. Private capital also has these characteristics, though its economic life is usually much shorter.

Testing of the potential for development approach developed by Biehl *et al* (1986) posed various problems The main difficulties lay in how to measure the capacity incorporated within the different types of infrastructure, how to sum up the different types of infrastructure in order to analyse their net effect on production, identifying the geographical limits of the regions, and the lack of statistical sources for comparison, among others. These researchers chose to estimate normalised synthetic indices in physical units. They developed two aggregate indicators for the years 1970 and 1980. They then estimated quasi-production functions, using the GDP per inhabitant and the GDP per worker as endogenous variables. The explanatory variables were infrastructure, a location index, density, and share of industry and services in total employment, plus a series of national dummy variables. The estimations proved to provide a good fit, and infrastructure proved to be highly significant. The authors considered these results to support their theoretic approach, and they attached more relevance to the role of pubic capital as a tool for regional policy. Nonetheless, they also admitted the presence of some limitations (similar to those affecting the investigations by Aschauer, 1989, or Munnel, 1990). The first had to do with the omission of relevant variables in the study: there were no homogeneous data relating to private capital. The likely correlation between public and private capital could give rise to biased estimations. If, however, we accept that private capital is comparatively mobile, and therefore responds to the accumulation of potentiality factors, the problem will not be too serious, since the correlation between the two will be determined by the attraction exerted by the second on the first.

The second limitation could prove to be more relevant. Researchers in the study group acknowledged that the strong correlation between development and public capital, as happens with most economic phenomena, is a result of the complex relationship between supply and demand. Public capital is at once a cause and an effect of development. Some types of infrastructure, those with more of the features of a public good, may be seen primarily as a cause, while others will be considered more as an effect.

3. Analysis of the impact of infrastructure

The following pages contain an extension of the work begun by Biehl *et al* (1986) on the impact of public capital and other PF involved in the regional development of the European Union. An attempt is made to make the maximum use of available information. Statistical constraints limit us to focusing on three periods: 1970-1980, with data extracted from the Biehl Report; the 1980-1985 time period, with completed data from the same report, Biehl (1988), statistics from Eurostat's *Regio* database and from the "Third report on the socio-economic situation and developments in the regions of the Community" (EEC, 1987); and the 1988-1994 time period, with data collected for *Regio*. Though there is a gap in the data relating to a period in the mid eighties, it may actually prove useful, since the entry of Spain and Portugal into the Union and the subsequent strengthening of regional policy may have an effect on regional development.

3.1. The 1970-1980 period

We submit two new elements to the study carried out by Biehl *et al* for this period. First of all, we include the Spanish and Portuguese regions which were not included in the original analysis. Also, we address the issue of inverse causation in our analysis of regional convergence in relation to infrastructure endowment and the remaining PF.

Before embarking on the study, we will attempt to verify the coherence of the data used For this purpose we will use an approach similar to that used by Prud'homme (1993) for the regions of France.

We begin by assuming that regions with very similar GDP per inhabitant will also be very close in infrastructure endowment, such that their supply of services will also be similar. We then place the regions in order of GDP per inhabitant. If i and i+1 are two consecutive regions in this ordering, their ratios of GDP and infrastructure indicators should also be similar. Let us use the term GII to denote Biehl's general infrastructure indicator, S to denote surface area, and Pop for population, we then have:

$$\frac{GII_i}{S_i^{\alpha} * Pop_i^{\beta}} = \frac{GII_{i+1}}{S_{i+1}^{\alpha} * Pop_{i+1}^{\beta}} \qquad [1]$$

If Biehl's infrastructure indicator is properly constructed, we may expect α and β to be not very far off 0. The formula could also include the ratio of the GDPpc in case there were significant differences among them:

$$\frac{GII_i}{S_i^{\alpha} * Pop_i^{\beta}} * \left(\frac{GDPpc_{i+1}}{GDPpc_i}\right)^{\lambda} = \frac{GII_{i+1}}{S_{i+1}^{\alpha} * Pop_{i+1}^{\beta}} \qquad [2]$$

The infrastructure indicators for Spain and Portugal are comparable only within each of the two countries, we will, therefore, introduce dummy variables for these countries:

$$\frac{GII_i * \left(XS^{DS_i} * XP^{DP_i}\right)}{S_i^{\alpha} * Pop_i^{\beta}} * \left(\frac{GDPpc_{i+1}}{GDPpc_i}\right)^{\lambda} = \frac{GII_{i+1} * \left(XS^{DS_{+1i}} * XP^{DP_{+1i}}\right)}{S_{i+1}^{\alpha} * Pop_{i+1}^{\beta}} \qquad [3]$$

where XS is the value used to normalise the indices for the Spanish regions; XP is the value used to normalise indices for the Portuguese regions; and DS, DP are dummy variables for Spain and Portugal.

Using logarithms

$$\ln\frac{GII_{i+1}}{GII_i} = \alpha * \ln\frac{S_{i+1}}{S_i} + \beta * \ln\frac{Pop_{i+1}}{Pop_i} + \lambda * \ln\frac{GDPpc_{i+1}}{GDPpc_i} + DS_i * \ln(XS) - DS_{i+1}\ln(XS) + DP_i * \ln(XP) - DP_{i+1} * \ln(XP) \qquad [4]$$

Values XS and XP will be used to transform the indices for Spain and Portugal into values that can be compared with those of the EU-10 regions.

We have data covering the aggregated infrastructure indicator (GII), the GDP in current ecus and in purchasing power parity, total employment and employment by sectors for 161 regions.

Table 1. Impact of surface area, population and Spain and Portugal

Variable	Year 1970		Year 1980	
	Coefficient	t	Coefficient	t
LnS	-0,205	-4,38	-0,122	-3,44
LnPOP	0,218	4,88	0,186	5,73
DS	-0,589	-6,02	-0,757	-9,87
DP	-1,232	-7,01	-1,29	-10,38
	R^2.Aj. 0,39	DW 2,3	R^2.Aj. 0,38	DW 2,33

The estimated values for surface area and population in equation [4] are significant for both years (table 1), these coefficients are therefore used to transform Biehl's indices. Since, as might be expected, the dummy variables for Spain and Portugal are also significant, their indices have also been transformed for the Spanish and Portuguese regions.

From these transformed values, we estimate a quasi-production function, for 1970 and 1980, similar to Biehl's, except that, in order to avoid as far as possible the omission of relevant variables, we have decided to include employment in the regression. The estimated function (for 1970) is:

$$\ln(GDP70pc_i)=ct+aLG^{70}_i+bLL^{70}_i+cLLOCI_i+dLDEN^{70}_i+eLLA^{70}_i+\Sigma f_j D_j+u_i \qquad [5]$$

where LG^{70} is the logarithm of Biehl's adjusted infrastructure indicator en 1970; LLOCI the logarithm of Biehl's location index, with higher values for periferal regions (we expect their value to negative); LDEN is the logarithm of the population per km^2; LL, the logarithm of per capita labour; LLA, the logarithm employment in agriculture over total labour in 1970; and D_j are the national dummy variables.

Table 2. Results of the estimated production function.

Variable	Year 70 [2-1]	Year 70 [2-2]	Year 80 [2-3]	Year 80 [2-4]
Constant	3,34 (3,91)	2,17 (4,73)	2,97 (3,83)	3,22 (6,71)
LG	0,174 (4,56)	0,211 (9,21)	0,171 (4,17)	0,131 (4,33)
LLOCI	-0,298 (-3,26)	-0,275 (-6,27)	-0,312 (–3,8)	-0,295 (-4,9)
LDEN	0,049 (2,02)	0,05 (3,33)	0,045 (2,47)	0,043 (2,73)
LL	0,714 (6,23)	0,948 (13)	0,814 (7,53)	0,735 (9,36)
LLA	-0,115 (-4,24)	-0,101 (-6,4)	-0,098 (-4,08)	-0,082 (-4,08)
Germany	0,07 (1,35)		0,22 (5,45)	0,239 (8,79)
France	0,057 (0,99)		0,136 (2,68)	0,136 (4,26)
Italy	0,052 (0,75)		0,04 (0,7)	
Holland	-0,068 (-0,94)		0,178 (3,15)	0,174 (3,22)
UK	0,079 (1,12)		-0,088 (-1,47)	
Ireland	-0,046 (-0,54)		0,123 (1,53)	
Denmark	0,175 (2,45)		-0,016 (-0,2)	
Greece	0,022 (0,21)		0,122 (1,33)	
Spain	0,082 (0,96)		0,179 (2,6)	0,128 (3,94)
Portugal	-0,007 (-0,07)		0,01 (0,1)	
R^2 Aj/ DW	0,89 / 1,68	0,89 / 1,65	0,91/1,81	0,9/1,67

Table 2 shows the most significant results of the estimations for 1970 and 1980. The variable LG is significant to the 1% level in both years, therefore coinciding with the results obtained by Biehln *et al* (1988). The remaining potentiality factors are also significant. Employment per inhabitant is, as may be expected, highly significant.

The second issue to be addressed in this study is the nature of the causal relationship between infrastructure and growth. A primary approach to examining this aspect is a test to see whether overuse of resources is causing bottle-necks to hold back the development process, or the under-usage of resources means that there exists some potential for future growth. We use the difference between the real and the potential GDPpc to measure over/under-usage:

$$\Delta LGDPpc_i = aIUPF_i + b\Delta LL_i + c\Delta LA_i + d\Delta LG_i + eLGDP70_i + \Sigma f_i D_j \qquad [6]$$

where ΔLGDPpc is the result of subtracting ($LGDP^{80}$pc-$LGDP^{70}$pc); IUPF70 is the result of subtracting ($LGDP^{70}$pc real) - ($LGDP^{70}$pc estimated); ΔLL is the result of subtracting (LL^{80} - LL^{70}); ΔLA is (LA^{80} – LA^{70}); and ΔLG is (LG^{80} - LG^{70}).

We introduce the logarithm of the beginning-of-period GDP because there is a mild correlation between this and the IUPF70, and also because this allows checking for the presence of an absolute convergence mechanism. As Table 3 shows, not only the 1970 factor utilisation indicator, but increases in labour, in agricultural labour, and in the infrastructure index are significant and positive or negative as expected. The latter is also true of the beginning-of-period GDP, though it is only mildly significant, the indication being that, once this comes under the impact of other factors, the most backward regions tend to speed up their growth.

By including IUPF70 in the regression, we are in fact estimating a conditioned convergence equation, so that, by finding the sum of the coefficients for IUPF and the beginning-of-period GDP, we are able to obtain the parameter β.

By using IUPF70 instead of LGDP70, LLOCI, $LDEN^{70}$, LL^{70}, LLA^{70}, LG^{70} we are imposing the condition that the coefficients of these variables are correlated in the same way as revealed by the 1970 cross section analysis. It is possible to estimate a real convergence equation by using the PF as conditioning variables:

$$\Delta LGDPpc = aLG^{70} + bLLOCI + cLDEN^{70} + dLL^{70} + eLLA^{70} + fLGDP^{70} + g\Delta LL + h\Delta LLA + i\Delta LG + \Sigma k_i DR_i \qquad [7]$$

When the fuller formulation is used (table 3, column [3-3]), the most relevant variables for our investigation (ΔLG, and particularly LG^{70} since it is free of inverse causation) present the expected signs, but they are not very significant. If we eliminate the least informative variables, the level of significance of the infrastructure indicators increases. The rates of convergence towards the steady state, conditioned by infrastructure endowment and the remaining potentiality factors, range between 3 and 4%, which is a considerable increase with respect to those reported in the literature quoted above. As is the case in the Spanish regions, the greater the number of conditioning variables (dummy variables in some cases), the higher the rate of convergence.

Table 3. Conditioned convergence in the 1970-1980 time period

Variable	[3-1]	[3-2]	[3-3]	[3-4]
Constant	0,21 (1,66)	0,377 (3,91)	0,69 (1,49)	0,507 (1,49)
IUPF70	-0,219 (-3,89)	-0,163 (-3,24)		
LG^{70}			0,029 (1,24)	0,04 (1,8)
LLOCI			-0,113 (-2,38)	-0,108 (-3,05)
LL^{70}			0,34 (4,66)	0,381 (6,25)
LLA^{70}			-0,02 (-1,73)	-0,015 (-1,4)
ΔLL	0,27 (3,16)	0,201 (3,28)	0,377 (4,21)	-0,314 (-7,65)
ΔLLA	-0,038 (-2,49)	-0,016 (-2,06)	-0,025 (-1,49)	-0,01 (-0,7)
ΔLG	0,04 (1,35)	0,053 (2,49)	0,025 (0,71)	0,051 (1,7)
$LGDP^{70}$	-0,07 (-2,26)	-0,114 (-4,8)	-0,31 (-7,33)	-0,31 (-7,64)
Germany	0,14 (5,8)	0,17 (10,2)	0,13 (5,1)	0,12 (7,01)
France	0,07 (3,06)	0,08 (4,58)	0,05 (1,56)	
UK	-0,16 (-6,2)	-0,15 (-6,81)	-0,17 (-4,89)	-0,19 (-8,5)
Ireland	0,15 (4,11)	0,15 (5,36)	0,12 (2,72)	0,11 (3,7)
Denmark	-0,04 (-1,49)		-0,06 (-1,47)	-0,1 (-4,25)
Portugal	0,09 (2,15)	0,1 (2,91)	0,07 (1,26)	
Italy	-0,04 (-1,38)		-0,05 (1,26)	
Holland	0,04 (0,87)		0,05 (1,02)	
Greece	0,04 (0,99)		0,02 (0,3)	
Spain	-0,01 (-0,2)		0,01 (0,02)	
Beta[a]	3,4%	3,2%	3,7%	3,8%
R^2 Aj/ DW	0,74 / 1,71	0,73 / 1,59	0,76 / 1,74	0,76 / 1,75

[a] Calculated from the sum of the coefficients for IUPF and LGDP70

Briefly, the results obtained support the hypothesis that the nature of the causal relationship is that potentiality factors and infrastructure lead towards development. These results are not categorical, however, since some variables are of very slight significance. In the pages that follow we will attempt to verify these results by testing other sample periods.

3.2. The 1980-1985 period

In this case, we will use Biehl's (1988) data, since this will bring us two advantages. Firstly, the indices for Spain and Portugal are comparable to those of the remaining regions. Also, the variables making up the index have been scaled down by dividing them by the weighted average of surface area and population for each region. The correlation coefficients were used as weightings. The data therefore requires no previous adjustment. The indices that will be used in this case only cover those types of infrastructure deemed by the study group to be most closely related to productivity (transport, communications, power and education). The classification of regions for some countries is different from that used in the Biehl report, which made it necessary to collect data from various sources. As a location index we take one constructed by the

EEC (1988), which we denote as ILOC2. This index takes account of the economic weight of the region itself. With respect to agricultural labour, we have at our disposal only data for 1985. These are used as an approximation to the sectorial structure of labour in the year 1980.

Tables 4 and 5 show the estimation results for the following functions:

$$LGDPpc80_i=aLG^{80}_i+bLL^{80}_i+cLLA^{85}_i+dLLOCI2_i+\Sigma e_jD_j+e_i \quad [8]$$

$$\Delta LGDPpc_i= fIUPF^{80} + g\Delta LL_i+hLGDPpc^{80}_i+\Sigma e_jD_j+e_i \quad [9]$$

$$\Delta LGDPpc_i=mLG^{80}_i+nLL^{80}_i+qLLA^{85}_i+rLLOCI2_i+s\Delta LL_i+tLGDPpc80_i+\Sigma e_jD_j+e_i \quad [10]$$

where LG^{80} denotes the logarithm of the infrastructure index for each of the four categories in 1980; $\Delta LGDPpc$ is the result of subtracting [ln(GDPpc85) - ln(GDPpc80)]; $IUPF^{80}$ the result of subtracting [($LGDP^{80}$pc real) - (LGDP70pc estimated)]; LL^{80} the logarithm of per capita labour in 1980; LLA^{85} the logarithm of the percentage of agricultural labour over total labour in 1985; LLOCI2 the logarithm of the EEC location index (central regions register higher values, which leads us to expect that the coefficient for this variable will be positive); ΔLL is the result of subtracting (LL^{85} – LL^{80}); and D_j are national dummy variables.

Table 4. Estimated quasi-production function for 1980

Variable	[4-1]	[4-2]	[4-3]
Constant	-0,651 (-1,1)	-0,757 (1,26)	-0,448 (-0,7)
LG^{80}	0,278 (6,74)	0,274 (7,94)	0,372 (9,66)
LLOCI2	0,044 (1,38)	0,047 (1,55)	0,111 (3,39)
LL^{80}	0,834 (8,95)	0,847 (9,6)	0,565 (6,93)
LLA^{85}	-0,067 (-3,98)	-0,067 (-4,1)	-0,017 (-0,85)
Belgium	0,168 (2,33)	0,199 (4,1)	
Germany	0,128 (2,01)	0,156 (4,61)	
UK	-0,36 (0,52)		
France	0,187 (3)	0,217 (5,93)	
Portugal	0,035 (0,4)		
Italy	0,287 (4,43)	0,317 (10,04)	
Holland	0,316 (4,3)	0,349 (6,56)	
Greece	-0,068 (-0,8)		
Spain	0,189 (2,81)		
R^2 Aj/ DW	0,89 / 1,91	0,89 / 1,84	0,81 / 1,39

The estimated parameters of equation [8] are significant and of the expected signs. In particular, the variables measuring infrastructure endowment, LG^{80}, labour per inhabitant, LL^{80}, and agricultural labour, LLA^{85}, are highly significant. Also significant to within normal levels is the location index LLOCI2. In column [4-3] we have omitted agricultural labour (because it refers to a year far removed from the rest of the sample) and the regional dummy variables, but results do not change appreciably.

The results of the convergence equations [9] and [10] are shown in table 5. Although the signs of the variables, especially the infrastructure indicator, are as expected, their significance is slight. The logarithm of the agricultural labour share is barely significant; if, however, it is introduced into an absolute value, its significance increases (columns [5-5] and [5-6]), as does that of the infrastructure indicator.

Biehl *et al* (1986) detected that more prosperous regions tended to make more intensive use of the potentiality factors. One of the possible reasons for this is that that elasticity of infrastructure is not constant. It may be that a slight increase in public capital, given its characteristics, and in particular its non‑exclusivity, does not have the expected effect on private factors. This being the case, we might expect increasing elasticity of public capital with respect to growth, at least until a region attains an adequate level in this factor.

Table 5. Convergence equation for the period between 1985 and 1980

End.Var.	LGDPpc85 – LGDPpc80					
Ex.Var..	[5-1]	[5-2]	[5-3]	[5-4]	[5-5]	[5-6]
Constant	0,119 (0,48)	-0,067 (-0,38)	0,031 (0,07)	-0,862 (-0,2)	-0,21 (-0,56)	-0,48 (-1,5)
IUPF80	-0,083 (-1,22)	-0,108 (-1,71)				
LG80			0,034 (1,1)	0,045 (1,55)	0,043 (1,42)	0,057 (1,97)
LLOCI2			-0,088 (-0,42)		0,001 (0,05)	0,014 (0,77)
LL80			0,076 (0,94)	0,071 (1,2)	-0,009 (-0,11)	0,039 (0,63)
LLA85			-0,0047 (-0,4)	-0,006 (-0,6)		
EAG85					-0,26 (-2,6)	0,163 (1,77)
LGDP80	0,00 (0,2)	-0,026 (-0,96)	-0,072 (-1,41)	-0,084 (-1,62)	-0,002 (-0,03)	-0,037 (-0,68)
ΔLL	0,127 (2)	0,168 (3,03)	0,128 (1,95)	0,15 (2,64)	0,11 (1,73)	0,166 (2,89)
Belgium	-0,164 (-3,79)	-0,152 (-7,38)	-1,319 (2,92)	-0,14 (-5,18)	-0,152 (-3,24)	
Germany	-0,113 (-2,85)	-0,103 (-5,06)	-0,093 (-2,23)	-0,091 (-4,5)	-0,1 (-2,44)	-0,1 (-4,73)
UK	0,00 (0,0)		0,004 (0,1)		0,025 (0,59)	
France	-0,164 (-4,1)	-0,15 (-7,38)	-0,145 (-3,47)	-0,137 (-6,43)	-0,167 (-4,06)	-0,152 (-7,4)
Portugal	-0,219 (-4,4)	-0,19 (-6,13)	-0,212 (-3,61)	-0,181 (-5,14)	-0,218 (3,81)	-0,174 (-4,94)
Italy	-0,218 (-5,45)		-0,188 (-2,23)	-0,173 (-7,74)	-0,207 (-4,63)	-0,18 (-8,38)
Holland	-0,118 (-2,7)		-0,082 (-1,61)	-0,86 (-2,8)	-0,114 (-2,26)	-0,11 (-3,36)
Greece	-0,04 (-078)		-0,043 (-0,81)		-0,068 (-1,29)	
Spain	-0,37 (-0,87)		-0,021 (-0,45)		-0,049 (-1,05)	
Beta	1,7%	2,88%	1,5%	1,75%	0,03%	0,7%
R^2 Aj/DW	0,54 / 1,58	0,54 / 1,53	0,53 / 1,57	0,54 / 1,55	0,55 / 1,59	0,55 / 1,53

3.3. The 1988-1994 time period

We can add to this study of the impact of infrastructure in the European regions by incorporating data on roads and motorways in kilometres provided by *Regio*. We have constructed an aggregate indicator for transport infrastructure, by allocating an average cost for each kilometre of road and motorway.

From the estimated values of parameters a, b and c given by:

$ln(GTpts88_i)=a+bln(Pop_i)+cln(S_i)+e_i$ [11]

where $GTpts88_i$ denotes transport infrastructure in region i; Pop_i denotes population in region i; and S_i is the surface area of region i.

By imposing the requirement that (b+c) = 1 we obtain the "infrastructure indices", G88:

$G88_i = GTpts88_i / (exp(a)*Pop_i^b*S_i^c)$ [12]

Table 6 shows the estimation results.

Table 6. Results of estimating [11]

	Unrestricted Model	Restricted Model	F restriction (probab)
Ct	5,115 (10,2)	4,699 (37,94)	0,73 (0,4)
ln(Pop)	0,642 (9,53)	0,673 (11,85)	
ln(S)	0,306 (4,96)	0,327 (5,75)	
R2 ajusted	0,66	0,66	

One of the most important factors not included in the above analysis is human capital. The Biehl group already thought that one of the possible reasons for differences in the degree of utilisation of potentiality factors is different educational levels among workers. A growing number of studies are constructing and testing models in which human capital is an essential factor. Some researchers consider that it is enough to extend the neo-classical model to include this type of capital in order to provide an explanation for its apparent inconsistencies. Furthermore, human capital presents some of the characteristics that have enabled us to identify potentiality factors. We think it could be useful to introduce dimensions into the production function that would give an approximation of this type of capital. The quantification process, however, is complex and the indicators available to us are not the most adequate. From *Regio* we have at our disposal data pertaining to the percentage of full-time students among the overall population of over 25 year-olds for all the European regions. A suitable indicator ought to capture the stock of training among workers, by incorporating not only a measurement of quantity but also of quality and suitability to productive requirements.

Whatever the case, we will estimate a quasi-production function extended to include this approximation to human capital (LCH). As table 7 shows, the transport infrastructure indicator is of the expected sign but barely significant. The human capital indicator fares worse, as it is negative. If labour is omitted from the regressions, thereby implying that the infrastructure effect can take place through an increase in regional labour, our indicator then improves in significance. In the conditioned convergence equation (columns [7-3] and [7-4]) the infrastructure indicator is significant provided the regional dummy variables are omitted.

Table 7. Quasi-production and convergence function estimation

Endog.Var..	LGDPpc88		ΔLGDPpc	
Exog. Var.	[7-1][a]	[7-2][a]	[7-3]	[7-4][a]
LGDP88			-0,06 (-0,8)	-0,2 (-3,5)
LG88	0,06 (1,5)	0,114 (2,4)	0,004 (0,7)	0,006 (2)
LLA88	-0,08 (-3,5)	-0,14 (5,4)	-0,00 (-0,0)	-0,003 (-1,2)
ILOC2	0,198 (4,1)	0,25 (4,1)	-0,01 (-1,7)	-0,006 (-1)
LL88	0,735 (7,4)		0,02 (1,2)	0,02 (1,6)
LCH	-0,23 (-1,5)		0,006 (0,3)	0,01 (0,6)
CT	8,96 (12)	6,54 (13,1)	-1,4 (-10,1)	-1,3 (-12,4)
Beta			1,03%	3,72%
R^2 Aj/ DW	0,87 / 1,93	0,8 / 1,63	0,3 / 1,94	0,15 / 1,55

[a] Include national dummy variables

To sum up this section, we can report that transport infrastructure is closely correlated to per capita output, and the regional endowment in a given year conditions economic progress in the years following.

4. Conclusions

In this study we have examined the influence of potentiality factors on the convergence/divergence process in the regions of the European Union. While these are all factors that are closely linked to the level of regional development, this is especially true of those relating to infrastructure.

The results obtained in the cross section regressions clearly reveal the close relationship between potentiality factors and growth in the European regions. The high degree of significance obtained in all three sample periods lends robustness to the results, which differ little from those of other authors. In this case, our analysis reports new evidence based on a wider geographical area and in some cases on different time periods.

Our approach to the issue of inverse causation by the analysis of convergence brings less convincing results. Thus, while variables behaved in the direction expected, their significance was at times relatively low.

Cross section regression techniques showed infrastructure to be highly significant, but validity is suspect because of inverse causation. An attempt was made to overcome this problem, while simultaneously furthering the study of convergence, by estimating equations by differences and taking as conditioning variables the initial values for infrastructure and the remaining PF. The variables behaved in the direction expected but were at times not very significant.

All this notwithstanding, the results obtained enable us to draw attention to the role of potentiality factors in regional growth. It is true that there are certain problems involved in obtaining reliable results. Some of these relate to the varying reliability of the different sources of statistical data used, the aggregation of the different types of infrastructure, and the varying impact of a given physical endowment on the supply of services depending on factors such as the population distribution or geographical relief in a particular area. In a cross-section regression, the fact that there are wide differences in production and factors prevents these problems from affecting results. But when estimating convergence functions, errors in the measurement of the dimensions of infrastructure can be very serious and produce estimations biased towards zero.

It is also worth mentioning that the results obtained have their implications for European regional policy. We have confirmed the existence of a close positive correlation between physical capital endowment and the economic growth rate, though the extent of its impact varies greatly over time and across regions. Likewise, marked differences remain between existing stocks in more developed and more backward regions. This being the case, financing of infrastructure may continue to be one of the primary instruments of regional policy within the community. We do not, of course, suggest that this be done in an indiscriminate manner, but subject to analysis of the main weaknesses in the productive fabric of each region. Across " Objective 1 Regions", that is, the most underdeveloped within the European Union, the situation varies greatly. Some, such as those of Greece, suffer from serious deficiencies in infrastructure, while others might be better advised rather to invest in training.

A second implication of this study points to the need to improve and increase available information at regional level in Europe. With a homogeneous and reliable statistical database, it would be possible to carry out relevant testing of some of these findings, particularly the direction in which the causal relationship works between infrastructure and growth.

Footnotes

1.- Gramlich (1994) revises the greater part of the literature concerning the effects of infrastructure. De La Fuente (1996) also revises all these studies, with a brief explanation of the econometric problems affecting early findings.

2.- See, for example, Cuadrado (1994), Cheshire and Carbonaro (1995) or Rodriguez-Pose (1998).

3.- Sanau (1996), when commenting on the methodology used in the "Biehl Report", remarks on the limitations of the study and the infrastructure indices used in it.

4.- It was not possible to extend this period because changes in regionalisation subsequently took place.

5.- Indicators for network-type infrastructure were divided by the surface area and those for tipo punto by regional population. In a later study, see Biehl (1988), the physical data were divided by the weighted average for population and surface area of the region, the weightings used were the coefficients of correlation between these variables and the physical indicator.

6.- These include 37 regions in Germany, 21 in France, 20 in Italy, 10 in Holland, 9 in Belgium, Luxemburg, 11 regions in the UK, 9 in Ireland, 12 in Denmark, 9 in Greece, 17 in Spain, and 18 in Portugal. In this last case, we do not dispose of 1980 data regarding GDPpc in PPP at this level, we have therefore opted to include them among the 5 present continental NUTS2 regions.

7.- The implicit coefficients for Spain and Portugal are 0'555 and 0'291, for 1970, and 0'469 and 0'275, for 1980.

8.- In Biehl's study, estimations using all the PF did not include employment.

9.- This index is the sum of the distances separating each individual regions from the remaining regions. Since the regions of Spain and Portugal are not included, we have opted to use approximate calculations based on the European Communities Commission index for the year 1988. The values thus obtained are reasonable.

10.- The number of regions analysed is 137. Denmark and Ireland are taken as a single region, and Germany is represented by 31 NUTS1 regions instead of the 37 functional regions of the Biehl report.

11.- Data relating to GDPpc in PPP for the year 1980 are taken from the "Biehl Report" and *Regio*. Those relating to total labour from the"Biehl Report" and *Regio* . Data on agricultural labour GDPpc in PPP for 1985 from the "Third periodical report on the socio-economic situation and evolution in the regions of the Community" (Commission for the European Communities, 1987).

12.- Though these may less suitable than those estimated by Biehl *et al* (1986), which capture more types of infrastructure and their quality by including such concepts as road-width, they will serve as confirmation of those obtained in previous stages of the study.

We have at our disposal data for 127 regions of the EU-12, mainly pertaining to 1988. When these were not available, 1987 or 1989 data were used.

13.- This involved comparing physical data taken from Regio with price data from Pérez, Mas and Uriel (1995) for the autonomous communities of Spain. Though various objections can be made to the application of this average cost, it is useful in that it allows one to obtain an approximate estimation of the price of transport infrastructure. The values to be used for conversion will be 21.5 million (1990 chained pesetas) per km. of road and 562 per km. of motorway. IVIE and Fundación BBV data distinguish between roads and toll motorways, so there is a difference in classification. We opted to use the conversion coefficient derived from the sum of the data for those AC that in 1988 had toll motorways and not dual carriageways. We consider the resulting outcome to be reasonable.

14.- For example, Mankiw, Romer and Weil (1992) when they widen their definition of capital, De la Fuente (1996) who link human capital to technical progress, and Gorostiaga (1999).

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