Public Capital and Infrastructure in Spain: A Regional Perspective*

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Abstract

The aim of this paper is to study the regional distribution and the evolution of the stock of public capital in Spain during the last four decades. To this end, a sigma and beta convergence analysis is made, along with the study of the dynamics of the distribution of public capital stock. Furthermore, we analyse whether regional policy based on public capital investment has contributed to economic growth and/or to the reduction of regional disparities. Finally, and considering different assignment criteria, a discussion is given of where public investment should be targeted.

Keywords: Public capital, infrastructure, productivity, growth, convergence.

JEL classification: D24, H54, O40

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Introduction

Development policies designed to reduce regional disparities are to a great extent based on public investment. In recent years, one observes a growing interest in studying how public capital affects economic growth. Together with theoretical developments, a large empirical literature has emerged. In a pioneer work using aggregate data for the US economy, Aschauer (1989) estimated a value of 0.39 for output elasticity with respect to public capital and highlighted the role of productive public capital in productivity growth. The values estimated in subsequent studies were lower (although still positive) both for the US and other OECD countries. However, other works questioned the validity of these findings. Indeed, the empirical evidence has turned out to be more ambiguous than the first contributions on the topic indicated[1].

In the case of the Spanish economy, the available evidence points to a significant contribution of public investment, especially in infrastructure, to economic growth (Bajo and Sosvilla 1993, 1998; Mas *et al.* 1994, 1996; Argimón *et al.* 1994; González-Páramo 1995; Gil *et al.* 1998; Bajo *et al.* 1999). In general, the Spanish rather than the American results are more favourable to a positive effect of public capital on economic activity. This lends support to the idea that the effects of public investment might depend on the existing stock of public capital.

The processes of growth and capital accumulation of the Spanish economy have been very intense in the last decades. However, its territorial distribution has been uneven. In particular, regional differences in the stock of public capital seem to be one of the factors explaining observed disparities in labour productivity among the Spanish regions. Moreover, while all regions partook a continuous growth in labour productivity, this process was more intense in the less developed ones, reflecting a convergence process among the Spanish regions (Cuadrado-Roura *et al.* 1999; Villaverde and Sánchez Robles 2002; De la Fuente 2002a).

Based on these facts, this article analyses the evolution of public capital in Spain and addresses the question of whether investment in public capital has contributed to economic growth. Traditional approaches to study convergence in public capital stocks are complemented by estimates of density functions and transition matrices, aiming at studying such phenomena as multimodality and the mobility within the distribution. Furthermore, an analysis is also made of where public investment should be targeted as a function of which placement criterion is adopted. The structure of the work is as follows. Section 1 examines the Spanish regional distribution of public capital and its evolution. Section 2 focuses on the relationship between public capital, productivity and economic growth. Additionally, an exercise is undertaken aimed at determining where public investment should be targeted depending on whether the criterion followed is one of redistribution or of efficiency. The paper ends with a presentation of the most relevant conclusions.

[1] De la Fuente (1996) reviews this literature with a particular focus on some of the main econometric problems that arise in empirical studies. Another fairly complete review may be found in Sturm *et al.* (1998).

1. The Regional Distribution of Public Capital in Spain

This section presents an analysis of the Spanish regional distribution of public capital. Total public capital (TPK) is disaggregated into two components: productive public capital (PPK) and social public capital (SPK). Special attention is paid to the first one, also known as infrastructure. The sample used refers to the Spanish regions (Autonomous Communities) and covers the period 1965-1997. Data on the stock of physical capital was obtained from the IVIE and published by the BBVA Foundation in «The Stock of Capital in Spain and its Territorial Distribution» (4th ed.). Data on production, population and employment come from the homogeneous series «The National Income of Spain and its Distribution by Province: Homogeneous Series 1955-93 and Advances 1994-97», published by the BBVA Foundation in 1999[2].

1.1. *The stock of public capital*

Analysing the major features of the stock of public capital in Spain, three aspects particularly stand out. The first is that both components —productive and social capital— underwent a process of intense growth, reflecting the effort made to improve initial endowments. This effort was greater in the 1965-75 subperiod, with a non-negligible fall recorded between 1975 and 1985 and a recovery from the middle of the 1980's (Table 1). The second remark is that investment in social capital was greater than in productive capital, leading to a steady rise in the relative weight of social capital in total public capital. Nonetheless, it is worthwhile noting that the share of social capital was, on average, about 19%, thus infrastructure being by far the main component of total public capital. The third aspect is the unequal evolution of public capital among the Autonomous Communities, even though no clear territorial pattern is observed.

The above features illustrate some interesting aspects of the process of capital accumulation undergone by the Spanish regions. However, it has greater interest to focus on the level and evolution of the stock of public capital in terms of some variables such as GVA, employment, area, and population. The ratios «PPK/GVA» and «PPK/Employment» approximate, for the public sector, the indicators «capital-product» and «capital-labour» commonly used in the economic growth literature. In addition, since infrastructure is related to a territory, it seems appropriate to scale PPK to the area using the ratio «PPK/Area». Finally, given that social capital is conceived to provide services to the population, the ratio «SPK/Population» is also considered.

The most outstanding aspect of these indicators is their marked growth. At the national level, the index with the most moderate growth was the «PPK/GVA» ratio (because of the growth in real GVA itself), which rose by almost 70% from 1965 to

[2] All monetary variables are expressed in constant 1986 euros.

TABLE 1.—*Evolution of total, productive, and social public capital (growth rates)*

	TPK				PPK				SPK			
	1965-75	1975-85	1985-97	1965-97	1965-75	1975-85	1985-97	1965-97	1965-75	1975-85	1985-97	1965-97
Andalucía	7.9	4.2	6.5	6.2	12.7	5.6	3.5	7.0		3.2	6.2	5.6
Aragón	5.8	3.0	3.4	4.0	11.0	3.6	3.8	5.9		2.5	2.3	3.3
Asturias	7.2	4.1	5.3	5.5	10.3	5.6	3.1	6.1		3.5	4.3	4.9
Baleares	6.8	3.7	6.3	5.7	11.8	6.1	6.4	8.0		2.6	5.1	4.5
Canarias	11.1	4.6	5.8	7.1	15.0	6.6	6.1	9.0		3.4	4.1	5.9
Cantabria	6.4	5.0	6.0	5.8	13.0	5.7	4.1	7.3		3.7	6.8	5.1
Castilla y León	4.9	2.7	4.1	3.9	9.2	3.9	3.4	5.3		2.2	3.6	3.3
Castilla-La Mancha	6.2	2.9	5.8	5.0	11.7	4.2	3.4	6.2		2.1	5.7	4.5
Cataluña	10.8	2.9	5.3	6.2	13.9	5.3	6.2	8.3		1.5	4.4	5.4
Com.Valenciana	10.3	4.5	5.8	6.8	14.3	5.8	6.3	8.6		3.3	5.1	6.0
Extremadura	4.4	3.2	6.7	4.9	9.0	4.8	5.1	6.2		2.2	5.5	3.8
Galicia	5.5	5.1	6.4	5.7	11.7	5.6	5.4	7.4		4.4	5.6	4.7
Madrid	12.5	4.1	4.9	7.0	18.6	6.5	4.7	9.4		2.6	4.3	6.1
Murcia	7.2	6.5	6.6	6.8	14.3	6.4	5.5	7.8		6.1	6.4	6.4
Navarra	5.7	5.1	5.4	5.4	12.0	6.3	6.0	6.9		3.8	4.0	4.4
País Vasco	10.5	5.2	5.3	6.9	15.5	4.4	4.3	7.7		4.0	3.5	5.7
Rioja (La)	4.9	11.0	1.7	5.5	8.6	4.1	3.9	5.4		12.1	0.0	5.1
Spain	8.1	4.0	5.5	5.8	12.9	5.4	4.8	7.4		2.9	4.7	5.0
C.V.	0.31	0.49	0.24	0.16	0.21	0.18	0.24	0.17		0.82	0.35	0.19

Note: C.V.=Coefficient of variation

1997 (Table 2). The other three ratios, however, presented far greater increases in that same period: «PPK/Employment» increased by a factor of 4.3 (Table 3), «PPK/Area» by 4.8 (Table 4), and «SPK/Population» by 8 (Table 5).

TABLE 2.—*PPK/GVA*

	Level*				Growth rate			
	1965-75	1975-85	1985-97	1965-97	1965-75	1975-85	1985-97	1965-97
Andalucía	0.3	0.3	0.4	0.3	2.6	1.1	3.0	2.3
Aragón	0.4	0.4	0.4	0.4	1.3	0.0	-0.7	0.1
Asturias	0.3	0.3	0.4	0.3	2.7	1.6	3.3	2.6
Baleares	0.2	0.1	0.2	0.2	-0.1	-0.9	2.3	0.5
Canarias	0.2	0.3	0.3	0.3	3.6	0.2	0.4	1.3
Cantabria	0.2	0.2	0.3	0.3	0.7	1.5	4.5	2.4
Castilla y León	0.4	0.4	0.4	0.4	0.6	0.2	0.7	0.5
Cast.La Mancha	0.4	0.4	0.5	0.4	0.9	0.5	2.1	1.2
Cataluña	0.2	0.2	0.2	0.2	5.7	-0.6	1.2	2.0
Com.Valenciana	0.2	0.2	0.3	0.2	4.5	0.3	1.7	2.2
Extremadura	0.4	0.4	0.5	0.4	0.2	0.2	2.2	1.0
Galicia	0.2	0.2	0.3	0.3	-0.9	1.9	2.9	1.4
Madrid	0.1	0.1	0.2	0.1	6.6	0.2	0.9	2.4
Murcia	0.2	0.2	0.3	0.2	1.5	3.4	2.6	2.5
Navarra	0.3	0.4	0.4	0.3	1.0	0.8	0.5	0.7
País Vasco	0.2	0.3	0.3	0.2	5.5	2.9	1.0	3.0
Rioja (La)	0.3	0.5	0.5	0.4	0.8	8.6	-3.8	1.4
Spain	0.2	0.3	0.3	0.3	2.7	0.7	1.6	1.6
C.V.	0.44	0.45	0.37	0.39	0.85	3.32	1.21	0.53

Note: (*) Euros of PPK per euro of GVA. C.V.=Coefficient of variation.

There is some interesting additional information gathered from the analysis of these indicators. First, one observes major disparities between regions regarding both the levels and growth rates of public capital. Differences in the stock of public capital are notable in the case of productive public capital per Km^2 whereas the greatest disparities in terms of growth rates are observed for the «PPK/GVA» ratio. Disparities between regions were lower in the case of *per capita* social public capital, but they were also noticeable (cf. values of the coefficients of variation). Secondly, by subperiods, these ratios show a similar evolution to that noted above with respect to the absolute stock of public capital, following the cyclical profile of the Spanish economy. Finally, analysing the relationship between these indicators and the development level of the regional economies, measured by their *per capita* GVA, it is worthy to note the inverse relationship observed between the «PPK/GVA» ratio and the level of *per capita* GVA, with a correlation coefficient of –0.6. On the other hand, it is observed that, on average, the richest regions have grater endowments of infrastructure per km?, so the simple correlation coefficient between the «PPK/Area» ratio and *per capita* GVA is now positive, reaching a value of 0.62.

TABLE 3.—*PPK/Employement*

	Level*				Growth rate			
	1965-75	1975-85	1985-97	1965-97	1965-75	1975-85	1985-97	1965-97
Andalucía	2061	3476	5984	4010	7.7	4.0	5.0	5.5
Aragón	3781	6143	7392	5856	6.0	3.0	1.4	3.3
Asturias	2346	3881	6518	4418	7.1	4.6	4.9	5.5
Baleares	1639	2117	2828	2242	4.0	1.4	3.8	3.1
Canarias	2171	3667	4760	3599	9.1	2.6	2.1	4.4
Cantabria	1887	2975	5952	3810	4.6	4.6	6.9	5.5
Castilla y León	2979	4563	6665	4871	5.3	3.7	3.3	4.0
Cast.-La Mancha	2823	4610	7909	5336	6.6	3.6	5.1	5.1
Cataluña	1983	3199	4224	3196	9.3	2.0	3.4	4.8
Com.Valenciana	1778	3163	4619	3281	9.1	3.1	4.0	5.3
Extremadura	2640	4021	6849	4695	5.3	4.2	4.8	4.8
Galicia	1330	2156	3945	2606	3.0	5.8	6.3	5.1
Madrid	1547	2502	3207	2464	9.0	2.4	2.5	4.5
Murcia	1348	2736	5039	3196	6.0	6.7	4.5	5.6
Navarra	2765	5651	7009	5274	5.2	4.3	2.8	4.0
PaísVasco	2172	4271	6264	4365	9.3	5.2	2.9	5.6
Rioja (La)	2155	7341	8567	6196	4.7	13.1	-1.2	5.0
Spain	2088	3447	5087	3651	6.9	3.6	3.8	4.7
C.V.	0.31	0.41	0.32	0.32	0.30	0.74	0.51	0.17

Note: (*) Euros of PPK per euro of GVA. C.V.=Coefficient of variation.

TABLE 4.—*PPK/Area*

	Level*				Growth rate			
	1965-75	1975-85	1985-97	1965-97	1965-75	1975-85	1985-97	1965-97
Andalucía	45615	71709	128321	85811	7.3	3.2	6.2	5.6
Aragón	35879	54334	66867	53270	5.2	2.5	2.3	3.3
Asturias	93747	146084	223196	159205	7.0	3.5	4.3	4.9
Baleares	84254	119963	188813	135411	5.9	2.6	5.1	4.5
Canarias	119714	220860	324303	228669	10.7	3.4	4.1	5.9
Cantabria	68470	104620	196197	129558	4.6	3.7	6.8	5.1
Castilla y León	32731	43705	60430	46738	4.1	2.2	3.6	3.3
Cast.-La Mancha	21683	31333	51821	36356	5.5	2.1	5.7	4.5
Cataluña	130965	214671	296312	219014	10.9	1.5	4.4	5.4
Com.Valenciana	91869	170067	266317	182491	10.0	3.3	5.1	6.0
Extremadura	24511	30404	50057	36344	3.4	2.2	5.5	3.8
Galicia	53554	83042	136325	94807	3.7	4.4	5.6	4.7
Madrid	284454	512491	742425	527922	11.9	2.6	4.3	6.1
Murcia	35726	72273	144243	89057	6.8	6.1	6.4	6.4
Navarra	50540	98235	131048	96170	5.6	3.8	4.0	4.4
País Vasco	220359	416722	600743	424725	10.4	4.0	3.5	5.7
Rioja (la)	44679	139235	168445	121386	4.5	12.1	0.0	5.1
Spain	53689	87106	132394	94143	7.5	2.9	4.7	5.0
C.V.	1.3	1.5	1.4	1.4	0.4	0.8	0.4	0.2

Note: (*) Euros of PPK per euro of GVA. C.V.=Coefficient of variation.

TABLE 5.—*SPK/Population*

	Level*				Growth rate			
	1965-75	1975-85	1985-97	1965-97	1965-75	1975-85	1985-97	1965-97
Andalucía	126.4	267.2	394.6	270.8	12.5	4.5	2.9	6.3
Aragón	185.9	342.0	493.6	350.6	10.7	3.1	4.0	5.8
Asturias	150.7	292.9	455.2	309.1	9.6	5.3	3.4	5.9
Baleares	118.6	240.0	410.6	268.1	9.7	4.7	5.0	6.3
Canarias	130.0	286.2	500.9	319.1	12.6	5.4	5.0	7.5
Cantabria	152.0	334.6	529.2	351.2	12.2	4.8	4.1	6.8
Castilla y León	177.9	329.1	483.7	340.3	10.2	3.7	3.8	5.7
Cast.-La Mancha	121.1	258.7	372.1	257.7	13.2	4.1	3.2	6.5
Cataluña	103.2	204.5	363.4	234.2	11.2	4.5	6.0	7.1
Com.Valenciana	118.7	242.8	414.6	270.2	12.1	4.5	5.7	7.3
Extremadura	112.7	232.8	389.0	255.4	10.9	4.8	5.2	6.8
Galicia	122.4	254.7	467.9	295.4	11.6	5.2	5.7	7.3
Madrid	135.1	299.5	491.7	321.4	14.6	5.1	4.3	7.7
Murcia	119.9	237.5	395.2	261.3	11.3	4.8	4.7	6.8
Navarra	156.2	319.8	579.6	370.3	7.3	5.4	5.9	6.2
PaísVasco	152.1	308.1	496.4	330.8	12.5	3.8	4.5	6.7
Rioja (La)	174.3	303.1	417.8	306.6	8.4	3.2	3.8	5.0
Spain	131.4	267.8	433.1	288.1	11.7	4.5	4.5	6.7
C.V.	0.19	0.15	0.14	0.14	0.15	0.16	0.21	0.11

Note: (*) Euros of PPK per euro of GVA. C.V.=Coefficient of variation.

1.2. *Regional convergence in public capital stock*

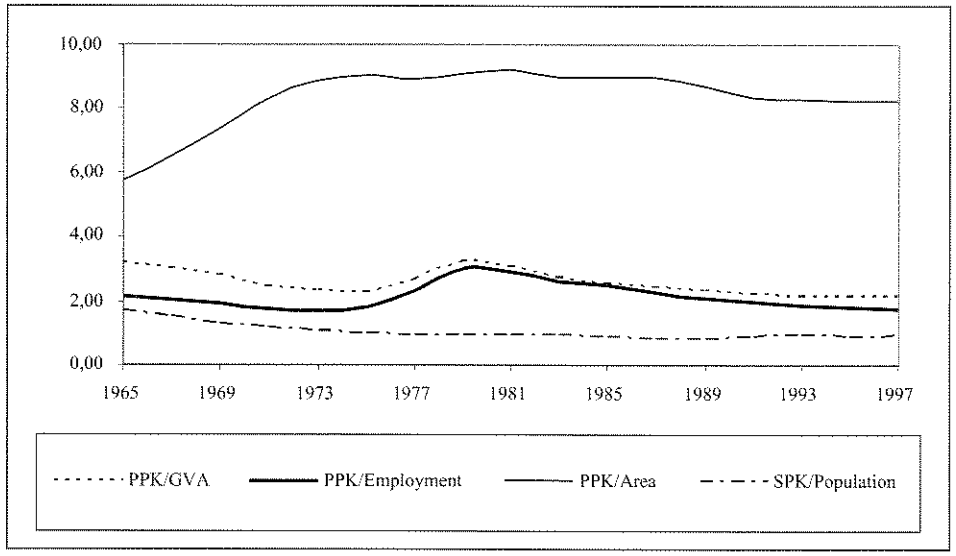
Given the unequal regional levels and evolution of the aforementioned public capital indicators, one could wonder whether existing disparities increased or decreased over time. To answer this question we use the traditional concepts of sigma and beta convergence, coined by Barro and Sala-i-Martin (1991, 1992).

Figure 1 shows the profile of the so-called sigma convergence, measured by the coefficient of variation. As can be observed, there have been small advances in the process of convergence in three of the four ratios under analysis («PPK/GVA», «PPK/Employment», and «SPK/Population»), but a notable increase of divergence in the «PPK/Area» ratio. Only in the case of *per capita* social capital was this mild process of convergence monotonic over the entire sample period whereas disparities in the «PPK/GVA» and «PPK/Employment» ratios increased in the 1975-79 subperiod. Regarding the «PPK/Area» ratio, disparities increased considerably in the 1965-75 subperiod, followed by a low level of convergence until the end of the period in 1997.

We also analyse the evolution of the disparities in terms of the beta convergence[3], calculated by an ordinary least squares (OLS) estimate of an equation of the type

[3] Beta convergence refers to a negative relationship between a variable's growth rates and its initial level. Hence, if on average regions with the lowest initial levels of public capital stock are those which present the greatest growth in that parameter, there is a beta convergence process with respect to the stock of public capital.

FIGURE 1.—*Sigma convergence*



$$(\log x_{i,t} - \log x_{i,t-T}) / T = \alpha + \beta \log x_{i,t-T} + \varepsilon_{it}$$

where x denotes the public capital ratio under consideration, and all the other variables have their usual meanings. The results are shown in Table 6. As was also the case for the sigma convergence, one observes beta convergence in the «PPK/GVA», «PPK/Employment», and «SPK/Population» ratios and beta divergence in the «PPK/Area» ratio. The rate of beta convergence was considerably higher for the «SPK/Population» ratio than for the other two ratios[4].

TABLE 6.—*Absolute beta convergence*

Ratio	Beta	Adjusted R^2	Speed of convergence (%)
PPK/VAB	-0.01219		
	(-3.55429)	0.42981	1.54
PPK/E	-0.01053		
	(-1.94442)	0.14807	1.28
PPK/S	0.00825		
	(2.49608)	0.24636	-0.73
SPK/P	-0.02219		
	(-5.19310)	0.61876	3.87

Note: t-statistic in parentheses.

[4] For a straightforward explanation of how the rate of convergence may be calculated, see Goerlich and Mas (2001), volume II.

The analysis carried out above may be criticised —see, for instance, Quah (1993a,b)— on the basis that those statistics only refer to certain moments of the distribution. In order to get a more complete characterization of the distribution, we shall estimate the corresponding density functions and transition matrices, aiming at studying the possible existence of such phenomena as multimodality and the mobility within the distribution.

The identification of possible multimodality phenomena (polarization or stratification), understood as an increase in homogeneity within some groups of the distribution together with an increase in heterogeneity between these same groups[5], could be undertaken by estimating the density function, which is illustrative of the external shape of the distribution. In this study we estimate the density functions of our four indicators of public capital stock by applying a Gaussian kernel with optimal bandwidth following the procedure by Silverman (1986). The results (Figure 2) show the following three characteristics:

1. In general, the shape of the density functions varies considerably with time, although there is no apparent definite pattern in their evolution.
2. Bimodality is observed in isolated cases, but this phenomenon is not very significant.
3. Except in the case of the «PPK/Area» ratio, there seems to be a slight reduction of the spread of the distribution and a tendency towards concentration of the probability mass, both facts pointing to the aforementioned convergence phenomena. On the other hand, there is an important increase in the degree of dispersion corresponding to the «PPK/Area» ratio in the 1965-75 subperiod, followed essentially by stabilization for the rest of the period under study.

The information provided by the density functions complements that obtained from the more conventional approach, but do not carry any information about the changes that might have taken place within the distributions. It is possible for the density functions to be the same in two different years, even though the ranking of the regions in the distribution may experience substantial changes. We shall tackle the analysis of this type of phenomenon, known as intradistributional dynamics or mobility in ranking, by computing the so-called transition matrices[6]. These are square matrices in which the elements m_{ij} are the probabilities that a region initially belonging to interval i ends by belonging to interval j. Hence, the elements of the main diagonal ($i=j$) are measures of persistence in the same class, while the off-diagonal elements ($i \neq j$) are measures of mobility in the ranking (upwards when $i<j$ and downwards when $i>j$)[7]. From results displayed in Table 7 we may draw the following conclusions:

[5] Polarization, as was observed by Esteban (2002), is a somewhat slippery concept to pin down. However, for a given distribution it can be understood as the «degree to which the population clusters around a small number of poles» that maintain some distance between each other.

[6] Another way of approaching this issue is by means of stochastic kernels. An application and simple interpretation of these kernels may be found, for example, in Villaverde and Maza (2003).

[7] Formally, if one uses F_0 and F_t to denote the initial and final distributions, and M_t the transition matrix, the relationship between these distributions and the transition matrix will be written as $F_t = M_t * F_0$. In this

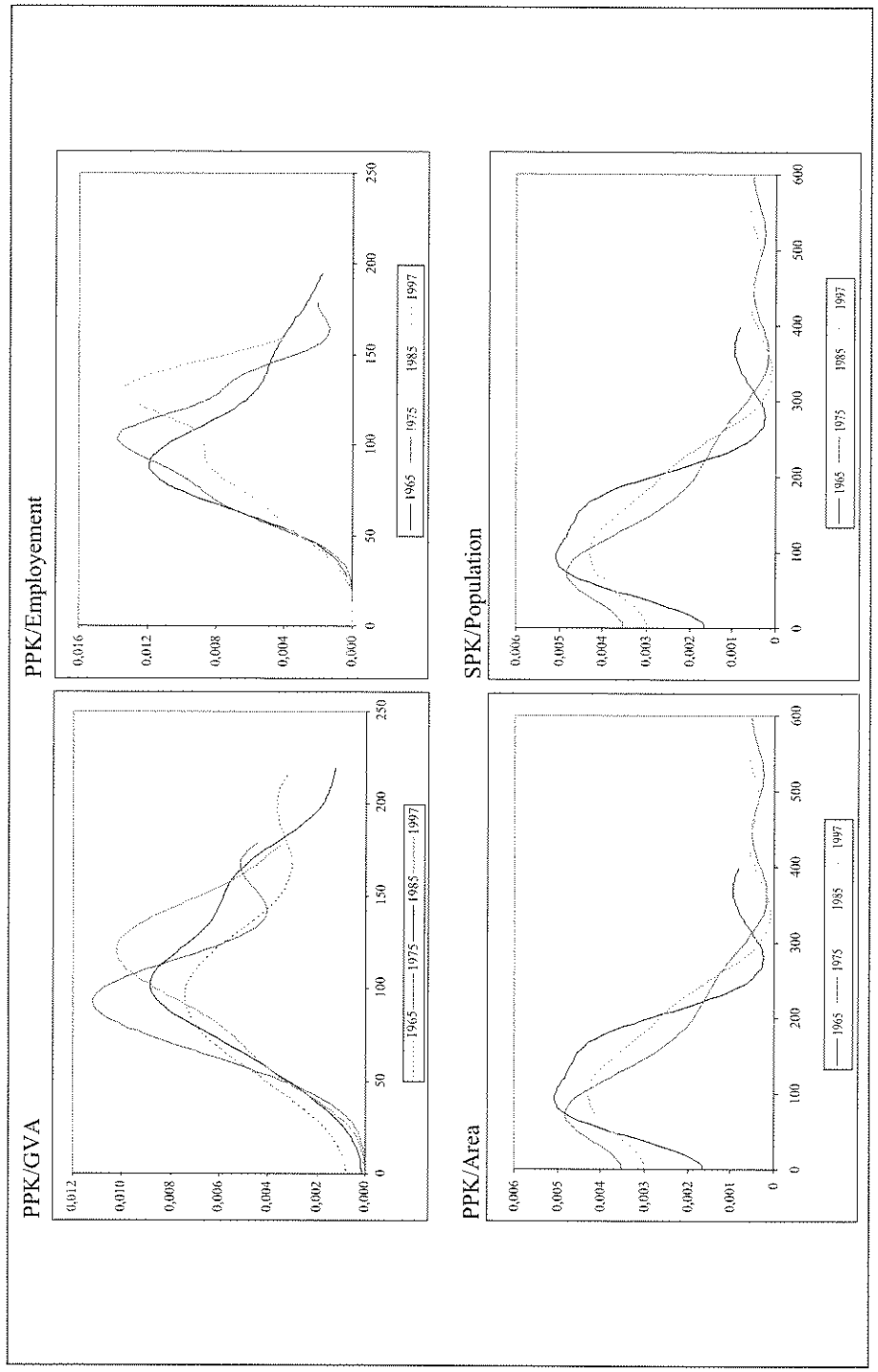


FIGURE 2.—*Density functions*

1. The degree of persistence or immobility is not very high, except for the «PPK/Area» ratio[8].
2. Both upward and downward transitions occur, neither being clearly predominant.
3. Initial and final distributions comparison confirms the aforementioned convergence phenomena in three of the ratios analysed. With respect to the «PPK/Area» ratio, differences between initial and final distributions are minimal, reflecting no apparent sign of convergence.

The ergodic distribution presents clear signs of convergence in the regional distribution of the «PPK/Employment» and «SPK/Population» ratios, and to a lesser degree in the ratio «PPK/GVA». On the contrary, there is no sign of convergence in the case of the «PPK/Area» ratio.

TABLE 7.—*Transition matrices 1965-97*

a) PPK/GVA

Intervals		1	2	3	4	5
	Obs.	8	18	13	11	1
1	8	*0.625*	0.375	0.000	0.000	0.000
2	19	0.158	*0.684*	0.105	0.000	0.053
3	10	0.000	0.200	*0.700*	0.100	0.000
4	9	0.000	0.000	0.333	*0.667*	0.000
5	5	0.000	0.000	0.200	0.800	*0.000*
Initial dist.		0.157	0.373	0.196	0.176	0.098
Final dist.		0.157	0.353	0.255	0.216	0.020
Ergodic dist.		0.154	0.366	0.288	0.133	0.019

Upper limits: 1=75.6; 2=110.5; 3=145.5; 4=180.4; 5= ∞

study, we divided the 51 observations (we considered three subperiods —1965/75, 1975/85 and 1985/95— and seventeen regions) into five intervals chosen with the criterion of achieving a uniform distribution. Thus, the limits and size of each interval are different for each of the considered indicators.

[8] In order to synthesise the degree of mobility into a single number, we use the following indicator put forward by Shorrocks (1978): M(A)= [n-trace(A)]/(n-1); where A is the transition matrix and n the total number of intervals. One obtains a degree of mobility of 40% for «PPK/GVA», 44% for «PPK/Employment», 18% for «PPK/Area», and 42% for «SPK/Population». The degree of mobility is thus fairly high in three of our four indicators.

[9] The complete development of the model, with the production functions corresponding to each of its stages, can be found in De la Fuente (1994) and in Alonso-Carrera and Freire (2002).

TABLE 7 *(cont.).—Transition matrices 1965-97*

b) PPK/Employment

Intervals		1	2	3	4	5
	Obs.	13	16	17	2	3
1	14	0.643	0.357	0.000	0.000	0.000
2	21	0.190	0.476	0.286	0.000	0.048
3	11	0.000	0.091	0.727	0.182	0.000
4	1	0.000	0.000	1.000	0.000	0.000
5	4	0.000	0.000	0.500	0.000	0.500
Initial dist.		0.275	0.412	0.216	0.020	0.078
Final dist.		0.255	0.314	0.333	0.039	0.059
Ergodic dist.		0.089	0.168	0.615	0.112	0.016

Upper limits: 1=89.4; 2=115.7; 3=142.1; 4=168.5; 5= ∞

c) PPK/Area

Intervals		1	2	3	4	5
	Obs.	13	16	17	2	3
1	24	0.958	0.042	0.000	0.000	0.000
2	14	0.286	0.571	0.143	0.000	0.000
3	6	0.000	0.000	0.833	0.167	0.000
4	1	0.000	0.000	1.000	0.000	0.000
5	6	0.000	0.000	0.000	0.000	1.000
Initial dist.		0.471	0.275	0.118	0.020	0.118
Final dist.		0.529	0.176	0.157	0.020	0.118
No ergodic dist.						

Upper limits: 1=116.8; 2=187.3; 3=257.7; 4=328.2; 5= ∞

d) SPK/Population

Intervals		1	2	3	4	5
	Obs.	13	16	17	2	3
1	20	0.800	0.200	0.000	0.000	0.000
2	12	0.167	0.417	0.417	0.000	0.000
3	14	0.000	0.357	0.643	0.000	0.000
4	2	0.000	0.000	1.000	0.000	0.000
5	3	0.000	0.333	0.333	0.333	0.000
Initial dist.		0.392	0.235	0.275	0.039	0.059
Final dist.		0.353	0.294	0.333	0.020	0.000
Ergodic dist.		0.287	0.344	0.402	0.000	0.000

Upper limits: 1=94.8; 2=112.4; 3=129.9; 4=147.4; 5= ∞

2. PRODUCTIVE PUBLIC CAPITAL AND ECONOMIC GROWTH

2.1. *Public capital and productivity*

After the intense process of public capital accumulation undergone by the Spanish economy over the last decades, a reduction in public capital productivity could be expected. Whichever the case, as long as the contribution of public investment to growth continues to be positive, investment in public infrastructure can be a major instrument of regional policy. In order to test the effect of public infrastructure on economic growth, we shall next estimate a regional production function to obtain the corresponding output elasticity to public capital. The production function to estimate is based on the model described by De la Fuente (1994) and De la Fuente and Vives (1995). This includes transport costs explicitly, so that one can analyse the effects of public infrastructure as a factor reducing these costs. In particular, these authors introduce transport costs by means of a two-stage production process. In the first stage, intermediate goods are produced and sent to other regions where, in the second phase, final goods are produced for consumption. The key assumption in introducing transport costs between these two stages is that these costs are negatively related to the stock of public infrastructure and positively to the size of the territory. The resulting final goods production function is given by the following expression[9]:

$$Y_i = A_i K_i^{\alpha} L_i^{\beta} H_i^{\eta} P_i^{\gamma} S_i^{1-\alpha-\beta-\gamma} \tag{1}$$

where Y_i is the final output, A_i is a productivity index, K_i is the stock of private capital, L_i is the number of workers, H_i is the mean stock of human capital per worker, P_i is the stock of productive public capital[10], and S_i is the area of the region.

Assuming constant returns to scale, the productivity of labour can be expressed as:

$$Q_i = \frac{Y_i}{L_i} = A_i \left(\frac{K_i}{L_i}\right)^{\alpha} H_i^{\eta} \left(\frac{P_i}{L_i}\right)^{\gamma} \left(\frac{S_i}{L_i}\right)^{1-\alpha-\beta-\gamma} \tag{2}$$

and, using lower case letters to denote logarithms, we get the equation to be estimated:

$$q_{it} = a_{it} + \alpha(k-l)_{it} + \eta h_{it} + \gamma(p-l)_{it} + \phi(s-l)_{it} + \varepsilon_{it} \tag{3}$$

This equation was estimated in levels by OLS for our panel data, including dummy time variables to take into account the possible effects of the economic cycle and technological progress. No fixed effects were included at the regional level, however, because of the lack of sufficient degrees of freedom, and because, as observed by Argimón and González-Páramo (1997), the inclusion of dummy regional variables could rise problems

[10] For simplicity, productive public capital (KKP) will now be denoted by *P*.

of multicollinearity when the area, which is constant in time, is included. Output was approximated by Gross Value Added at factor cost (GVAcf) while human capital, as is usual in the empirical literature, was approximated by the percentage of workers who had at least completed intermediate level education. Data on this last variable was obtained from the publication «Human Capital, Economic Growth, and Regional Development in Spain (1964-1997)» of the Bancaja Foundation (Perez and Serrano, 1998). The resulting estimates are given in Table 8. The effect of productive public capital on regional productivity was positive and significant, the output elasticity to productive public capital being 0.15. The size of the territory affected productivity negatively (as was predicted by the model estimated after including transport costs). The elasticity to area was —0.07. Lastly, the elasticities to private capital and human capital were 0.25 and 0.24, respectively[11].

TABLE 8.—*Estimated production function*

Variable	Coefficient	t-statistic
Constant	0.6099	(12.298)
k-l	0.2492	(8.973)
H	0.2409	(10.940)
p-l	0.1502	(7.568)
s-l	-0.0722	(-9.121)
Adjusted-R^2	0.9590	
SE	0.0715	

2.2. *Effective stock of public capital*

As was pointed out in the previous section, the analysis of absolute levels of public capital stock is of little use since these levels are biased by the size (economic, geographic, demographic, etc.) of the regions. However, when we take into account these scale variables, the problem is that considerable variations in regional rankings may be found depending on which scale variable is considered. De la Fuente (1994) solved this ambiguity by defining a measure of effective capital stock calculated as the geometric mean of productive public capital normalized both by employment and by area. Thus, from Equation (2), labour productivity can be re-expressed as

$$Q_i = \frac{Y_i}{L_i} = A_i \left(\frac{K_i}{L_i}\right)^{\alpha} H_i^{\eta} \left(\frac{P_i}{L_i}\right)^{1-\alpha-\beta} \left(\frac{P_i}{S_i}\right)^{\alpha+\beta+\gamma-1} \tag{4}$$

or, equivalently, as

[11] These results are similar to those of other studies. Thus, De la Fuente and Vives (1995) estimate an elasticity with respect to public infrastructure of 0.14, and with respect to area of —0.07. For private and human capital, their estimates (0.33 and 0.37, respectively) are slightly higher than ours, although our values lie within the usual intervals estimated for these variables in various studies (see Gorostiaga, 1999).

$$Q_i = \frac{Y_i}{L_i} = A_i \left(\frac{K_i}{L_i}\right)^{\alpha} H_i^{\eta} \left(P_i^{ef}\right) \tag{5}$$

where $P_i^{ef} = \left(\frac{P_i}{L_i}\right)^{\frac{1-\alpha-\beta}{\gamma}} \left(\frac{P_i}{S_i}\right)^{\frac{\alpha+\beta+\gamma-1}{\gamma}}$ is the effective stock of productive public capital.

From the previous estimation of the production function, we may obtain the elasticities corresponding to the «PPK/Employment» and «PPK/Area» ratios, and hence calculate the weights needed to compute the aforementioned indicator of effective capital stock. Using these weights, which were found to be 0.52 for «PPK/Employment» and 0.48 for «PPK/Area», and the average values of «PPK/Employment» and «PPK/Area», and applying the expression

$$P_i^{ef} = \left(\frac{P_i}{L_i}\right)^{0,52} \left(\frac{P_i}{S_i}\right)^{0,48} \tag{6}$$

we obtain the effective levels of the capital stock given in the third column of Table 9 (the national mean is taken to be 100). For comparison, the first two columns present the average rank in decreasing order corresponding to the relative indicators of «PPK/Employment» and «PPK/Area». These results confirm the critical dependence of the rank of any given region on the choice of the scaling variable. The fourth column gives the regional

TABLE 9.—*Effective capital stock of public infrastructure (average 1965-97)*

	Ranking		Effective stock	Ranking
	PPK/Employment	PPK/Area	(Spain=100)	Effective stock
Andalucía	9	13	100.4	10
Aragón	2	14	97.3	11
Asturias	7	6	142.0	5
Baleares	17	7	92.2	12
Canarias	11	3	151.8	3
Cantabria	10	8	119.2	9
Castilla y León	5	15	83.0	15
Castilla-La Mancha	3	16	77.1	16
Cataluña	13	4	139.9	6
Com.Valenciana	12	5	129.9	7
Extremadura	6	17	72.1	17
Galicia	15	11	84.2	14
Madrid	16	1	186.2	2
Murcia	14	12	90.8	13
Navarra	4	10	122.3	8
P-Vasco	8	2	226.2	1
Rioja (La)	1	9	148.7	4

ranking on the basis of the levels of effective capital stock. As can be observed, this is noticeably different from the previous two cases. In particular, the Basque Country and Madrid are the Communities with the highest levels of effective capital stock (126 and 86 percentage points above the mean, respectively), while Extremadura and Castilla la Mancha have much lower levels (28 and 23 percentage points below the mean, respectively). These results seem to be coherent with the developmental level of each region, as reflected in the corresponding correlation coefficient (0.61).

2.3. *Regional policy and the location of public investment*

By investing in public infrastructure, public policy-makers can try to influence the spatial distribution of capital stock and thereby of economic activity. We shall next analyse what would be the ranking of the regions according to different criteria —whether of equity or of efficiency— for the placement of public investment.

In terms of equity, we may consider two criteria. First, the criterion of equalization, or convergence, of public capital stock. With this criterion, public investment should go to the regions with the lowest levels of public capital stock. We have already analysed the distribution of the stock of public capital between the Spanish regions, so that we shall not insist further on it[12]. A second criterion would be that of convergence in terms of production or regional income. Thus, given that public capital contributes positively to labour productivity growth, public investment could be directed to the most backward regions with the aim of favouring their development. The first two columns of Table 10 present the average levels of productivity and the ranking that results from this criterion. The Communities of Galicia, Extremadura, and the two Castillas have the lowest levels of output per worker, and are therefore amongst the priority regions to receive public investment; while Madrid and the Basque Country are at the end of the scale. Although there are some differences between the ranking that results from this redistributive criterion and that based on effective public capital stock, there is a coincidence between the two criteria in including the first four regions amongst those most needing public investment and the last two regions at the opposite extreme.

Even though public investment can contribute to redistribution, it could be argued that it would be preferable to target public investment on the basis of efficiency and economic growth criteria in order to maximize aggregate output. The resulting income could then be distributed with instruments that are specific to this purpose (for example, via taxation or social protection)[13].

[12] The ranking of relative capital stock levels in Table 9 is presented in decreasing order: rank 1 corresponds to the region with the greatest relative stock of capital, rank 17 to the region with the lowest. With the criterion of equalizing capital stock levels, one would have to consider the inverse order so that the top-ranked region with priority in the placement of public investment would be that with the lowest level of capital stock.

[13] A discussion of the trade-off between efficiency and equity as it effects the targeting of public investment can be found in De la Fuente (2002b).

From a growth and economic efficiency standpoint, some authors (Mulligan and Sala-i-Martín 1993; Sala-i-Martín 1997) note that public investment should go to regions where the ratio between public and private capital is the lowest. The basis of this criterion is the marginal productivity of public capital (in particular, the existence of decreasing returns on public capital) and the relationship of complementarity between public and private capital (so that the marginal productivity of public capital is positively related to the stock of private capital). The «PPK/Private capital» ratio is presented in the third column of Table 10. It was calculated by averaging over the entire period. The fourth column of the table presents the ranking corresponding to this criterion, *i.e.*, greater public investment in those regions where this ratio is lower. Columns 5 and 6 present the results of adapting this criterion to our production function in Equation (5), where the arguments of the productivity function are capital per worker and effective public capital stock. In particular, these two columns list the values of the «effective public/private capital» ratio and the corresponding ranking. One observes that there are substantial variations in the results according to which criterion is used. Thus, on the basis of the «PPK/K» ratio, some of the most developed regions (Baleares, Madrid, Catalonia, and the Community of Valencia) are at the top of the ranking, while less public investment would go to the least productive regions. These relationships are somewhat smoothed out when considering the effective stock of public capital, although a similar pattern is maintained in many cases. Nevertheless, regions such as Madrid and Catalonia are no longer at the top of the ranking, and regions such as Castilla la Mancha and Extremadura move to a significantly more favourable position, even though at no time do they reach positions at the top of the ranking.

TABLE 10.—*Criteria for the territorial placement of public investment (average 1965-97)*

	Redistribution		Efficiency (1)		Efficiency (2)		Efficiency (3)	
	Y/L	Ranking	PPK/K	Ranking	Pef/K	Ranking	PMPef	Ranking
Andalucia	12.47	5	0.18	8	0.79	4	0.12	7
Aragón	14.32	12	0.31	16	0.88	9	0.13	6
Asturias	13.57	7	0.22	11	1.26	15	0.09	16
Baleares	14.93	13	0.08	1	0.55	1	0.14	2
Canarias	14.14	9	0.16	6	1.14	14	0.09	15
Cantabria	13.58	8	0.17	7	0.92	10	0.11	9
Castilla y León	12.25	4	0.27	13	0.82	7	0.13	5
Cast-La Mancha	11.75	3	0.29	14	0.74	3	0.14	3
Cataluña	16.55	15	0.11	3	0.86	8	0.11	10
Com.Valenciana	14.29	11	0.12	4	0.80	5	0.10	12
Extremadura	10.53	2	0.30	15	0.82	6	0.13	4
Galicia	9.95	1	0.18	9	1.05	13	0.11	11
Madrid	17.74	17	0.08	2	1.02	11	0.09	14
Murcia	12.99	6	0.13	5	0.62	2	0.15	1
Navarra	15.17	14	0.26	12	1.04	12	0.11	8
P-Vasco	17.24	16	0.19	10	1.70	17	0.07	17
Rioja (la)	14.21	10	0.34	17	1.42	16	0.10	13
Spain	14.23		0.15		0.73		0.13	

Note: (*) Euros of PPK per euro of GVA. C.V.=Coefficient of variation.

The above efficiency criterion bases on the relationship between public and private capital, targeting public investment at regions where this ratio is lowest. Alternatively, one could analyse whether the resources allocated to public investment are more productive in one place or another. From the estimate of the output elasticity to public capital (g), we calculate the marginal productivity of this variable. Given that the area of the territory had a negative impact on the productivity per worker, reducing the utility of a given infrastructure endowment as a consequence of the transport costs, we calculate the marginal productivity of effective productive public capital which, besides considering the level of «PPK/Employment», also includes the effect of the size of the region[14]. Hence, on the basis of Equation (5), we obtain the marginal productivity of effective productive public capital from the following expression:

$$PMP^{ef} = \gamma \frac{Q}{P^{ef}} \tag{7}$$

These productivities are calculated from values averaged over the entire sample period. They are shown, together with the resulting ranking, in the last two columns of Table 10. Again, comparing the results of this criterion with the foregoing results, one observes some interesting features. Thus, Baleares (which is also the top-ranked region with the other two efficiency criteria) and Murcia are the two regions where an increase in the effective stock of public capital would contribute more to the growth of output per worker. This contribution would also be large in Extremadura and the two Castillas which were the regions with the lowest levels of effective public capital stock; on the other side, the Basque Country, the region with the greatest effective stock, has the lowest marginal productivity of effective public capital. In sum, this analysis further confirms that different criteria —whether of equity or of efficiency— for the placement of public investment give rise to very different rankings of regions by investment priority.

3. Conclusions

The Spanish economy has undergone a major process of growth over the last few decades. While this process has been common to all the country's regions, it has not been uniform across them. One of the factors accounting for this growth and for regional differences in development levels is the increase in public capital stock and its distribution over the territory. The study of the existing public capital stock, its evolution over time, and its contribution to regional growth, has been the principal issue under study in the present work. In particular, the aim has been to answer these three questions: Firstly, what is the stock of public capital in the different regions and how has

[14] This criterion of locating public investment on the basis of the marginal productivity of public capital is found in De la Fuente (2002b), although that work considers the marginal productivity of public capital, not of effective public capital.

public investment evolved over the last decades? Secondly, could investment in infrastructure contribute to growth and to reducing the existing regional disparities? And thirdly, where should public investment be targeted? As for this last question, we considered different criteria in terms of both efficiency and equity.

The analysis of the regional distribution of public capital in Spain showed there to exist significant disparities between the Autonomous Communities, although there is no apparent particular territorial pattern. Moreover, the results varied considerably according as to whether public capital was normalised relative to population size, employment, output, or area, so that the conclusions to be drawn depend on which indicator is used. An attempt was made to solve this ambiguity by considering an indicator of effective public capital stock. In all cases, the stock of public capital was highly disparate between regions, with the effective stock in the most poorly endowed region (Extremadura) being three times less than that of the best endowed (Basque Country). Public investment, however, has grown considerably in the last decades, and to a greater extent in regions with relatively low initial levels of public capital stock, leading to a reduction in existing disparities. The study of the density functions and the intradistributional mobility also tended to confirm this phenomenon of convergence in the relative public capital endowments of the different Spanish regions.

Furthermore, a regional production function was estimated in order to obtain the elasticity of the output per worker with respect to the stock of infrastructure. This function explicitly included the area and transport costs so as to pick up the role of infrastructure as a cost reduction factor. The results indicated that the productive public capital stock contributes to determining regional productivity, although the area of the territory has a negative influence as it reduces the utility of a given amount of infrastructure. Since public investment contributes positively to regional growth, it could be used as an instrument of regional policy, favouring the development of the relatively more backward regions. Nonetheless, the relatively more developed regions in general have a lower public/private capital ratio and are hence where public investment seems to be more productive. From a standpoint of criteria of efficiency and economic growth, therefore, public investment should be concentrated in these regions. In the last part of the paper, a discussion was given of different public investment location criteria and of the differences that they lead to. Where public investment is allocated will depend ultimately on which are the economic policy objectives set out by public decision makers.

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