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PUBLIC INVESTMENT AND CONVERGENCE IN THE SPANISH REGIONS

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Abstract

This paper studies the empirical relationships that have settled down in the Spanish regions between public investment and per capita income growth over period 1965-1995. From a neoclassical growth model with public and human capital, we derive a convergence equation that is estimated through panel data techniques. Besides providing evidence in favour of the conditional convergence hypothesis, the results show a negative effect of productive public investment on the rate of regional economic growth. On the other hand, public investment in education, although not very significant, and public resources devoted to health investment offer a positive correlation with the increment of per capita income. Alternative estimates to deal with the possible endogeneity of some variables as well as changes in the specification confirm the thick of the previous results.

Key words: Public investment, convergence, panel data.

Code JEL: H 54, R 40, R 53.

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I. Introduction

The discussion about the effects of regional policy on economic growth has been stimulated by the increasing economic integration in EU and their consequences on regional convergence. In a sense, some argue that such integration will affect negatively to the peripheral regions; their arguments are based on endogenous growth theory. In other sense, a regional convergence may be reached and public policies would help to get this purpose; in this way, public investment appears as main instrument for reducing differences in regional per capita income levels.

In the academic literature both questions have converged in a common topic that has been studied from different perspectives. In one hand, we find Biehl (1986) and Vickerman (1991), among others. The first one elaborates a regional index of endowments in different infrastructures that relates to per capita GDP, showing a high positive correlation between both variables. Vickerman (1991) underlines the importance of transport systems in the production processes that enlarge the benefits of the common market for regions geographically outlying.

On the other hand, economic growth models have also treated this question. Although the incorporation of public capital was already considered in a neoclassical model by Arrow and Kurz (1970), it was not until seminal article of Barro (1990) when it begins to be studied the topic in a deeper way. At the same time that the beginning of a wide literature on the interrelations between infrastructures and economic performance (Aschauer, 1989; Munnell, 1990), Barro builds an endogenous growth model where per capita income growth rate is sustained by existence of public capital. The advances on this topic were abundant, with novel contributions on congestion (Glomm and Ravikumar, 1994; Fisher and Turnovsky, 1998), transitional dynamics (Futagami *et al.*, 1993), implications on social welfare (González-Páramo, 1995; Dasgupta, 1999), inclusion of others public spending variables (Bajo-Rubio, 2000) and different tax systems (Jones *et al.*, 1993; Marrero, 1999).

The papers that into the neoclassical framework have offered empirical evidence of public investment effects on growth rate comprise a wide miscellany. Barro (1991) points out the existence

of a weak negative relationship between public investment and growth rate in a cross-section analysis for almost 90 countries over 1965-1985. Evans and Karras (1994) show through a panel data analysis that public capital does not affect positively to a group of OECD countries over period 1963-1983. Conversely, studies as Knight *et al.* (1993) offer evidence in favour of a direct relationship between public investment and growth. De la Fuente (1997) also finds a positive effect of public investment on growth in OECD countries (although subjected to decreasing returns). Galindo and Escot (1998), on the other hand, provide ambiguous evidence about the effects of public capital on per capita income growth rate in some OECD countries.

From a regional view, the abundance of published works that explicitly relate public investment to growth through estimates of convergence equations is more limited. Hulten and Schwab (1993) estimate a convergence equation for US manufacturing and do not detect a direct effect of public capital on productivity for period 1970-1986. Thomas (1996) evaluates the importance of infrastructures stock on growth rate for seventy European regions from 1970 to 1991 and reaches the conclusion that, considered by categories, regional endowments of infrastructures do not exert any significant effect on per capita income growth, while an index of all them is positively related to growth.

For the Spanish regional case, Mas *et al.* (1994) find evidence in favour of a positive effect of public capital on regional convergence over period 1955-1991, although carrying out estimates for shorter periods this result does not remain. Dolado *et al.* (1994) do not find any explanatory capacity for highways and roads infrastructures in convergence equations estimated for the Spanish provinces from 1955 to 1989. De la Fuente y Vives (1995) recognise the importance of public capital endowments in the determination of per capita regional income, although they indicate that the impact of regional policies in Spain during the 80's has been reduced. Also, a recent work of Gorostiaga (1999) estimates a positive but not significant effect of public investment on convergence rate. Bajo *et al.* (1999) also detect a positive effect (and significant) of public investor effort on

regional GDP. From a dual perspective, Avilés *et al.* (2001) show the capacity of public capital to reduce firm costs, so much in a regional as in a sectoral dimension.

This paper seeks to throw some light about the empirical relationships that have settled down in the Spanish regions between public investment and per capita income growth between 1965 and 1995. From a neoclassical model with public and human capital, a convergence equation is derived. This will be estimated through panel data techniques. Among the contributions of this work we can quote the explicit consideration of public investment in an empirical growth model through core infrastructures and human capital, the separation between public revenues and productive public spending and the statistical methods which we have used.

Second section presents the theoretical framework. Section III describes the estimation procedure as well as the results obtained under different specifications for the convergence equation. Next (section IV), we consider the econometric implications that are derived of likely endogeneity of some regressors. Section V offers alternative specifications of convergence equation: multiplicatives and time dummies and non-linear relationships between public investment and per capita income growth. Section VI pretends to establish a link between our results and theoretical contributions. Finally, Section VII concludes.

II. Theoretical framework

The theoretical framework that we will use is based on well-known Solow (1956) growth model; it will be treated from empirical view as proposed by Mankiw *et al.* (1992). In this section we provide the most general version for the model, *i.e.*, including private, public and human capital as production factors simultaneously. It will not avoid to use alternative specifications in the empirical estimation, taking account that these can be easily obtained from the presented one here. Therefore we assume a Cobb-Douglas production function with decreasing returns in acumulable factors for region i at time t as follows:

$$Y_{it} = (\Psi_{it} L_{it})^{1-\alpha-\beta-\gamma} (K_{it})^\alpha (G_{it})^\beta (H_{it})^\gamma, \quad (1A)$$

where $\Psi_{it} = \psi_{i0} e^{xt}$ and $L_{it} = L_0^i e^{nit}$, Y is regional output, ψ_{i0} a parameter that reflects unobserved or measured-difficult characteristics of region i (resource endowments, climate, institutions, etc.), L labour, K private capital, G productive public capital and H is human capital, with $\alpha + \beta + \gamma < 1$. Note that technology and labour grow exogenously at constant rates x y n , respectively¹. Based on constant returns to scale in all inputs we rewrite this expression in terms of effective labour (symbolised by $\hat{\cdot}$):

$$\hat{y}_{it} = \left(\hat{k}_{it} \right)^\alpha \left(\hat{g}_{it} \right)^\beta \left(\hat{h}_{it} \right)^\gamma. \quad (1B)$$

Next we define movement equations for acumulable production factors:

$$\begin{aligned} \dot{\hat{k}}_{it} &= (1 - \tau_{it}) s_{pi} \hat{y}_{it} - (\delta + n_i + x) \hat{k}_{it} \\ \dot{\hat{g}}_{it} &= s_{gi} \hat{y}_{it} - (\delta + n_i + x) \hat{g}_{it} \\ \dot{\hat{h}}_{it} &= s_{hi} \hat{y}_{it} - (\delta + n_i + x) \hat{h}_{it}, \end{aligned} \quad (2)$$

where a dot over a variable denote its time derivative; τ is the share of tax revenue in total output that government collect to finance productive and non-productive public spending; s_{pi} is the constant

¹ In a recent work (Martínez, 2000), a similar specification for the production function is used but incorporating spillovers effects from infrastructure located in other regions. The results do not detect any significant effect in this way. In other sense, it found that the spillovers may reduce per capita income growth rate through crowding-out private investment under certain circumstances (Martínez, 2001).

share of gross private investment in net taxes output; δ is the depreciation rate (constant and common); s_{gi} is the share gross public investment in net taxes output and variable s_{hi} is the equivalent concept for human capital. As it is well-known, whether this equations system is expressed in terms of growth rates and we solve for state variables, we obtain the steady-state values of private capital (\hat{k}_i^*), productive public capital (\hat{g}_i^*), human capital (\hat{h}_i^*) and output (\hat{y}_i^*).

When we write the per labour unit income growth rate as a logarithmically differential equation we obtain:

$$\frac{d \ln y_i}{dt} = \frac{d \ln \psi_i}{dt} + \alpha \frac{d \ln k_i}{dt} + \beta \frac{d \ln g_i}{dt} + \gamma \frac{d \ln h_i}{dt} . \quad (3)$$

In other hand, whether we use the expressions for the production factors growth rates from system (2) and we write them now in terms of log, we can reached the next expression for the growth rate of per labour effective income:

$$\begin{aligned} \frac{d \ln y_i}{dt} = & \alpha \left[(1 - \tau) s_i^p e^{(\alpha-1) \ln k} e^{\beta \ln g} e^{\gamma \ln h} \right] + \beta \left[s_i^g e^{\alpha \ln k} e^{(\beta-1) \ln g} e^{\gamma \ln h} \right] + \gamma \left[s_i^h e^{\alpha \ln k} e^{\beta \ln g} e^{(\gamma-1) \ln h} \right] \\ & - (\alpha + \beta + \gamma)(\delta + n_i + x). \end{aligned} \quad (4)$$

This formula is used to yield a first-order Taylor approximation around steady-state values. If $\lambda = (1 - \alpha - \beta - \gamma)(\delta + n_i + x)$ denotes the speed of convergence to steady state, solving the differential equation (4) and expressing all in per capita terms, we obtain:

$$\begin{aligned} \ln y_{it} - \ln y_{it-T} = & \rho \ln \psi_{it} + x \left(t - e^{-\lambda T} (t-T) \right) - \rho \ln y_{it-T} + \rho \frac{\alpha}{1 - \alpha - \beta - \gamma} \ln s_{pit} + \rho \frac{\beta}{1 - \alpha - \beta - \gamma} \ln s_{git} + \\ & \rho \frac{\gamma}{1 - \alpha - \beta - \gamma} \ln s_{hit} - \rho \frac{\alpha + \beta + \gamma}{1 - \alpha - \beta - \gamma} \ln (\delta + n_{it} + x) + \rho \frac{\alpha}{1 - \alpha - \beta - \gamma} \ln (1 - \tau_{it}) \end{aligned} \quad (5)$$

where $\ln y_{it-T}$ is the log of per capita income at the beginning of the period of length T and $\rho = 1 - e^{-\lambda T}$.

In the next section we estimate this last equation. As you can see, we have included into the model productive public spending and taxes collected by government to finance *any kind* of public

expenditure. This enable to us to dealt with the public sector role in a more extensive view and without conditioning both sides of public budget. In other hand, the parameter A_{i0} yields a way to incorporate directly unobserved differences across regions.

III. Estimation of convergence equation

Most empirical works on economic growth estimate the speed of convergence and the effects of some conditioning variables on growth rate using cross-section analysis. This methodology uses Ordinary Least Squared that is able to control the existence of different steady states across economies. However, as Islam (1995) points out, this approach do not allow to consider unobservable individual-regional characteristics and it may imply biased coefficients from estimation. A panel data approach avoids this circumstance and data time dimension is exploited in a better way².

We are going to estimate equation (5) with panel data techniques. We have based on that expression but we will offer also some alternative specifications. In this sense, three different measures of human capital investment rate s_h have been used as proxies: s_e is public investment in education, s_d is public investment in health and s_s the sum of both of them³; h is a stock variable of human capital. The sample consists of 17 Spanish regions over period 1965-1995. Regional unemployment rate has been added to control business cycle; we incorporate an error term to (5) that we assume is distributed as a normal with zero mean and constant variance. Details on variables elaboration and sources can be found in data appendix.

The term that symbolizes technical growth, $x(t - e^{-\lambda T}(t - T))$, depends on exogenous, constant variables, so it can be studied jointly to $\ln \psi_{i0}$. This has been the chosen specification. Anyway, we have used a time trend previously, but as this alternative caused multicollinearity problems, mainly

² However, De la Fuente (2000) considers that panel data studies can be sometimes deceiving because of specification problems.

³ The use of social public capital as a proxy to human capital, although not very frequent, is not a novelty in the literature (see, for example, Rivera and Currais, 2000).

on the coefficient of $(1 - \tau_{it})$, and in smaller degree on y_{it-1} , we have opted to eliminate it⁴. Later we will employ time dummies to control technical progress in a different way.

Hausman (1978) test provides evidence on the existence of correlations between individual effects and regressors, for what we have taken a within-groups estimator. On the other hand, all the estimates have been carried out pondering the observations in the cross-section to avoid heteroskedasticity caused by the different size of the units. Also we have used White covariances matrix.

As it is habitual in empirical works on convergence, the results that are presented in table 1 impose the restriction that the coefficients of demographic variables, private investment rate and public investment rate in infrastructures and human capital, add zero. This hypothesis is accepted in most of the specifications (except the presented one in column (6)), as Wald statistics show. Table 1 also includes a F test to evaluate joint significance of individual effects for each region. For the specifications (3)-(6) the null hypothesis (*i.e.*, only a constant term for all the regions) is rejected at a level of significance of five percent. On the other hand, the first two estimates accept this null hypothesis. Nevertheless, guided partly by the economic sense that notices us of the existence of individual characteristics and not controlled in our analyses, and partly to facilitate the comparison to later specifications, we have decided to include the results that estimate a constant for each region.

⁴ Easterly and Rebelo (1993) point out the sensibility from the taxes to the remaining regressors in the growth equations, being difficult to isolate the effects of the taxation in presence of a remarkable multicollinearity.

Table 1: Estimation of convergence equation. Spanish regions (1965 - 1995)**Dependent variable: Per capita income growth rate for each span.**

	(1)	(2)	(3)	(4)	(5)	(6)
$\text{Log}(y_{i,t-T})$	-0.058 (-5.95)	-0.062 (-6.07)	-0.089 (-7.80)	-0.086 (-7.64)	-0.102 (-9.25)	-0.190 (-9.61)
$\text{Log}(s_{pit})-\text{log}(n_{it}+x+\delta)$	0.032 (5.80)	0.025 (3.96)	0.031 (4.89)	0.034 (5.31)	0.029 (5.04)	0.035 (6.43)
$\text{Log}(s_{git})-\text{log}(n_{it}+x+\delta)$		0.006 (1.71)	-0.003 (-0.77)	-0.002 (-0.47)	-0.006 (-1.65)	-0.004 (-1.02)
$\text{Log}(s_{sit})-\text{log}(n_{it}+x+\delta)$		0.002 (0.84)	0.003 (1.23)			
$\text{Log}(s_{eit})-\text{log}(n_{it}+x+\delta)$				0.001 (0.58)		
$\text{Log}(s_{dit})-\text{log}(n_{it}+x+\delta)$					0.011 (5.05)	
$\text{Log}(h_{it})$						0.056 (6.38)
$\text{Log}(u_{it})$	-0.0001(-0.10)	0.0002 (0.14)	-0.005 (-2.39)	-0.005 (-2.43)	-0.004 (-2.12)	-0.011 (-5.25)
$\text{Log}(1-\tau_t)$			-0.213 (-4.94)	-0.211 (-4.80)	-0.230 (-5.78)	-0.060 (-1.15)
λ	0.029	0.032	0.046	0.044	0.053	0.105
α	0.35	0.26	0.258	0.290	0.213	0.158
β		0.06	- 0.024	- 0.017	- 0.044	- 0.018
γ		0.02	0.024	-0.008	0.080	0.253
RSS	0.091	0.089	0.082	0.082	0.079	0.073
Durbin-Watson	1.73	1.79	1.80	1.79	1.85	1.57
Hausman	20.36 [0.000]	26.79 [0.000]	56.66 [0.000]	53.43 [0.00]	90.37 [0.000]	110.79 [0.00]
Wald (χ^2)	0.09 [0.75]	0.25 [0.61]	0.27 [0.60]	1.56 [0.21]	0.0002 [0.98]	5.89 [0.015]
F	0.46 [16, 232]	0.69 [16, 230]	1.75 [16, 229]	1.75 [16, 229]	2.97 [16, 229]	4.00 [16, 229]

Notes: t-ratios shown in parentheses. P-values in brackets, except in last row where degrees of freedom are. Number of observations: 252 (see data appendix). Source: IVIE and Fundación BBVA.

From table 1 we can extract a group of comments about the interrelations that have settled down between regional convergence in Spain and public sector performance. First, the existence of conditional β -convergence among regions toward their respective steady states is found. The speed to which takes place this process is in a range between three and ten percent, according to specification. So, the versions (1) and (2) are in the line of studies as Barro and Sala-i-Martin (1999) that reach values next to three percent for the Spanish regions. On the other hand, the specifications (3)-(5) find values among four and five percent that are those obtained by Dolado *et al.* (1994). In any case the

speeds of convergence here obtained are the ones found by Gorostiaga (1999) and located by 17-18 percent. The last specification -column (6)- offers a rate of convergence of 10 percent, very similar to the one reached by Islam (1995) for OECD countries when human capital is included as a variable stock; nevertheless, it is very likely that this estimation suffers multicollinearity problems, so the results should be interpreted with caution.

Second, we should indicate that so much private investment rate as human capital indicators present the predicted signs for the theoretical model. Regarding private investment, and given the structural character of estimated equation, we are able to retrieve the share of productive factors in production function. In this sense, we find a wide interval of values for the elasticity of output to private capital: from 0.35 obtained under the simplest specification to more reduced figures as those presented in column (6). Human capital, on the other hand, appears with positive sign in all specifications but only when as variable stock (column (6)) or it is approximated through public investment in health (column (5)), it acquires statistical significance⁵. In the first case the elasticity overcomes sensibly the magnitude obtained in similar works; for the obtained values when human capital is included in rate terms, the elasticities are already in a range comparable to other works. Finally, we should indicate that public investment in education is not significant to explain regional per capita income growth. Maybe it shows the difficulties that other researchers have already pointed out when incorporate human capital to regional growth processes (Gorostiaga, 1999; Bajo *et al.*, 1999; Wolf, 2000). Also labour migrations across the Spanish regions could bias this coefficient (Raymond and García, 1996).

Third, noting the results obtained for productive public capital formation is required. From our analysis we see that productive public investment has exerted no influence -even negative- on growth rate of the Spanish regions: we find a negative sign in four out of five specifications where this

⁵ This result is, partially, in the line of Rivera and Currais (2000) for the OECD countries. These authors obtain that current health spending and capital health spending exert a positive influence on growth rate, although the estimated coefficient for the second of these variables is not significant.

variable appears. It invites to an additional discussion since it is commonly admitted the importance that public capital endowments play in the regional development.

Finally, income proportion available for private capital accumulation after discounting taxes ($1 - \tau_{it}$) appears with a negative sign, although the theoretical framework advances a positive sign for its coefficient. This may be caused by the Spanish public sector expansion over period; also, the figure of coefficient does not coincide (in absolute value) with the predicted one in the convergence equation⁶. Regarding unemployment rate u_{it} , its negative sign in all specifications is according to economic sense.

IV. An alternative possibility: endogeneity of the regressors

The possible endogeneity of some regressors in the estimate of convergence equation may cause that the obtained coefficients are not consistent. This circumstance could explain, at least partially, the results relative to the null significance of public investment in infrastructures and even its widespread negative sign. The literature about economic growth has shown in diverse occasions the suspicion that private investment rate depends on income growth rate; King and Levine (1994), Dolado *et al.* (1994) and Gorostiaga (1999) suppose a sample of this statement. On the other hand, as it is well known, an important shortcoming pointed out to the seminal works on public capital resides in the possible simultaneity of infrastructures with output (see for example Sturm, 1998), generating an inverse causation that biases the estimates.

Next we will offer additional empirical evidence to the shown one but carrying out an effort to take account the possible endogeneity of the rate of private and public investment (in infrastructures and social public capital). With this aim, convergence equation will be estimated using an instrumental

⁶ The theoretical framework used in this paper does not present enough scope to deal with the (in)efficiency of taxation. For a detailed analysis of the taxation effects on growth, see Mendoza *et al.* (1997) and Doménech and García (2001). As we have already said, Easterly and Rebelo (1993) also show the difficulties of apprehending the influence of tax system on economic growth.

variables (IV) estimator; we will enlarge this approach through Generalised Method of Moments (GMM) to select the optimal instruments matrix.

So we will take a specification based on column (3) of table 1. This is sufficiently general as to illustrate the implications of likely endogeneity⁷. Since the used estimator has been the within-groups, it provokes that choosing lagged regressors as possible instruments is not the best option. We will employ, therefore, the transformation of variables in orthogonal deviations proposed by Arellano (1988) and Arellano and Bover (1990).

The construction of the matrix of instruments has followed GMM. Because of nature of this estimation procedure resides in minimizing the correlations between regressors and residuals, its use will allow us to generate an efficient group of instruments. In other hand, the potential heteroskedasticity in the disturbances invites to use two-step GMM estimator. Nevertheless, different simulations *à la* Montecarlo have shown that the standard errors estimated in a two-step procedure may be biased, so it is advisable for the inference based on asymptotic standard errors to take one-step GMM estimators⁸.

As it is known, when there are more instruments available than parameters to estimate, the model is overidentified. In this way, a test of overidentifying restrictions can be interpreted as a test about the validity of the group of instruments and/or the appropriate specification. We will use, therefore, a Sargan test to offer empirical evidence in one or other sense. On the other hand, keeping in mind that the assumption of not serial correlation in the disturbances is essential for the consistency of estimators, this null hypothesis should be tested. Therefore we adopt the strategy suggested by Arellano and Bover (1990) and Arellano and Bond (1991): if the errors are not correlated, the series of differentiated residuals should present a significant first-order correlation, while indications of

⁷ Estimates of alternative specifications are available on request. They corroborate the results obtained for the equation that serves us as reference.

⁸ For a further discussion, see Arellano and Bond (1991). Also Judson and Owen (1999) justify one-step GMM estimator from another point of view: the smaller bias that generates in non-balanced panels with a time dimension next to 20.

second-order serial correlation ought not to be appreciated. In the results that we offer, none of the two statistics linked to both circumstances ($m1$ and $m2$) provide hard evidence for the presence of serial correlation in the errors.

Table 2: GMM Estimation of convergence equation. Spanish regions (1965 - 1995).

Dependent variable: Per capita income growth rate for each span.

	(1)	(2)	(3)	(4)	(5)
$\text{Log}(y_{i,t-T})$	-0.096 (-10.94)	-0.095 (-12.69)	-0.094 (-11.68)	-0.102(-10.16)	-0.092 (-11.66)
$\text{Log}(s_{pit})-\text{log}(n_{it}+x+\delta)$	0.028 (3.58)	0.034 (5.71)	0.029 (4.07)	0.039 (6.08)	0.029 (3.95)
$\text{Log}(s_{git})-\text{log}(n_{it}+x+\delta)$	-0.009 (-2.13)	-0.009 (-1.89)	-0.007 (-1.90)	-0.020 (-2.98)	-0.003 (-1.14)
$\text{Log}(s_{sit})-\text{log}(n_{it}+x+\delta)$	0.003 (1.17)	0.005 (2.15)	0.006 (2.65)	0.008 (2.49)	0.003 (1.38)
$\text{Log}(u_{it})$	-0.005 (-2.88)	-0.004 (-2.80)	-0.004 (-2.74)	-0.005 (-2.79)	-0.004 (-2.76)
$\text{Log}(1-\tau_t)$	-0.243 (-7.47)	-0.234 (-7.20)	-0.223 (-5.98)	-0.286 (-6.04)	-0.208 (-6.74)
λ	0.050	0.049	0.049	0.053	0.048
α	0.237	0.271	0.237	0.302	0.239
β	-0.076	-0.071	-0.057	-0.154	-0.024
γ	0.025	0.039	0.049	0.061	0.025
RSS	0.085	0.084	0.084	0.090	0.083
m_1	2.999	3.186	3.081	3.163	3.313
m_2	-2.008	-1.768	-1.853	-1.639	-1.839
Sargan	153.31 [78]	127.64 [26]	156.22 [52]	114.74 [26]	171.82 [78]

Notes: Instruments set in each specification: (1) $\text{Log}(s_{pit})-\text{log}(n_{it}+x+\delta)$ and $\text{Log}(1-\tau_t)$ with one lag, $\text{Log}(s_{git}^e)$ and $\text{Log}(is_{it})$ with one and two lags and remaining variables as exogenous. (2) $\text{Log}(s_{git}^e)-\text{log}(n_{it}+x+\delta)$ with one and two lags and remaining variables as exogenous. (3) $\text{Log}(s_{pit}^e)-\text{log}(n_{it}+x+\delta)$ y $\text{Log}(s_{sit}^e)-\text{log}(n_{it}+x+\delta)$ with one and two lags and remaining variables as exogenous. (4) $\text{Log}(s_{sit}^e)$ with one and two lags and remaining variables as exogenous. (5) $\text{Log}(s_{pit}^e)-\text{log}(n_{it}+x+\delta)$, $\text{Log}(s_{git}^e)$, $\text{Log}(is_{it})$ with one and two lags and remaining variables as exogenous.

t-ratios shown in parentheses. Degrees of freedom in brackets. Robust standard deviations for the presence of heteroskedasticity between units. Number of observations: 235 (Orthogonal deviation transformation reserve one extra observation; see data appendix). Source: IVIE and Fundación BBVA.

Table 2 summarizes the results of five estimates of the convergence equation taking as basis the specification (3) of table 1. A first impression that underlies in view of these new results is their relative similarity with those before presented. Indeed, it stays the evidence of conditional β -

convergence with speeds towards the steady-state around five percent; again negative values are obtained for public investment and positive coefficients for human capital, with a bigger statistical significance. The coefficients estimated for unemployment rates and income proportion available for private capital accumulation after tax collection continue according to the economic sense. On the other hand, Sargan tests of overidentifying reject the validity of the different groups of instruments⁹. The implicit rejection of endogeneity hypothesis for private and public investment is not a novelty in the academic literature on this topic (De Long and Summers, 1991; Clarida, 1993; Hulten and Schwab, 1993).

V. Other results obtained under different specifications

In this section we will offer additional empirical evidence in order to guarantee the solidity of the results reached up to now. Thus, alternative estimates of an expression based on the previous convergence equation will be presented, though it will be modified *ad hoc* with the aim of enlarging the range of relationships between public investment and economic growth. We will study, in short, the results derived of three different scheme: 1) Introduction of regional multiplicatives dummies in the coefficients estimated for public investment in order to detect potential differential effects on regional growth; 2) Inclusion of non-linear relationships between productive and social public investment and regional growth rate; and 3) Inclusion of time dummies to measure technical progress through an alternative way.

V.1 Regional multiplicatives dummies

A first option in the estimate of convergence equation resides in the inclusion of variables fictitious in the coefficients corresponding to public investment, as well as the estimated dummies as unobservable fixed effects. It will allow us to observe how the different components of public investment affect to each region. The results are presented in table 3, where each one of columns

⁹ The results remain for different definitions of the matrix of instruments. Arellano and Bond (1991) demonstrate the tendency to over-reject the null hypothesis of Sargan test in the presence of heteroskedasticity. Since option of estimating via two-step GMM was excluded before, we could have identified one of the factors that cooperate to the widespread rejection of the selected matrix of instruments. It is not appreciated, on the other hand, a remarkable sensibility of the results to the choice of the matrix of instruments.

displays the estimated values according to variable public investment whose coefficient is calculated for each region and for each regressors set.

Table 3: Estimation of convergence equation with multiplicative dummies. Spanish regions (1965 - 1993). Dependent variable: Per capita income growth rate for each span.

	(1)	(2)	(3)	(4)	(5)	(6)
$\text{Log}(y_{i,t-T})$	-0.084 (-6.53)	-0.081 (-6.36)	-0.099 (-8.10)	-0.099 (-8.34)	-0.093 (-7.91)	-0.104 (-9.21)
$\text{Log}(s_{pit})-\text{log}(n_{it}+x+\delta)$	0.030 (4.90)	0.033 (5.30)	0.028 (4.84)	0.029 (4.54)	0.032 (4.98)	0.026 (4.36)
$\text{Log}(s_{git})-\text{log}(n_{it}+x+\delta)$				-0.005 (-1.22)	-0.003 (-0.80)	-0.007 (-1.68)
$\text{Log}(s_{sit})-\text{log}(n_{it}+x+\delta)$	0.0019 (0.60)					
$\text{Log}(s_{eit})-\text{log}(n_{it}+x+\delta)$		-0.002 (-1.00)				
$\text{Log}(s_{dit})-\text{log}(n_{it}+x+\delta)$			0.011 (4.48)			
$\text{Log}(h_{it})$						
$\text{Log}(u_{it})$	-0.005 (-2.41)	-0.005 (-2.46)	-0.004 (-2.16)	-0.005 (-2.24)	-0.005 (-2.35)	-0.004 (-1.94)
$\text{Log}(1-\tau_{it})$	-0.204 (-4.56)	-0.203 (-4.49)	-0.226 (-5.43)	-0.247 (-5.68)	-0.236 (-5.33)	-0.241 (-5.53)
Multiplicatives <i>dummies</i>	s_{git}	s_{git}	s_{git}	s_{sit}	s_{eit}	s_{dit}
Andalucía	-0.003 (-0.30)	-0.002(-0.22)	-0.008 (-0.90)	0.025 (2.79)	0.017 (1.30)	0.019 (4.42)
Aragón	0.006 (0.36)	0.009 (0.52)	0.001 (0.07)	0.001 (0.23)	-0.003 (-0.71)	0.010 (1.11)
Asturias	-0.005 (-0.38)	-0.003 (-0.29)	-0.008 (-0.63)	-0.003 (-0.20)	-0.005 (-0.50)	0.006 (0.50)
Baleares	0.033 (2.00)	0.034 (2.04)	0.022 (1.34)	0.018 (1.36)	0.007 (0.67)	0.028 (2.10)
Canarias	0.007 (0.61)	0.008 (0.69)	0.000 (0.00)	0.007 (0.74)	0.003 (0.36)	0.011 (1.56)
Cantabria	0.004 (0.36)	0.005 (0.52)	0.000 (0.06)	0.016 (3.15)	0.009 (2.28)	0.016 (2.63)
Cataluña	-0.013 (-1.10)	-0.013 (-1.06)	-0.019 (-1.62)	-0.010 (-0.69)	-0.013 (-1.00)	0.000 (0.01)
Castilla-La Mancha	0.003 (0.20)	0.005 (0.32)	0.001 (0.12)	0.002 (0.15)	-0.002 (-0.18)	0.011 (0.77)
Castilla-León	-0.004 (-0.23)	-0.002 (-0.12)	-0.010 (-0.65)	-0.014 (-0.76)	-0.024 (-1.53)	0.012 (1.21)
Extremadura	-0.0006 (-0.03)	0.002 (0.13)	-0.004 (-0.27)	0.006 (0.49)	0.004 (0.54)	0.008 (0.46)
Galicia	0.009 (1.38)	0.010 (1.49)	0.004 (0.64)	0.028 (3.11)	0.017 (1.53)	0.023 (4.52)
Madrid	-0.025 (-1.11)	-0.027(-1.23)	-0.030 (-1.50)	0.000 (0.04)	-0.002 (-0.30)	0.015 (1.73)
Murcia	-0.015 (-3.27)	-0.015 (-2.98)	-0.017 (-3.48)	-0.009 (-1.50)	-0.006 (-2.16)	0.002 (0.40)
Navarra	-0.002 (-0.15)	-0.002 (-0.12)	-0.000 (-0.02)	0.000 (0.06)	-0.004 (-0.52)	0.004 (0.56)
País Vasco	-0.007 (-0.32)	-0.006 (-0.30)	-0.012 (-0.58)	-0.009 (-0.74)	-0.018 (-1.29)	0.013 (0.80)
La Rioja	0.015 (0.44)	0.016 (0.48)	0.017 (0.42)	0.004 (0.22)	0.001 (0.13)	0.003 (0.17)
Valencia (Comunidad)	-0.012 (-0.66)	-0.011 (-0.63)	-0.014 (-0.90)	0.005 (0.49)	-0.002 (-0.34)	0.017 (1.71)
RSS	0.078	0.078	0.075	0.079	0.079	0.076
Durbin-Watson	1.81	1.79	1.87	1.84	1.80	1.90

Notes: t-ratios shown in parentheses. Number of observations: 252 (see data appendix). Column (1): $\text{Log}(s_{pit}^g)-\text{log}(n_{it}+x+\delta)$; column (2): $\text{Log}(s_{git}^g)-\text{log}(n_{it}+x+\delta)$; column (3): $\text{Log}(s_{sit}^g)-\text{log}(n_{it}+x+\delta)$; column (4): $\text{Log}(is_{it})-\text{log}(n_{it}+x+\delta)$; column (5): $\text{Log}(ie_{it})-\text{log}(n_{it}+x+\delta)$; column (6): $\text{Log}(id_{it})-\text{log}(n_{it}+x+\delta)$. Source: IVIE and Fundación BBVA.

From table 3, two main conclusions can be drawn. First, the variables whose specification is not altered with the inclusion of multiplicatives dummies maintain their values and significance levels in essence. Second, few of the regional coefficients estimated are significant at the standard levels; hence, only very particular results can be extracted: that Baleares has experienced some positive effects of public investment on growth rate or that the contrary asseveration is certain for Murcia and, with smaller robustness, for Cataluña and Madrid. In the same way, it can be stated that Andalucía, Cantabria and Galicia seem to be the regions where social public investment has exercised positive effects; in the case of health investment, it should add Madrid and Valencia at previous regions¹⁰.

V.2 Non-linear relationships between public investment and regional growth

From another point of view, you can think about a specification of the convergence equation that take account some non-linear relationships between regional growth rate and public investment. A recent paper by Aschauer (2000) detects a positive, non-linear relationship between both variables for 48 U.S. states. The specification which we will use is not derived of the previously exposed theoretical framework; so the structural interpretation of the estimated coefficients is not possible. The convergence equation that we now are interested in estimating would present the following expression:

$$\begin{aligned} \ln y_{it} - \ln y_{it-T} = & \beta_0 \ln \psi_{i0} + x(t - e^{-\lambda T}(t-T)) - \beta_1 \ln y_{it-T} + \beta_2 \ln s_{pit} + \beta_3 (\ln s_{git})^2 + \\ & + \beta_4 (\ln s_{hit})^2 + \beta_5 \ln(\delta + n_{it} + x) + \beta_6 \ln(1 - \tau_{it}) \end{aligned} \quad (6)$$

Notice that variables that refer to public investment enter in a quadratic way. Table 4 present the results reached by the within-groups estimator, so much in the cases in that the quadratic relationship

¹⁰ A possible extension of this strategy could be the constitution of clubs of regions (Bajo *et al.*, 1999). However, we would have to recognise the decrease in the number of observations.

exists for both kind of public investment (productive and social) as when that only one is defined for productive public investment¹¹.

Table 4: Estimation of convergence equation with non-linear relationships. Spanish regions (1965 - 1995). Dependent variable: Per capita income growth rate for each span.

	(1)	(2)	(3)	(4)	(5)	(6)
$\text{Log}(y_{i,t-T})$	-0.086 (-6.79)	-0.080 (-6.57)	-0.103 (-8.62)	-0.086 (-6.72)	-0.080 (-6.53)	-0.102 (8.54)
$\text{Log}(s_{pit})$	0.028 (3.36)	0.027 (3.21)	0.029 (3.60)	0.028 (3.35)	0.027 (3.20)	0.029 (3.61)
$(\text{Log}(s_{git}))^2$	0.0003 (0.71)	0.0003 (0.63)	0.0007 (1.52)	0.0003 (0.71)	0.0003 (0.62)	0.0007 (1.52)
$\text{Log}(s_{sit})$				0.002 (0.80)		
$(\text{Log}(s_{sit}))^2$	-0.0002 (-0.89)					
$\text{Log}(s_{eit})$					-0.002 (-1.14)	
$(\text{Log}(s_{eit}))^2$		0.0002 (1.08)				
$\text{Log}(s_{dit})$						0.012 (4.95)
$(\text{Log}(s_{dit}))^2$			-0.0009 (-5.21)			
$\log(n_{it}+x+\delta)$	-0.033 (5.45)	-0.034 (-5.66)	-0.035 (-5.96)	-0.033 (-5.45)	-0.034 (-5.67)	-0.034 (-5.94)
$\text{Log}(u_{it})$	-0.005 (-2.17)	-0.007 (-2.60)	-0.004 (-1.75)	-0.005 (-2.18)	-0.007 (-2.61)	-0.004 (-1.75)
$\text{Log}(1-\tau_{it})$	-0.214 (-4.81)	-0.221 (-4.91)	-0.227 (-5.55)	-0.214 (-4.83)	-0.221 (-4.91)	-0.227 (-5.53)
RSS	0.082	0.082	0.078	0.082	0.082	0.079
Durbin-Watson	1.80	1.79	1.85	1.80	1.79	1.86

Notes: t-ratios shown in parentheses. Number of observations: 252 (see data appendix). Source: IVIE and Foundation BBVA.

Once again, the coefficients of variables that have not been modified in the equation remain in the proximity of the values and statistical significance obtained previously, except, slightly, in the case of unemployment rate in column (6). Productive public investment continues without being significant, although in this occasion it acquires a positive sign that before lacked. Social public investment (education plus health) loses statistical significance now and even changes its positive sign for negative when enters in a quadratic way in the equation. Squared public investment in

¹¹ We do not inform of the values of other statistics as Hausman or F; their values support the chosen specification. Anyway, they are available on request.

education presents a positive effect on regional growth rate while its effect is negative if enters into equation in a conventional way; anyway, the statistical significance of both coefficients is not acceptable. On the other hand, given the econometric specification, public investment in health behaves as inverse way than public investment in education.

V.3 Time dummies

In this point we have included among the regressors time dummies that take account explicitly time dimension of our data. This is an alternative way to control exogenous technical progress. Table 5 offers results of different specifications for convergence equation, sharing all of them the inclusion of time dummies¹².

¹² See previous footnote.

Table 5: Estimation of convergence equation with time dummies. Spanish regions (1965 - 1995).**Dependent variable: Per capita income growth rate for each span.**

	(1)	(2)	(3)
$\text{Log}(y_{i,t-T})$	-0.057 (-3.60)	-0.061 (-3.53)	-0.054 (-3.40)
$\text{Log}(s_{pit})-\text{log}(n_{it}+x+\delta)$	0.033 (6.45)	0.039 (8.33)	0.033 (6.41)
$\text{Log}(s_{git})-\text{log}(n_{it}+x+\delta)$	0.012 (2.28)	0.008 (1.20)	0.012 (2.36)
$\text{Log}(s_{sit})-\text{log}(n_{it}+x+\delta)$	0.003 (1.53)	-0.001 (-0.55)	0.003 (1.32)
$\text{Log}(u_{it})$	-0.001 (-1.64)	-0.001 (-2.01)	
$\text{Log}(1-\tau_t)$	-0.037 (-0.79)	-0.064 (-1.22)	-0.031 (-0.63)
λ	0.029	0.031	0.027
α	0.314	0.364	0.323
β	0.114	0.074	0.117
γ	0.028	-0.009	0.029
<i>RSS</i>	0.032	0.033	0.033
m_1	2.543	2.739	2.494
m_2	-0.087	-0.264	-0.027
Sargan		36.93 [26]	

Notes: (1) Within groups estimation and no IV's. (2) GMM; instruments: $\text{Log}(s_{it}^g)$ and $\text{Log}(is_{it})$ with one lag, remaining variables as exogenous and time dummies. (3) Within groups estimation and no IV's; unemployment rate has been eliminated. t-ratios shown in parentheses. Degrees of freedom in brackets. Robust standard deviations for the presence of heteroskedasticity between units. Number of observations: 235 (Orthogonal deviation transformation reserve one extra observation; see data appendix). Source: IVIE and Fundación BBVA.

It is noticed that goodness of fit improves, staying the evidence of β -conditional convergence, with a speed of convergence around 3 percent, and rising the statistical significance of private investment rate and decreasing of income per capita level corresponding to previous period. However, the most important change resides now in the significant positive sign of productive public investment, that differs to the loss of robustness suffering for the coefficient of social public investment. This last one even shows indications that it has affected negatively to regional growth; notice that positive effect of social investment was one of the most solid results of previous sections. Also, in the results obtained with instrumental variables and GMM of column (2), the coefficient of productive public

investment is not inside conventional statistical thresholds, although it is appreciated that the chosen matrix of instruments is the appropriate one at an acceptable significance level and there are not clear symptoms of bad specification (see statistics $m1$ and $m2$).

An additional counterpart in the valuation of these new results comes given by the effects that inclusion of time dummies has on income proportion to disposition of private sector after taxes and unemployment rate. Indeed, both of them lose explanatory power. Regarding the first one, its elimination would not be consistent into the theoretical framework followed in this work. On the other hand, it can be understood partially that unemployment rate reduces considerably its value and statistical significance; not in vain, the own nature of time dummies may be identified to business cycle. However, time dummies approach suffers from ignoring the different intensities that economic fluctuations have on each region.

In short, and even recognizing that results we have just exposed present reasonable econometric guarantees, we will not change our basic specification for convergence equation to include time dummies. This is because a time dummies specification strays from theoretical framework proposed (time dummies affect on other variables); business cycle is susceptible of being incorporate through unemployment rate, in a richer way from a regional point of view; and the statistical qualities of our previous estimates are not smaller than those presented in this subsection.

Therefore we are able to affirm -with all the cautions that are derived of the limitations of this paper¹³- that investment in productive public capital does not show a positive correlation with growth rate of the Spanish regions over 1965-1995. Mas *et al.* (1994), although recognise the fact that regions with a superior initial endowments of public capital have experienced higher growth rates, find for period 1967-1979 a negative effect (and not significant) of this endowments on the increase

¹³ We are aware that aspects of remarkable transcendence in the regional convergence are omitting in our paper. You can consult Dolado *et al.* (1994) and Raymond and García (1995) for the effects of the migratory flows on growth rate; De la Fuente (1997) and Serrano (1999) for the technological diffusion and the importance of the regional sectoral structure in a growth framework; Gorostiaga (1999) for the links between human capital and technological progress.

of regional Added Value; for period 1979-1991, the effect is positive although it is not significant from a statistical point of view. The already quoted De la Fuente y Vives (1995) show also the small impact that public investment carried out during the 80's has had on the reduction of territorial imbalances. Gorostiaga (1999) does not find significant coefficients for public investment in a convergence equations for the Spanish regions over a very similar period to ours.

Regarding public investor effort in education and health, it seems to be confirmed the positive effect of this variable on regional growth along time horizon studied. However, in the regressions with instrumental variables some doubts arise also around the statistical significance of estimated coefficients.

VI Is it possible that public investment has not affected to regional growth?

The previous statistical results have shown how productive public investment has not influenced positively on Spanish regional growth between 1965 and 1995. Conversely, social public investment has shown a positive correlation with growth rate of regional GDP. The first result is very surprising, of course when the thick of the regional policies stress on the endowment of infrastructures as the most effective instrument of reducing the interregional differences. We will try to explain our result into some theoretical framework.

The existence of a negative effect of (productive) public expenditure on per capita income growth rate is not a circumstance unknown for theoretical developments. We can provide some contributions that allow to dealt with this phenomenon from different views. One of them introduces the possibility that public capital exercises a negative effect on growth rate from Uzawa's (1965) and Lucas's (1988) works. As it is known, both papers link the dynamics of growth to ratio defined by human capital and private capital. With extensions like those of Mulligan and Sala-i-Martin (1993) or Sala-i-Martin (1997) and Bosch and Espasa (1999), and carrying out the corresponding translation to the scope of infrastructures, you can define an inverse relationship between public capital/private capital ratio and growth rate in transitional dynamics.

We are going to explain this relationship into a theoretical framework based on a two-sector model of endogenous growth. We consider a representative household, which maximizes this standard utility function over time:

$$\int_0^{\infty} \frac{C^{1-\theta} - 1}{1-\theta} e^{-\rho t} dt, \quad (7)$$

where C is consumption, θ is the inverse of elasticity of intertemporal substitution ($\theta > 0$) and ρ is the rate of time preference ($\rho > 0$). For sake of simplicity, there is no population growth.

On the production side we have a broad concept of private capital (K), which consists of physical capital (k) and human capital (h). Both of them are combined by a Cobb-Douglas aggregation function: $K = k^\beta h^{1-\beta}$. Public capital is accumulated according to the following movement equation:

$$\dot{G} = Y - C - \delta G = A G^\alpha (u K)^{1-\alpha} - C - \delta G, \quad (8)$$

where Y is the output of goods, δ is the rate of depreciation, A is a technological parameter and u is the fraction of private capital used in final goods production. The dynamics of private capital is given by

$$\dot{K} = B(1-u)K - \delta K. \quad (9)$$

B is a technological parameter too. The rate of depreciation is identical for two kinds of capital and $(1-u)$ is the fraction of private capital used in intermediate goods production¹⁴. In other hand, we can demonstrate that, under several assumptions, any constraint of nonnegative gross investment is not required (Barro and Sala-i-Martin, 1999).

Households maximize (7) subject to (8) and (9). It yields the steady-state values of the variables and their transitional dynamics. Similar to Uzawa-Lucas model for K and H , we can study now which

¹⁴ Notice that public capital has play no role in the accumulation of K , what it is a restrictive assumption. If we incorporate G to equation (9), we face to a very complicated transitional dynamics. However, numerical exercises based on reasonable values for the underlying parameters show how the main results of our restricted framework are maintained when public capital enters into equation (9) (See Barro and Sala-i-Martin, 1999).

effects has G/K ratio on growth rate of broad output. Since Y is the output of final goods, we define a broad concept of output as follows:

$$Q = Y + pB(1-u)K, \quad (10)$$

where p is shadow price of capital in units of Y ¹⁵. While long-term growth rate of Q is not affected by G/K , some results can be drawn for the transitional dynamics. Since growth rate of broad output Q

can be computed as $\gamma_Q = \gamma_Y - \gamma_u \frac{1-\alpha}{1-\alpha-\alpha u}$, where γ_x is growth rate of x , it is possible to

demonstrate that $\frac{\partial \gamma_Q}{\partial \left(\frac{G}{K}\right)} < 0$. In other words, growth rate of economy towards steady-state is

inversely related to G/K ratio. When an economy has a relatively high endowment of infrastructure related to private capital (high G/K), its growth rate is below its long-term growth rate, and vice versa.

The underlying explanation of this fact comes from the effects of imbalances between G and K . If an economy has a G/K ratio above its steady-state value, the marginal product of private capital is high, because this is a relatively scarce production factor (compared to infrastructures). This high return means a high cost for the sector which produces private capital, since this is intensive in private capital (a relatively expensive production factor). Then we find that the imbalance between both types of capital is reduced slowly, so economy's growth rate is below.

Conversely, whether G/K ratio is low, the dynamics of system provide an incentive to allocate resources to production of the relatively scarce factor. Households realize that their C/G ratio is bigger than they desire (its steady-state value) and they reduce their present consumption in favour of production of public capital (in a more general framework, it would mean paying taxes to finance public expenditure). This circumstance yields higher growth rates of Q than when a high G/K ratio exists.

¹⁵ Formally, p is the ratio between Lagrange multipliers implied in household's optimization problem.

Sala-i-Martin (1997) studies which the orientation of public investment policy has been in Spain. According to this author the regions with smaller public capital/private capital ratio between 1964 and 1991, and where public investment would generate the biggest income increments, were Baleares, Madrid and Cataluña. However their conditions of rich regions have not made them receiving of important volumes of spending in public capital, if we compare them to lower per capita income regions. It may have influenced on reduced return of public investment found before.

Sala-i-Martin (1997) and Bosch and Espasa (1999) demonstrate what we have just said using Spanish regions data for several periods. It seems that public investments policy implemented in Spain has made special stress on those regions where the social return of infrastructures was smaller. In this sense, we are going to make a similar exercise to test if our data support this hypothesis. Table 6

shows, in first column, a classification of the Spanish regions from bigger to smaller ratio $\frac{G_{it}}{K_{it}}$ over

period 1965-1995; second column places the regions according to values reached by $\frac{I_{git}}{I_{pit}}$, where I_{git}

is public investment in the region i in year t and I_{pit} is the equivalent concept referred to private investment; this last ratio may be interpreted as the proportion that public investor effort represents on private investment.

Table 6. Public capital endowments and private investment in the Spanish regions 1965-1995.**(Average values for all period)**

	$\frac{G_{it}}{K_{it}}$		$\frac{I_{git}}{I_{pit}}$
Extremadura	0.1436	Extremadura	0.1848
Castilla-La Mancha	0.1393	Castilla-La Mancha	0.1699
Aragón	0.1366	Aragón	0.1536
Castilla-León	0.1161	Castilla-León	0.1472
La Rioja	0.0997	Andalucía	0.1352
Navarra	0.0986	Asturias	0.1299
Canarias	0.0926	Canarias	0.1180
Andalucía	0.0916	Cantabria	0.1126
Asturias	0.0748	La Rioja	0.1116
Galicia	0.0725	Navarra	0.1053
Murcia	0.0701	Murcia	0.1041
Cantabria	0.0651	País Vasco	0.1009
País Vasco	0.0617	Valencia	0.0856
Valencia	0.0581	Madrid	0.0855
Cataluña	0.0481	Cataluña	0.0755
Madrid	0.0472	Baleares	0.0731
Baleares	0.0422	Galicia	0.0692

Source: IVIE y Fundación BBVA

The evidence that table 6 shows is clear. The regions with a high public capital endowments regarding their private capital (Extremadura, Castilla-La Mancha, Aragón, Castilla-León) are those that have received the biggest resources in concept of public investment on private investment. Conversely, regions as Baleares, Madrid, Cataluña and Valencia (the worst endowed on average over the period) have registered -together to Galicia- the smallest public investment rates.

The described fact could be partial responsible of the null or negative effect of public investment on regional growth in Spain from 1965 to 1995. This is because of government has invested in regions where, due to their high relative endowment of infrastructures, social return of the marginal public capital was smaller. Public investment policy has not been focussed on maximizing total output of country.

Similar conclusions are reached in other empirical papers that have studied the effect of infrastructures on economic performance in Spain from a regional point of view. Bajo *et al.* (1999) find that public investor effort has not affected to regional growth rate for the richest regions in 1967 (Madrid, País Vasco, Cataluña and Baleares). Moreno *et al.* (1997) sustain that an appropriate endowment of public capital becomes a necessary condition, but not sufficient, for the processes of economic growth. These authors notice that factors as an adequate industrial mix, business culture and managerial dynamism or capacity to generate agglomeration externalities, conform as worth conditions when evaluating the impact of infrastructures on economic activity. Moreno *et al.* (1997) show how the poorest Spanish regions have not benefited by public investment in the same magnitude that other, in spite of being the main recipient ones. They attribute this fact to the complex links between infrastructures and growth that require consider a miscellany of factors for measuring public capital effectiveness.

From a dual approach Boscá *et al.* (1999) find that in the regions where public capital/industrial private capital ratio is higher over period 1980-1993, infrastructures have a negative shadow price, that is, public capital have not reduced costs for manufacturing firms. Although it is likely that this result suffers some specification problems, it seems to be clear that in regions where magnitude of private capital is inadequacy (and other circumstances that encourage to economic development), there exist limits to the positive effects of public capital. The biggest shadow prices are located in the most industrialized regions, showing that the bigger congestion of public capital, the bigger return of public investment is.

VII. Conclusions

In the most of the western economies the regional policies concentrate their efforts on the provision of a level of infrastructures that guarantees the development of economic activity. This strategy is based on the recognition of a direct relationship between public capital and per capita income growth rate. The study of public investment effects on economic growth has received a considerable attention from academia since the nineties. The theoretical models that described a positive link among both variables were followed by studies that proceeded to estimate convergence equations under different specifications and methods from an empirical view. The results in this scope have not been as unanimous as in the theoretical plane.

In this paper a neoclassical growth model has been offered with public and human capital; these ones have been approximated through public investment in core infrastructures, health and education; it is also considered the influence that tax system exercises on private capital accumulation. Once the theoretical framework has been exposed, we have derived a convergence equation that has been estimated with Spanish regions data over period 1965-1995 and using panel data techniques.

A first battery of results supports the conditional convergence hypothesis among the Spanish regions, with speed of convergence toward steady-state around five percent. The signs of the coefficients are according to theory, except for the case of productive public investment, where a negative effect of this variable on regional economic growth rate is obtained, although with a limited statistical significance. On the other hand, public investment in education appears positive but not significant and public resources devoted to investment in health offer a solid positive correlation with the increment of per capita income.

From the doubts outlined by some authors about the possible endogeneity of variables as private and public investment, we have carried out estimates with instrumental variables. After adopting the appropriate cautions, the results are presented for different specifications of the matrix of

instruments, being confirmed the previous results in general and acquiring the negative coefficient for public investment a statistical significance of before lacked.

We have also considered alternative specifications for the convergence equation. First, multiplicatives dummies in the coefficients of public investment rates have been included; although the results do not present the robustness that would be desirable, you can distinguish some geographical peculiarities in what refers to public investment effects. Second, non-linear relationships between public capital spending and regional growth have also been studied; nevertheless, the empirical evidence provided by our estimates is very weak in this sense. Third, the inclusion of time dummies allows us to obtain a positive effect (and significant in some cases) of productive public investment on per capita regional income growth; however, some problems on other structural variables and smaller wealth in the specification suggest us doubts on this specification.

Finally, we have linked our empirical results to theoretical models that advance, under several assumptions, a non-positive effect of public capital spending on economic growth. In short, we have explored and confirmed the hypothesis that public investment in Spain over period has gone especially to regions that present a higher public capital/private capital ratio. The return of public investment in these regions is smaller and it may have provoked that the distribution of public capital spending among regions has had null or negative effects on economic growth. Our results may also be compatible with crowding-in theories; productive public investment has favoured regional growth through an indirect link: complementarity between public and private investment, as it is shown in Martínez (2001b).

Some questions remain without an answer. Which have the last determinants of public investment distribution been to correct the regional imbalances? Which have their effectiveness been? What magnitude should public resources reach to achieve a compromise between the objectives of

efficiency and equity in the allocation of public investment? All they constitute a stimulating starting point for future researches.

Data Appendix

The aim of this appendix is to offer information about the nature of variables employees as well as of the data sources that we have used. The variable y_{it} corresponds to per active regional GDP, with biannual observations. The choice of active population for measuring per capita regional output has not been arbitrary. After having used figures corresponding to employed population and working-age population, we have checked that the best behaviour of the estimates happened for active population. This circumstance is specially clear if our purpose is to control the regional business cycle through unemployment rate (u_{it}), since some papers point out that the regional differentials in unemployment rates have transcendence on the process of regional convergence in Spain (Bentolila and Jimeno, 1995; Raymond and García, 1995).

The variable s_{pit} has been defined as ratio private investment to regional GDP. On the other hand, s_{git} is the share of productive public investment (highways and roads, hydraulic infrastructures, urban structures, ports and airports) in the regional GDP. The variable s_{hit} has been treated from three views: s_{eit} is public investment devoted to education as percentage of the regional GDP; s_{dit} is an equivalent concept but corresponding to investment in health; s_{sit} is the share of public investment in education and health in the regional GDP. For these categories, it is considered productive or social capital spending by central, regional and local governments as well Social Security.

In the group of demographic variables, n_{it} is the average growth rate of active population in each span (two years). x is progress technical rate whose value has been fixed in 0.02. δ is the rate of capital goods depreciation that we suppose constant and common to three types of assets considered in this paper; its value is fixed in 0.05. The estimates presented here are robust to changes in these parameters.

All the previous variables have been obtained from the Base de Conocimiento Regional Sophinet, available in Internet (<http://bancoreg.fbbv.es>), and endorsed by Foundation BBVA (BBVA) and IVIE. Additional information about data can be found in that site of Internet and in Mas *et al.* (1996).

The variable τ_{it} is the share of tax resources collected by government in the regional GDP. The series have been extracted from Foundation BBVA (various years). This concept consists of social security contributions, direct and indirect taxes. All the previous monetary variables are measures at 1986 prices.

Human capital stock h_{it} is the share of working-age population with secondary and university studies. The data have been provided by IVIE.

The number of observations has oscillated between 252 and 235. It corresponds to data for 17 regions and 16 years. Anyway, for unemployment rate, three observations with values very near to zero have been eliminated for not distorting the logarithmic transformation of data.

References

- Arellano, M. (1988): "An alternative transformation for fixed effects model with predetermined variables", *Applied Economics Discussion Paper*, nº 57. Institute of Economics and Statistics, Oxford.
- Arellano, M. y Bover, O. (1990): «La econometría de los datos de panel», *Investigaciones Económicas*, 14, pp. 3-45.
- Arellano, M. y Bond, S. R. (1991): "Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations", *Review of Economic Studies*, 58, pp. 277-297.
- Arellano, M. y Bover, O. (1995): "Another look at the instrumental-variable estimation of error-components models", *Journal of Econometrics*, 68, pp. 29-52.
- Arellano, A. y Honoré, B. (1999): "Panel data models: some recent developments", *mimeo*.

- Arrow, K. J. y Kurz, M. (1970): *Public investment, the rate of return and optimal fiscal policy*, Johns Hopkins Press, Baltimore.
- Aschauer, D. A. (1989): "Is public expenditure productive", *Journal of Monetary Economics*, vol. 23, pp. 177-200.
- Avilés, A., Gómez, R. y Sánchez Maldonado, J. (2001): "The effects of public infrastructure on the cost structure of Spanish industries", *Spanish Economic Review*, 3 (2), pp. 131-150.
- Bajo-Rubio, O. (2000): "A further generalization of the Solow model: the role of the public sector", *Economics Letters*, 68, pp. 79-84.
- Bajo-Rubio, O., Díaz, C. y Montávez, D. (1999): "Política fiscal y crecimiento en las comunidades autónomas españolas", *Papeles de Economía Española*, 80, pp. 203-218.
- Barro, R. J. (1990): "Government spending in a simple model of endogenous growth", *Journal of Political Economy*, vol 98, nº 5, pp. 103-125.
- Barro, R. (1991): "Economic growth in a cross-section of countries", *Quarterly Journal of Economics*, 106, 2, pp. 407-443.
- Barro, R. J. y Sala-i-Martin, X. (1991): "Convergence across states and regions", *Brookings Paper on Economic Activity*, nº 1, pp. 107-182.
- Barro, R. J. y Sala-i-Martin, X. (1999): *Economic Growth*, The MIT Press, Cambridge, Massachusetts.
- Bentolila, S. y Jimeno, J. F. (1995): "Regional unemployment persistence (Spain, 1976-1994)", *CEPR Discussion Paper*, nº 1259.
- Biehl, D. (1986) (Ed.): "*The contribution of infrastructure to regional development*", Final Report of the Infrastructure Study Group, Commission of the European Communities, Luxemburgo.
- Boscá, J. E., Escribá, J. y Dabán, T. (1999): "Capital privado e infraestructuras en la producción industrial regional", *Revista de Economía Aplicada*, 21, pp. 61-94.
- Bosch, N. y Espasa, M. (1999): "¿Con qué criterios invierte el sector público central?", en Castells, A. y Bosch, N. (1999), *Desequilibrios territoriales en España y Europa*, Ariel Economía, pp. 150-177.

- Clarida, R. H. (1993): "International capital mobility, public investment and economic growth", *NBER Working Paper*, nº 4506.
- Conrad, K. y Seitz, H. (1992): "The public capital hypotheses: the case of Germany", *Recherches Economiques de Louvain*, 58 (3-4), pp. 309-327.
- Dasgupta, D. (1999): "Growth versus welfare in a model of nonrival infrastructure", *Journal of Development Economics*, 58, pp. 359-389.
- De la Fuente, A. (1997a): *Fiscal policy and growth in the OECD*, D. T. 97007, Dirección General de Análisis y Programación Presupuestaria, Ministerio de Economía y Hacienda, Madrid.
- De la Fuente, A. (1997b): "On the sources of convergence: a close look at the Spanish regions", *Documento de Trabajo FEDEA*, EEE1.
- De la Fuente, A. (2000): "Convergence across countries and regions: theory and empirics", *WP 447.00*, Instituto de Análisis Económico (CSIC).
- De la Fuente, A. y Vives, X. (1995): "Regional policy and Spain: Infrastructure and Education as Instruments of Regional Policy: Evidence from Spain", *Economic Policy*, 20, April 1995, pp.11-54.
- De Long, J. B. y Summers, L. (1991): "Equipment investment and economic growth", *The Quarterly Journal of Economics*, 106, 2, pp. 445-502.
- Dolado, J. J., González-Páramo, J. M. y Roldán, J. M. (1994): "Convergencia económica entre las provincias españolas", *Moneda y Crédito*, 198, pp. 81-131.
- Domenech, R. y García, J. R. (2001): "Estructura fiscal y crecimiento económico en la OCDE", *Investigaciones Económicas*, XXV (3), pp. 441-472.
- Easterly, W. y Rebelo, S. (1993): "Fiscal policy and economic growth: an empirical investigation", *Journal of Monetary Economics*, 32, pp. 417-458.
- Evans, P. y Karras, G. (1994): "Is government capital productive? Evidence from a panel of seven countries", *Journal of Macroeconomics*, vol. 16, nº 2, pp. 271-279.
- Evans, P. y Karras, G. (1996): "Convergence revisited", *Journal of Monetary Economics*, 37, pp. 249-265.

- Fisher, W. H. y Turnovsky, S. J. (1998): "Public investment, congestion and private capital accumulation", *The Economic Journal*, 108, pp. 399-413.
- Fundación BBV (1999): *Renta Nacional de España y su Distribución Provincial. Serie Homogénea. Años 1955 a 1993 y avances 1994 a 1997*, varios tomos, Fundación BBV, Bilbao.
- Fundación BBV (2000): *Renta Nacional de España y su Distribución Provincial. Año 1995 y avances 1996 a 1999*. Fundación BBV, Bilbao.
- Futagami, K., Morita, Y. y Shibata, A. (1993), "Dynamic analysis of an endogenous growth model with public capital", *Scandinavian Journal of Economics*, 95 (4), pp. 607-625.
- Galindo, M. A. y Escot, L. (1998): "Los efectos del capital público en el crecimiento económico", *Hacienda Pública Española*, 144, pp. 47-61.
- Glomm, G. y Ravikumar, B. (1994), "Public investment in infrastructure in a simple growth model", *Journal of Economic Dynamics and Control*, 18, pp. 1173-1187.
- González-Páramo, J. M. (1995): "Infraestructuras, productividad y bienestar", *Investigaciones Económicas*, vol. XIX, pp. 155-168.
- Gorostiaga, A. (1999): "¿Cómo afectan el capital público y el capital humano al crecimiento?: Un análisis para las regiones españolas en el marco neoclásico", *Investigaciones Económicas*, XXIII (1), pp. 95-114.
- Hausman, J.A. (1978): "Specification test in econometrics", *Econometrica*, 46, pp. 1.251-1.271.
- Hulten, C. R. y Schwab, R. M. (1993): "Endogenous growth, public capital and the convergence of regional manufacturing industries", *NBER Working Paper*, nº 4538.
- Islam, N. (1995): "Growth empirics: a panel data approach", *The Quarterly Journal of Economics*, 95, pp. 1127-1170.
- Jones, L. E., Manuelli, R. E. y Rossi, P. E. (1993): "Optimal taxation in models of endogenous growth", *Journal of Political Economy*, 101, 3, pp. 485-517.
- Judson, R. A. y Owen, A. L. (1999): "Estimating dynamic panel data models: a guide for macroeconomist", *Economics Letters*, 65, pp. 9-15.
- King, R. G. y Levine, R. (1994): "Capital fundamentalism, economic development and economic growth", *Carnegie-Rochester Conference Series on Public Policy*, 40, pp. 259-292.

- Kneller, R., Bleany, M. F. y Gemmell, N. (1999): “Fiscal policy and growth: evidence from OECD countries”, *Journal of Public Economics*, 74, pp. 171-190.
- Knight, M., Loayza, N., y Villanueva, D. (1993): “Testing the neoclassical theory of economic growth. A panel data approach”, *FMI Staff Papers*, vol. 40.
- Lucas, R. E. (1988): “On the mechanics of development planning”, *Journal of Monetary Economics*, 22, 1, pp. 3-42.
- Mankiw, N. G., Romer, D. y Weil, D. (1992): “A contribution to the empirics of economics growth”, *Quarterly Journal of Economics*, CVII, pp. 407-437.
- Marrero, G. A. (1999): “Growth and welfare: distorting vs. non-distorting taxes”, *mimeo*.
- Martínez, D. (2000): “Is there any relationship between public investment and economic growth in the Spanish regions?”, *WP 0002/Nº 13*, Departamento de Economía Aplicada, Universidad de Jaén.
- Martínez, D. (2001a): “Inversión pública y convergencia regional en España: una introducción empírica”, *VIII Encuentro de Economía Pública*, Cáceres, 8-9 de febrero de 2001.
- Martínez, D. (2001b): “Linking public investment to private investment. The case of the Spanish regions”, *Documento de Trabajo centra Economía*, forthcoming.
- Mas, M., Maudos, J. Pérez, F. y Uriel, E. (1994): “Disparidades regionales y convergencia en las Comunidades Autónomas”, *Revista de Economía Aplicada*, 4 (2), pp. 129-148.
- Mas, M., Maudos, J. Pérez, F. y Uriel, E. (1996): “*El stock de capital en España y sus Comunidades Autónomas*”, Fundación BBV, Bilbao.
- Mendoza, E., Milesi-Ferreti, G. y Asea, P. (1997): “On the Ineffectiveness of tax policy in altering long-run growth: Harberger’s superneutrality conjecture”, *Journal of Public Economics*, 66, pp. 99-126.
- Moreno, R., Artís, M., López-Bazo, E. y Suriñach, J. (1997): “Evidence on the complex link between infrastructure and regional growth”, *International Journal of Development Planning Literature*, 12 (1-2), pp. 81-108.
- Mulligan, C. B. and Sala-i-Martin, X. (1993): “Transitional dynamics in two-sector models of endogenous growth”, *Quarterly Journal of Economics*, 108, 3, pp. 737-773.

- Munnell, A. H. (1990) (Ed.): “*Is there a shortfall in public investment?*”, Conference Series nº 34, Federal Reserve Bank of Boston.
- Raymond, J. L. and García, B. (1996): “Distribución regional de la renta y movimientos migratorios”, *Papeles de Economía Española*, 67, pp. 185-201.
- Rivera, B. y Currais, L. (2000): “The contribution of publicly provided health to growth and to productivity”, *Estudios Economicos*, 30 (2), pp. 191-206.
- Rodríguez, A. (1995): “*Reestructuración socioeconómica y desequilibrios regionales en la Unión Europea*”, Instituto de Estudios Económicos, Madrid.
- Sala-i-Martin, X. (1997): “És bo que el govern inverteixi sempre a les regions menys desenvolupades?”, *Nota d'Economia*, 57, pp. 123-157.
- Serrano-Martínez, L. (1999): “Capital humano, estructura sectorial y crecimiento en las regiones españolas”, *Investigaciones Económicas*, vol. XXIII (2), pp. 225-249.
- Solow, R. (1956): “A contribution to the theory of economic growth”, *Quarterly Journal of Economics*, 70, pp. 65-94.
- Sturm, J. B. (1998): “*Public capital expenditure in OECD countries*”, Edward Elgar, Cheltenham.
- Thomas, B. (1996): “Infrastructure and regional growth in the European Union”, *Birmingham Economics Discussion Paper*, 96-25.
- Uzawa, H. (1965): “Optimal technical change in aggregative model in economic growth”, *International Economic Review*, 6, pp. 18-31.
- Vickerman, R. W. (1991) (Ed.): “*Infrastructure and regional development*”, European Research in Regional Science, vol. 1, Londres.
- Wolf, E. N. (2000): “Human capital investment and economic growth: exploring the cross-country evidence”, *Structural Change and Economics Dynamics*, 11, pp. 433-472.