# PUBLIC INVESTMENT AND CONVERGENCE IN THE SPANISH REGIONS

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**Abstract**

This paper studies the empirical relationships that exist between public investment and per capita income growth over the period 1965-1995 in the different Spanish regions. Using a neoclassical growth model with public and human capital, we derive a convergence equation, estimated through panel data techniques. Besides providing evidence in favour of the conditional convergence hypothesis, the results show the negative effect of productive public investment on the rate of regional economic growth. Also, both public investment in education, although not very significant, and public resources devoted to health investment have a positive correlation to 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 most of the previous results. A simple two-sector model of endogenous growth is presented to explain these results.

**Key words**: Infrastructure, regional growth, 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 the EU and its consequences on regional convergence. Some authors argue that such integration negatively affects the peripheral regions; their arguments are based on endogenous growth theories. On the other hand, others think that regional convergence may be reached and public policies would help towards this purpose; in this way, public investment appears as the main instrument for reducing differences in regional per capita income levels.

In the academic literature both questions have converged toward a common topic that has been studied from different perspectives. Biehl (1986) elaborates a regional index of endowments in different infrastructures in relation to per capita GDP, showing a high positive correlation between both variables. Vickerman (1991) underlines the importance of transport infrastructure in the production processes that enlarge the benefits of the common market for regions geographically outlying.

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 the seminal article of Barro (1990) that the topic began to be studied in a depth. Linked to a vast literature on the interrelations between infrastructure and economic performance (Aschauer, 1989; Munnell, 1990), Barro builds an endogenous growth model in which per capita income growth rate is sustained by the 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), the implications on social welfare (González-Páramo, 1995; Dasgupta, 1999), inclusion of other public spending variables (Bajo-Rubio, 2000) and different tax systems (Jones *et al*., 1993; Marrero, 1999).

The neoclassical literature offers varied empirical evidence regarding public investment effects on growth rate. Barro (1991) points out the existence of a weak negative relationship between public investment and growth rates in a cross-section analysis for almost 90 countries between 1965 and 1985. Evans and Karras (1994) show through panel data analysis that public capital does not positively affect the growth rate of a group of OECD countries between 1963 and 1983. Conversely, studies such 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 subject to decreasing returns). Galindo and Escot (1998) provide ambiguous evidence about the effects of public capital on per capita income growth rate in some OECD countries.

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

Regarding the Spanish case, Mas *et al*. (1994) find evidence in favour of a positive effect of public capital on regional convergence over the period 1955-1991, although when carrying out estimates for shorter periods this result does not hold. Dolado *et al*. (1994) do not find any explanatory capacity for highway and road infrastructure in convergence equations estimated for the Spanish provinces from 1955 to 1989. De la Fuente and 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 small. Also, the recent work of Gorostiaga (1999) estimates a positive but statistically insignificant effect of public investment on the convergence rate. Bajo *et al*. (1999) also detect a positive (and significant) effect of public investment on regional GDP. From a dual perspective, Avilés *et al*. (2001) show the capacity of public capital to reduce firm costs, in both regional and sectoral dimensions.

This paper seeks to explore the empirical relationships found in the different Spanish regions between public investment and per capita income growth between 1965 and 1995. A convergence equation is derived from a neoclassical model with public and human capital. This will be estimated through panel data techniques. In this paper, we explicitly consider public investment through core infrastructure and human capital and the separation between tax revenues and productive public spending in an empirical growth model. We also use non customary statistical methods.

Section II presents the theoretical framework. Section III describes the estimation procedure used as well as the results obtained under different specifications for the convergence equation. Next we consider the econometric implications that are derived of the likely endogeneity of some regressors. Section V offers alternative specifications of the convergence equation: multiplicative and time dummies and non-linear relationships between public investment and per capita income growth. Section VI draws a link between our results and theoretical contributions found in the literature. Finally, Section VII presents a conclusion.

## II. Theoretical framework

The theoretical framework we will use is based on the well-known Solow (1956) growth model. The empirical treatment follows Mankiw *et al*. (1992). In this section, we provide the most general version for the model, *i.e.*, including simultaneously private, public and human capital as production factors. Alternative specifications in the empirical estimation can be easily derived from the model presented here. Therefore, we assume a Cobb-Douglas production function with decreasing returns in acumulable factors for region $i$ at time $t$ is as follows:

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

where $\psi_{it} = \psi_{i0}\, e^{xt}$ and $L_{it} = L^{i}_{0}\, e^{nit}$, $Y$ is regional output, $\psi_{i0}$ a parameter that reflects unobserved or difficult to measure characteristics of region $i$ (resource endowments, climate, institutions, etc.), $L$ labour, $K$ private capital, $G$ productive public capital and $H$ is human capital, with $\alpha + \beta + \gamma < 1$. Technology and labour grow exogenously at constant rates $x$ and $n$, respectively. Based on constant returns to scale in all inputs we rewrite this expression in terms of effective labour (symbolised by ^):

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

Next we define the movement equations for acumulable production factors:

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

where a dot over a variable denotes its time derivative; $\tau$ is the share of tax revenue over total output that the government collects to finance productive and non-productive public spending; $s_{pi}$ is the constant share of gross private investment in physical capital over net taxes output and variable $s_{hi}$ is the equivalent concept for human capital; $\delta$ is the depreciation rate (constant and common); $s_{gi}$ is the gross public share investment over output. As is well-known, this equation system is expressed in terms of growth rates and we solve for state variables, obtaining 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 income growth rate as a logarithmically differential equation we obtain:

$$\frac{d \ln y_i}{dt} = \frac{d \ln \psi_i}{dt} + \alpha \frac{d \ln \hat{k}_i}{dt} + \beta \frac{d \ln \hat{g}_i}{dt} + \gamma \frac{d \ln \hat{h}_i}{dt} \quad . \tag{3}$$

If we rewrite equation (3) for the growth rate of per labour effective income using the production factors growth rates from system (2), we get the next expression:

$$\begin{aligned} \frac{d \ln \hat{y}_i}{dt} &= \alpha\left[(1-\tau) s_{pi} e^{(\alpha-1)\ln k} e^{\beta \ln g} e^{\gamma \ln h}\right] + \beta\left[s_{gi} e^{\alpha \ln k} e^{(\beta-1)\ln g} e^{\gamma \ln h}\right] + \\ &\quad \gamma\left[(1-\tau) s_{hi} e^{\alpha \ln k} e^{\beta \ln g} e^{(\gamma-1)\ln h}\right] - (\alpha+\beta+\gamma)\,(\delta + n_i + x) \ . \end{aligned} \tag{4}$$

If we make a first-order Taylor approximation in this formula around steady-state values, we get

$$\frac{d \ln \hat{y}_{it}}{dt} \approx -\alpha\lambda\left(\ln \hat{k}_{it} - \ln \hat{k}_i^*\right) - \beta\lambda\left(\ln \hat{g}_{it} - \ln \hat{g}_i^*\right) - \gamma\lambda\left(\ln \hat{h}_{it} - \ln \hat{h}_i^*\right) = -\lambda\left(\ln \hat{y}_{it} - \ln \hat{y}_i^*\right), \tag{5}$$

where $\lambda = (1-\alpha-\beta-\gamma)(\delta + n_i + x)$. $\lambda$ can be interpreted as the speed of convergence to a steady state. Solving the differential equation (5) and expressing everything in per capita terms, we obtain:

$$\begin{aligned} \ln y_{it} - \ln y_{it-T} &= \rho \ln \psi_{i0} + x\left(t - e^{-\lambda T}(t-T)\right) - \rho \ln y_{it-T} + \rho \frac{\alpha}{1-\alpha-\beta-\gamma} \ln s_{pit} + \rho \frac{\beta}{1-\alpha-\beta-\gamma} \ln s_{git} + \\ &\quad \rho \frac{\gamma}{1-\alpha-\beta-\gamma} \ln s_{hit} - \rho \frac{\alpha+\beta+\gamma}{1-\alpha-\beta-\gamma} \ln\left(\delta + n_{it} + x\right) + \rho \frac{\alpha+\gamma}{1-\alpha-\beta-\gamma} \ln\left(1 - \tau_{it}\right) \end{aligned} \tag{6}$$

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

In the next section we estimate this equation (6). Note that we have included into the model productive public spending and taxes collected by the government to finance *any kind* of public expenditure. This enables us to deal with the role of the public sector from a more extensive perspective and without conditioning both sides of the public budget. The parameter $\psi_{i0}$ allows us to incorporate unobserved differences across regions.

## III. Estimation of the 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 the Ordinary Least Squared estimation procedure and is able to control the existence of different steady states across economies. However, as Islam (1995) points out, this approach does not allow unobservable individual-regional characteristics to be considered and it may imply biased coefficients from estimation. A panel data approach avoids this circumstance and the data time dimension is explored in a better way[1].

We estimate the equation (6) through panel data techniques and also offer 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[2]; $h$ is human capital stock. The sample consists of 17 Spanish regions over the period 1965-1995. The regional unemployment rate ($u_{it}$) has been added to control the business cycle; we incorporate an error term to (6) that we assume is distributed as normal with a zero mean and constant variance. Details on variable elaboration and sources can be found in the data appendix.

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

[1] However, De la Fuente (2000) considers that panel data studies can be sometimes deceiving because of specification problems.
[2] The use of social public capital as a proxy to human capital, although not very common, is not a novelty in the literature (see, for example, Currais and Rivera, 1999a, 1999b).

coefficient of (1 - $\tau_{it}$), and to a smaller degree on $y_{it-1}$, we have opted to eliminate it[3]. Later we will employ time dummies to control technical progress in a different way.

The Hausman (1978) test provides evidence of the existence of correlations between individual effects and regressors, that is, in favour of a fixed effect model, what we have taken as a within-groups estimator. On the other hand, all the estimates have been carried out weighing the observations in cross-section to avoid heteroskedasticity caused by the different sizes of the units. Also we have used a White covariance matrix.

As is customary in empirical works on convergence, the results presented in Table 1 impose the restriction that coefficients of demographic variables, private investment rate and public investment rate in infrastructure and human capital sum up to zero. This hypothesis is accepted in most of the specifications (except the one presented in column (6)), as Wald statistics show. Table 1 also includes an F test to evaluate joint significance of individual effects for each region. For the specifications (3)-(6) the null hypothesis (*i.e.*, only one constant term for all the regions) is rejected at a level of significance of five percent. Instead, the first two estimates accept this null hypothesis. Nevertheless, guided partly by economic sense that informs us of the existence of individual characteristics not controlled in our analysis, and partly to make the comparison to later specifications easier, we have decided to include the estimates with a different constant for each region.

[3] Easterly and Rebelo (1993) point out the sensitivity of the taxes to the remaining regressors on 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 time span.**

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| 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) |
| Log($s_{pit}$)-log($n_{it}$+$x$+δ) | 0.032 (5.80) | 0.025 (3.96) | 0.031 (4.89) | 0.034 (5.31) | 0.029 (5.04) | 0.035 (6.43) |
| Log($s_{git}$)-log($n_{it}$+$x$+δ) | | 0.006 (1.71) | -0.003 (-0.77) | -0.002 (-0.47) | -0.006 (-1.65) | -0.004 (-1.02) |
| Log($s_{sit}$)-log($n_{it}$+$x$+δ) | | 0.002 (0.84) | 0.003 (1.23) | | | |
| Log($s_{eit}$)-log($n_{it}$+$x$+δ) | | | | 0.001 (0.58) | | |
| Log($s_{dit}$)-log($n_{it}$+$x$+δ) | | | | | 0.011 (5.05) | |
| Log($h_{it}$) | | | | | | 0.056 (6.38) |
| 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) |
| Log(1-$\tau_{it}$) | | | -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 ($\chi^2$) | 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 brackets enclose the degrees of freedom. Number of observations: 252 (see data appendix). Source: IVIE and Foundation BBVA.

On Table 1, we can make some comments about the interrelations between regional convergence and the public sector performance in Spain. First, we find the existence of conditional β-convergence among regions toward their respective steady states. The speed with which this process takes place ranges between three and ten percent, according to specification. Versions (1) and (2) are in the line of studies such as Barro and Sala-i-Martin (1999) that reach values near to three percent for the Spanish regions. Specifications (3)-(5) find values between four and five percent that are similar to those obtained by Dolado *et al*. (1994). In any case the speeds of convergence obtained here 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 private investment rate and 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 factors in production function. 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 presented in column (6). Human capital, on the other hand, appears with a positive sign in all specifications but only when included as variable stock is (column (6)) or approximated through public investment in health (column (5)), does it acquire statistical significance[4]. In the first case, the magnitude of the elasticity is substantially larger than results obtained in similar works; for the values obtained when human capital is included as an investment rate, the elasticities are in a range comparable to other works. Finally, public investment in education is not significant to explain regional per capita income growth. This perhaps reinforces the difficulties that other researchers have already pointed out when incorporating 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, we see that productive public investment $s_{git}$ exerts no influence –both even negative- on the growth rate of the Spanish regions: we find a negative sign in four out of five specifications where this variable appears. This requires additional discussion since it is commonly admitted that public capital endowments play an important role in regional development.

[4] 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.

Finally, income proportion available for private capital accumulation after discounting taxes ($1 - \tau_{it}$) appears with a negative sign, although the theoretical framework implies a positive sign for its coefficient. This may be caused by the great expansion of the Spanish public sector over period[5]. Regarding unemployment rate $u_{it}$, its negative sign in all specifications is consistent to economic theory.

## IV. An alternative analysis: endogeneity of the regressors

The possible endogeneity of some regressors in the estimate of the convergence equation may result in inconsistent estimations. This circumstance could explain, at least partially, the insignificance, and even negative effect of public investment on infrastructure. The literature about economic growth has shown that private investment rate depends on income growth rate; King and Levine (1994), Dolado *et al*. (1994) and Gorostiaga (1999) are examples of this. On the other hand, as is well known, an important shortcoming pointed out regarding the seminal works on public capital resides in the possible simultaneity of infrastructure with output (see, for example, Sturm, 1998), generating an inverse causation that biases the estimate.

We will offer additional empirical evidence in an effort to take into account the possible endogeneity of the rate of private and public investment (in infrastructure and social public capital). With this aim, the convergence equation will be estimated using an instrumental variable (IV) estimator; we will enrich this approach through Generalised Method of Moments (GMM) to select the optimal instrument matrix.

Hence, we will take a specification based on column (3) of Table 1. This is sufficiently general to illustrate the implications of a likely endogeneity[6]. Since the estimator is within-groups, the use of

[5] 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 isolating the influence of the tax system on economic growth.

[6] Estimates of alternative specifications are available on request. They corroborate the results obtained for the equation that serves as our reference.

lagged regressors as possible instruments is not the best option. We will employ, therefore, the transformation of variables in orthogonal deviations as proposed by Arellano (1988) and Arellano and Bover (1990).

The construction of the matrix of instruments followed GMM. Since the nature of this estimation procedure is to minimize the correlations between regressors and residuals, its use will allow us to generate an efficient group of instruments. The potential heteroskedasticity in the disturbances suggests a two-step GMM estimator. Nevertheless, different Montecarlo simulations show 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 estimators[7].

As is well-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 the appropriate specification. Therefore, we will use the Sargan test. On the other hand, keeping in mind that the assumption of absence of serial correlation in the disturbances is essential for the consistency of estimators, this null hypothesis should be tested. So, 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 second-order serial correlation ought not to be present. In the results that we offer, none of the statistics linked to both circumstances (*m1* and *m2*) provide evidence for the presence of serial correlation in the errors.

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[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 generated in non-balanced panels with a time dimension near 20.

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

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

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| Log($y_{i,\ t\text{-}T}$) | -0.096 (-10.94) | -0.095 (-12.69) | -0.094 (-11.68) | -0.102(-10.16) | -0.092 (-11.66) |
| Log($s_{pit}$)-log($n_{it}$+$x$+δ) | 0.028 (3.58) | 0.034 (5.71) | 0.029 (4.07) | 0.039 (6.08) | 0.029 (3.95) |
| Log($s_{git}$)-log($n_{it}$+$x$+δ) | -0.009 (-2.13) | -0.009 (-1.89) | -0.007 (-1.90) | -0.020 (-2.98) | -0.003 (-1.14) |
| Log($s_{sit}$)-log($n_{it}$+$x$+δ) | 0.003 (1.17) | 0.005 (2.15) | 0.006 (2.65) | 0.008 (2.49) | 0.003 (1.38) |
| Log($u_{it}$) | -0.005 (-2.88) | -0.004 (-2.80) | -0.004 (-2.74) | -0.005 (-2.79) | -0.004 (-2.76) |
| Log(1-$\tau_{it}$) | -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) Log($s_{pit}$)-log($n_{it}$+x+δ) and Log(1-$\tau_{it}$) with one lag, Log($s_{git}$) and Log($s_{sit}$) with one and two lags and remaining variables as exogenous. (2) Log($s_{git}$)-log($n_{it}$+x+δ) with one and two lags and remaining variables as exogenous. (3) Log($s_{pit}$)-log($n_{it}$+x+δ) y Log($s_{git}$)-log($n_{it}$+x+δ) with one and two lags and the remaining variables as exogenous. (4) Log($s_{git}$) with one and two lags and the remaining variables as exogenous. (5) Log($s_{pit}$)-log($n_{it}$+x+δ), Log($s_{git}$), Log($s_{sit}$) with one and two lags and the remaining variables as exogenous.
t-ratios are 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 reserves one extra observation; see data appendix). Source: IVIE and Foundation BBVA.

Table 2 summarizes the results of five estimates of the convergence equation taking as the base the specification (3) of Table 1. A first impression in view of these new results is their relative similarity with those presented before. Indeed, it supports the evidence of conditional β-convergence with speeds towards the steady-state of around five percent; again, negative coefficients are obtained for public investment and positive ones for human capital, with a greater statistical significance. The coefficients estimated for the unemployment rates and income share available for capital accumulation after taxes hold. The Sargan tests of overidentifying reject the validity of the different groups of instruments[8]. The implicit rejection of endogeneity hypothesis for public and private investment is not new 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 confirming the robustness of the previous results. 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 from three different schemes: 1) Introduction of regional multiplicative 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 method.

### V.1 Regional multiplicative dummies

A first option is the inclusion of variables dummies in the coefficients corresponding to public investment, as well as the estimated dummies as unobservable fixed effects. This allows us to observe how the different components of public investment affect each region. The results are presented in Table 3, where each column displays the values estimated according to public investment whose coefficient is calculated for each region and for each regressor set.

[8] The results are robust for different definitions of the matrix of instruments. Arellano and Bond (1991) demonstrate the tendency to over-reject the null hypothesis of the Sargan test in the presence of heteroskedasticity. Since the option of estimating via two-step GMM was excluded before, a remarkable sensitivity of the results we could have identified one of the factors that cooperate in the widespread rejection of the selected matrix of instruments. Instead, it is not appreciated regarding the choice of the matrix of instruments.

**Table 3: Estimation of convergence equation with multiplicative dummies. Spanish regions (1965 - 1995). Dependent variable: Per capita income growth rate for each span.**

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| 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) |
| Log($s_{pit}$)-log($n_{it}$+$x$+δ) | 0.030 (4.90) | 0.033 (5.30) | 0.028 (4.84) | 0.029 (4.54) | 0.032 (4.98) | 0.026 (4.36) |
| Log($s_{git}$)-log($n_{it}$+$x$+δ) | | | | -0.005 (-1.22) | -0.003 (-0.80) | -0.007 (-1.68) |
| Log($s_{sit}$)-log($n_{it}$+$x$+δ) | 0.0019 (0.60) | | | | | |
| Log($s_{eit}$)-log($n_{it}$+$x$+δ) | | -0.002 (-1.00) | | | | |
| Log($s_{dit}$)-log($n_{it}$+$x$+δ) | | | 0.011 (4.48) | | | |
| 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) |
| Log(1-$\tau_{i\ t}$) | -0.204 (-4.56) | -0.203 (-4.49) | -0.226 (-5.43) | -0.247 (-5.68) | -0.236 (-5.33) | -0.241 (-5.53) |
| Multiplicative dummies | $s_{git}$ | $s_{git}$ | $s_{git}$ | $s_{sit}$ | $s_{eit}$ | $s_{dit}$ |
| 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 | -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): Log($s_{git}$)-log($n_{it}$+x+δ); column (2): Log($s_{git}$)-log($n_{it}$+x+δ); column (3): Log($s_{git}$)-log($n_{it}$+x+δ); column (4): Log($s_{sit}$)-log($n_{it}$+x+δ); column (5): Log($s_{eit}$)-log($n_{it}$+x+δ); column (6): Log($s_{dit}$)-log($n_{it}$+x+δ). Source: IVIE and Foundation BBVA.

On Table 3, two main conclusions can be drawn. First, the variables whose specification is not modified with the inclusion of multiplicative dummies maintain their values and significance levels. Second, few of the regional coefficients are significant; hence, only very particular results can be extracted: Baleares has experienced some positive impact of public investment on its growth rate while the opposite is true for Murcia and, with smaller robustness, for Cataluña and Madrid. In the same way, social public investment has exercised positive effects in Andalucía, Cantabria and Galicia; in the case of health investment, we should add Madrid and Valencia to the previous group[9].

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

Now we will consider a specification of the convergence equation that takes 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 we will use is not derived from the previously discussed theoretical framework; so the structural interpretation of the coefficients estimated is not possible. The convergence equation that we are now interested in estimating has the following expression:

$$\begin{aligned} \ln y_{it} - \ln y_{it-\mathrm{T}} &= \beta_0 \ln \psi_{i0} + x\left(t - e^{-\lambda \mathrm{T}}(t-\mathrm{T})\right) - \beta_1 \ln y_{it-\mathrm{T}} + \beta_2 \ln s_{pit} + \beta_3 \left(\ln s_{git}\right)^2 + \\ &+ \beta_4 \left(\ln s_{hit}\right)^2 + \beta_5 \ln(\delta + n_{it} + x) + \beta_6 \ln(1 - \tau_{it}) \end{aligned} \qquad (7)$$

Notice that the variables that refer to public investment enter in a quadratic form. Table 4 presents the results reached by the within-groups estimator, both when the quadratic relationship exists for both types of public investment (productive and social) or when only one is defined for productive public investment[10].

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[9] A possible extension of this strategy could be the constitution of regional clubs (Bajo *et al*., 1999). However, we would have to deal with a decrease in the number of observations.

[10] We do not present the values of other statistics such as Hausman or F; their values support the chosen specification. They are available upon request.

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

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| Log($y_{i,\, t\text{-}T}$) | -0.086 (-6.79) | -0.080 (-6.57) | -0.103 (-8.62) | -0.086 (-6.72) | -0.080 (-6.53) | -0.102 (8.54) |
| 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) |
| (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) |
| Log($s_{sit}$) | | | | 0.002 (0.80) | | |
| (Log($s_{sit}$))$^2$ | -0.0002 (-0.89) | | | | | |
| Log($s_{eit}$) | | | | | -0.002 (-1.14) | |
| (Log($s_{eit}$))$^2$ | | 0.0002 (1.08) | | | | |
| Log($s_{dit}$) | | | | | | 0.012 (4.95) |
| (Log($s_{dit}$))$^2$ | | | -0.0009 (-5.21) | | | |
| log($n_{it}$+$x$+δ) | -0.033 (5.45) | -0.034 (-5.66) | -0.035 (-5.96) | -0.033 (-5.45) | -0.034 (-5.67) | -0.034 (-5.94) |
| 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) |
| 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 close to the values and statistical significance obtained previously, except in the case of unemployment rate in column (6) where there is a slight difference. Productive public investment continues to be insignificant, although in this instance it acquires a positive sign that was lacking before. Social public investment (Education plus Health) loses statistical significance now and even changes from a positive sign to a negative one when entered in a quadratic way in the equation. Squared public investment in education presents a positive effect on regional growth rate while its effect is negative if entered into the equation in a conventional way; in either case, neither of the coefficients are not statistically significant. On the other hand, given the econometric specification, public investment in Health behaves inversely to public investment in Education.

### V.3 Time dummies

In this subsection, we include among the regressors time dummies to take explicitly into account the time dimension of our data. This is an alternative way to control exogenous technical progress. Table 5 offers results for different specifications of the convergence equation, all of them including time dummies[11].

**Table 5:Estimation of convergence equation with time dummies. Spanish regions (1965 - 1995).**

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

| | (1) | (2) | (3) |
|---|---|---|---|
| Log($y_{i,\, t-T}$) | -0.057 (-3.60) | -0.061 (-3.53) | -0.054 (-3.40) |
| Log($s_{pit}$)-log($n_{it}$+$x$+δ) | 0.033 (6.45) | 0.039 (8.33) | 0.033 (6.41) |
| Log($s_{git}$)-log($n_{it}$+$x$+δ) | 0.012 (2.28) | 0.008 (1.20) | 0.012 (2.36) |
| Log($s_{sit}$)-log($n_{it}$+$x$+δ) | 0.003 (1.53) | -0.001 (-0.55) | 0.003 (1.32) |
| Log($u_{it}$) | -0.001 (-1.64) | -0.001 (-2.01) | |
| Log(1-$\tau_t$) | -0.037 (-0.79) | -0.064 (-1.22) | -0.031 (-0.63) |
| $\lambda$ | 0.029 | 0.031 | 0.027 |
| $\alpha$ | 0.314 | 0.364 | 0.323 |
| $\beta$ | 0.114 | 0.074 | 0.117 |
| $\gamma$ | 0.028 | -0.009 | 0.029 |
| *RSS* | 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: Log($s_{git}$) and Log($s_{sit}$) with one lag, remaining variables as exogenous and time dummies. (3) Within groups estimation and no IV's; unemployment rate has been removed. 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 reserves one extra observation; see data appendix). Source: IVIE and Foundation BBVA.

[11] See previous footnote.

Notice that goodness of fit improves, supporting the evidence of β-conditional convergence, with a convergence rate around 3 percent. The statistical significance of private investment rate has increased; on the other hand, the significance of income per capita level corresponding to previous period has decreased. However, the most important change resides now in the significant positive sign of productive public investment, in contrast with the loss of robustness for the coefficient of social public investment. This last factor even shows indications that it negatively affected 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 within conventional statistical thresholds, although it must be noted that the chosen matrix of instruments is the appropriate one at an acceptable significance level and there are no clear symptoms of a bad specification (see statistics *m1* and *m2*).

An additional dimension to these new results comes by observing the effect that inclusion of time dummies has on income proportion in the private sector after taxes and on the unemployment rate. Indeed, both of them lose explanatory power. Regarding the first one, elimination would not be consistent with the theoretical framework followed by this paper. On the other hand, if time dummies are related to the business cycle, the statistical significance of the unemployment rate might be reduced considerably. A disadvantage of the time dummies approach is that it does not take into account the different intensities that economic fluctuations have on each region.

In short, and while recognizing that the results we have presented above provide reasonable econometric guarantees, we will not change our basic specification for the convergence equation to include time dummies. This is because a time dummies specification strays from the proposed theoretical framework (time dummies affect other variables). Moreover, the business cycle can be incorporated through the unemployment rate; this last strategy offers a richer regional analysis. Also, the statistical qualities of our previous estimates are not less than those presented in this subsection.

Therefore, we are able to state that investment in productive public capital does not show a positive correlation with the growth rate of the different Spanish regions over the period 1965-1995[12]. Mas *et al*. (1994) recognise the fact that regions with a superior initial endowment of public capital have experienced higher growth rates, but find that for period 1967-1979 a negative (but not significant) effect of these endowments on the increase in regional Value Added; for the period 1979-1991, the effect is positive although it is not significant from a statistical point of view. De la Fuente and Vives (1995) also show 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 equation for the Spanish regions over a period very similar to ours.

Regarding public investment in Education and Health, the positive effect of this variable on regional growth along the time horizon studied here seems to be confirmed. However, in the regressions with instrumental variables some doubts arise regarding the statistical significance of coefficients estimated.

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

The previous results have shown how productive public investment has not positively influenced Spanish regional growth between 1965 and 1995. Conversely, social public investment has shown a positive correlation with the growth rate of regional GDP. The first result is very surprising, of course, as the bulk of regional policies stress the endowment of infrastructure as the most effective instrument for reducing the interregional differences. We will try to explain our result through a theoretical framework provided in the specialised literature.

The existence of a negative effect of (productive) public expenditure on per capita income growth rate is not a circumstance unknown to development theory. One line of research introduces the

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[12] We are aware that some aspects of remarkable transcendence in the regional convergence literature are omitted in our paper. See 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 theoretical framework; Gorostiaga (1999) for links between human capital and technological progress.

possibility that public capital exercises a negative effect on growth rate from Uzawa's (1965) and Lucas's (1988) papers. Both papers link the dynamics of growth to the ratio defined by human capital and private capital. With extensions like Mulligan and Sala-i-Martin (1993) or Sala-i-Martin (1997) and Bosch and Espasa (1999), and carrying out the corresponding translation to the particular type of infrastructure, an inverse relationship can be obtained between public capital/private capital ratio and growth rate in transitional dynamics (adapting the models to the infrastructure domain).

Using a two-sector model of endogenous growth, we consider a representative household, which maximizes this standard utility function over time:

$$\int_0^\infty \frac{C^{1-\theta}-1}{1-\theta} e^{-\rho t}\, dt, \tag{8}$$

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

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

$$\dot{G} = Y - C - \delta\, G = \mathrm{A}\, G^{\alpha} \left(u\, K\right)^{1-\alpha} - C - \delta\, G, \tag{9}$$

where $Y$ is the output of goods, $\delta$ 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 are given by

$$\dot{K} = B\left(1-u\right)K - \delta\, K\,. \tag{10}$$

$B$ is also a technological parameter. The rate of depreciation is identical for two kinds of capital and $(1 - u)$ is the fraction of private capital used in intermediate goods production[13]. Also, we can

[13] Notice that public capital has played no role in the accumulation of $K$, which is a restrictive assumption. If we incorporate $G$ to equation (10), we will face very complicated transitional dynamics. However, numerical exercises based on reasonable values for the underlying parameters show how the main results of our restricted framework hold when public capital enters into the equation (10) (See Barro and Sala-i-Martin, 1999).

demonstrate that, under several assumptions, a nonnegative of gross investment constraint is not required (Barro and Sala-i-Martín, 1999).

Households maximize (8) subject to (9) and (10). It yields the steady-state values of the variables and their transitional dynamics. Similar to the Uzawa-Lucas model for *K* and *H*, we can study now which effects the *G/K* ratio has on growth rate of broad output. Since *Y* is the output of final goods, we define a broad concept of output as follows:

$$Q = Y + p\,B\left(1-u\right)K\,, \tag{11}$$

where *p* is shadow price of capital in units of *Y*[14]. 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 $\gamma_Q = \gamma_Y - \gamma_u \dfrac{1-\alpha}{1-\alpha-\alpha u}$, where $\gamma_x$ is growth rate of *x*, it is possible to demonstrate that $\dfrac{\partial \gamma_Q}{\partial\left(G/K\right)} < 0$. In other words, growth rate of the economy towards steady-state is inversely related to the *G/K* ratio. When an economy has a high endowment of infrastructure relative 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 the economy growth rate is slow.

Conversely, when the *G/K* ratio is low, the dynamics of the system provide an incentive to allocate resources to production of the relatively scarce factor. Households realize that their *C/G* ratio is

[14] Formally, *p* is the ratio between Lagrange multipliers implied in household's optimization problem.

lagger 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 productive public spending). This circumstance yields higher growth rates of $Q$ than when a high $G/K$ ratio exists.

Sala-i-Martin (1997) studies the orientation of public investment policy in Spain. According to this author, the regions with smaller public capital/private capital ratios between 1964 and 1991, and where public investment should generate the biggest income increments were: Baleares, Madrid and Cataluña. However, these are rich regions, which have not made them eligible for large volumes of spending in public capital, in comparison to lower per capita income regions. This circumstance may have influenced the reduced return of public investment found above.

Sala-i-Martin (1997) and Bosch and Espasa (1999) demonstrate what we have just said using Spanish regional data for several periods. It seems that the public investment policy implemented in Spain has given special emphasis to those regions where the social return of infrastructure was smaller. In this sense, we are going to undertake an exercise to test if our data support this hypothesis. Table 6 shows, in the first column, a classification of the Spanish regions from lagger to smaller ratio $\frac{G_{it}}{K_{it}}$ over the period 1965-1995; the 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 in private investment; this last ratio may be interpreted as the share that public investment represents over private investment.

**Table 6. Public capital endowments and private investment in the Spanish regions 1965-1995.**

**(Average values for whole 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 and Foundation BBVA

The evidence shown in Table 6 is clear. The regions with a high public capital endowment in relation to their private capital (Extremadura, Castilla-La Mancha, Aragón, Castilla-León) are those that have received the greatest resources in concept of public investment relative to private investment. Conversely, regions as Baleares, Madrid, Cataluña and Valencia (the least endowed on average over the period) have registered -together with Galicia- the lowest public investment rates.

This fact could be partially responsible for the null or negative effect of public investment on regional growth in Spain from 1965 to 1995. This is because the government has invested in regions where, due to their relatively high endowment of infrastructure, social return on the marginal public capital was less. Public investment policy has not been focussed on maximizing total output of the country but a redistributive objetive.

Similar conclusions are reached in other empirical papers that have studied the effect of infrastructure on economic performance in Spain from a regional point of view. Bajo *et al*. (1999) find that public investment has not affected the regional growth rate for the richest regions in 1967 (Madrid, País Vasco, Cataluña and Baleares). Moreno *et al*. (1997) prove that an appropriate endowment of public capital becomes a necessary, but not sufficient, condition, for the process of economic growth. They show how the poorest Spanish regions have not been benefited by public investment in the same magnitude as others, in spite of being the main recipients.

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

## VII. Conclusions

In most Western economies, regional policies concentrate their efforts on the provision of a level of infrastructures that guarantee 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 considerable attention from academia since the nineties. The theoretical models that described a positive link between both variables were followed by studies that estimated convergence equations under different specifications and methods. The results in this scope have not been as unanimous as in the theoretical plane.

In this paper a neoclassical growth model has been provided with public and human capital (approximated through public investment in core infrastructures, Health and Education); the influence that tax system has on private capital accumulation is also considered. After presenting our theoretical framework, we derived a convergence equation estimated with Spanish regions data over the period 1965-1995 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 consistent with 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.

To adress the doubts outlined by some authors about the possible endogeneity of variables such as private and public investment, we have carried out estimates with instrumental variables. After adopting the appropriate precautions, the results are presented for different specifications of the matrix of instruments. The results confirmed our previous findings. The coefficient for public investment maintains its negative sign and now acquires statistical significance.

We have also considered alternative specifications for the convergence equation. First, multiplicative dummies in the coefficients of public investment rates have been included; although the results do not present the robustness that would be desirable, we discern some geographical peculiarities relating 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 shows a positive effect (and significant in some cases) of productive public investment on per capita regional income growth; however, some problems found in other structural variables and the lesser wealth of the specification give us doubts regarding 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 a period has been directed especially to regions that present a higher public capital/private capital ratio. The return of public investment in these regions is less so that the distribution of public capital spending among regions has had null or negative effects on aggregated 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 shown in Martínez (2001).

Since public investment is one of the main instruments for reaching regional convergence, our empirical findings have some policy implications for EU and Spain in particular. It is likely that the impact of infrastructure on economic activity depends on factors such as an adequate industrial mix, business culture, managerial dynamism or the capacity to generate agglomeration externalities. So the complex links between infrastructures and growth require us to consider a miscellany of factors for measuring public capital effectiveness. And these circumstances do not seem to have been taken into account explicitly by policy-makers.

Anyway, some questions remain to be answered. What role has public investment distribution played in correcting regional imbalances? What has 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 these points constitute a stimulating starting point for future research.

**Data Appendix**

The aim of this appendix is to offer information about the variables employed as well as the data sources that we have used. The variable $y_{it}$ corresponds to per active worker regional GDP, with biannual observations. The choice of active population for measuring per capita regional output is intentional. After having used figures corresponding to employed population and working-age population, we have checked that the best behaviour of the estimations happens 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 the ratio of private investment in physical capital over regional GDP and $s_{git}$ is the share of productive public investment (highways and roads, hydraulic infrastructures, urban structures, ports and airports) over the regional GDP. The variable $s_{hit}$ has been proxied by three series: $s_{eit}$ 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 both Education and Health in the regional GDP. For these categories, we considered productive or social capital spending by central, regional and local governments as well as by the Social Security.

In the group of demographic variables, $n_{it}$ is the average growth rate of active population in each time span (two years). $x$ is technical progress rate whose value has been fixed in 0.02. $\delta$ is the rate of capital goods depreciation that we suppose constant and common for all three types of assets considered in this paper; its value is fixed at 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 the BBVA Foundation and IVIE. Additional information about data can be found in the cited Internet site and in Mas *et al*. (1996).

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

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

The number of observations has oscillated between 252 and 235. It corresponds to data for 17 regions over 16 years. Anyway, for unemployment rate, three observations with values very near to zero have been eliminated to avoid the distortion of the logarithmic transformation of data.

**Table 7: Summary of variables abbreviations and definitions**

| | | | |
|---|---|---|---|
| $y_{it}$ | per active worker regional GDP (biannual) | $\tau_{it}$ | ratio of tax resources collected by government over the regional GDP |
| $s_{pit}$ | ratio of private investment in physical capital over regional GDP | $n_{it}$ | average growth rate of active population in each time span (two years) |
| $s_{git}$ | ratio of productive public investment (highways and roads, hydraulic infrastructures, urban structures, ports and airports) over the regional GDP | $x$ | exogenous technical progress rate whose value has been fixed at 0.02. |
| $s_{eit}$ | ratio of public investment devoted to Education as percentage of the regional GDP | $\delta$ | rate of capital goods depreciation that we suppose constant and common to all the three types of assets considered in this paper; its value is fixed at 0.05 |
| $s_{dit}$ | ratio of public investment in Health as percentage of the regional GDP. | $h_{it}$ | share of working-age population with secondary and university studies |
| $s_{sit}$ | ratio of public investment in both Education and Health as percentage of the regional GDP. | $u_{it}$ | unemployment rate |

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