Abstract
This paper studies the empirical relationships between public investment and per capita income growth over period 1965-1995 in the 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 a negative effect of productive public investment on the rate of regional economic growth. Also public investment in education, although not very significant, and public resources devoted to health investment have a positive correlation with the increment of per capita income. Alternative estimates to dealt 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.

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 will affect negatively to the peripheral regions; their arguments are based on endogenous growth theories. Instead, others think that a regional convergence may be reached and public policies would help to get this purpose; in this way, public investment appears as the main instrument for reducing differences in regional per capita income levels.

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

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until the seminal article of Barro (1990) that the topic began to be studied in a deeper way. Linked to a vast literature on the interrelations between infrastructure and economic performance (Aschauer, 1989), 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) transitional dynamics (Futagami et al., 1993), implications on social welfare (González-Páramo, 1995), inclusion of other public spending variables (Bajo-Rubio, 2000) and different tax systems (Jones et al., 1993).

The neoclassical literature offers a varied empirical evidence of the public investment effects on growth rate (Barro, 1991; De la Fuente, 1997; Galindo and Escot, 1998). From a regional perspective, the abundance of published works that explicitly relate public investment to growth through estimations of convergence equations is wide: Hulten and Schwab (1993), Mas et al. (1994), Dolado et al. (1994), De la Fuente and Vives (1995), Gorostiaga (1999), Bajo et al. (1999).

This paper seeks to explore the empirical relationships found in the 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 work we explicitly considerate public investment through core infrastructure and human capital and the separation between tax revenues and productive public spending in an empirical growth model.

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. Section VI draws a link between our results and theoretical contributions in the literature. Finally, Section VII concludes.

**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 \( t \) as follows:

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

(1A)

where \( \psi_{it} = \psi_{i0} e^{x_{it}} \) and \( L_{it} = L_{it0} e^{x_{it}} \). \( Y \) 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 \(^\wedge\)): 

\[
\dot{y}_u = \left( k_{it} \right)^{\alpha} \left( g_{it} \right)^{\beta} \left( h_{it} \right)^{\gamma}.
\] (1B)

Next we define the movement equations for accumulable production factors:

\[
\begin{align*}
\dot{k}_{it} &= \left(1 - \tau_{it}\right) s_{pi} \dot{y}_{it} - \left( \delta + n_i + x \right) \dot{k}_{it} \\
\dot{g}_{it} &= s_{gi} \dot{y}_{it} - \left( \delta + n_i + x \right) \dot{g}_{it} \\
\dot{h}_{it} &= \left(1 - \tau_{it}\right) s_{hi} \dot{y}_{it} - \left( \delta + n_i + x \right) \dot{h}_{it},
\end{align*}
\] (2)

where a dot over a variable denotes its time derivative; \( \tau \) is the share of tax revenue over total output that government collect 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 share gross public investment over output. As 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 (\( k_{i}^* \)), productive public capital (\( g_{i}^* \)), human capital (\( h_{i}^* \)) and output (\( y_{i}^* \)).

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

\[
\frac{d \ln y_i}{dt} = \alpha \frac{d \ln k_i}{dt} + \beta \frac{d \ln g_i}{dt} + \gamma \frac{d \ln h_i}{dt}.
\] (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 have the next expression:

\[
\frac{d \ln \hat{y}_i}{dt} = \alpha \left[(1 - \tau)s_{pi}e^{(\alpha - 1)h_k} e^{\delta + n_i + x} \right] + \beta \left[s_{gi}e^{\delta + n_i + x} \right] + \gamma \left[(1 - \tau)s_{hi}e^{\delta + n_i + x} \right] - \left(\alpha + \beta + \gamma\right) \left(\delta + n_i + x\right).
\] (4)

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

\[
\frac{d \ln \hat{y}_i}{dt} \approx -\lambda \left(\ln k_i - \ln k_i^*\right) - \beta \lambda \left(\ln g_i - \ln g_i^*\right) - \gamma \lambda \left(\ln h_i - \ln h_i^*\right) = -\lambda \left(\ln \hat{y}_i - \ln \hat{y}_i^*\right),
\] (5)

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

\[
\ln \hat{y}_u - \ln \hat{y}_{u-1} = \rho \ln y_u + x(t - e^{-\lambda t}) + \rho \ln \hat{y}_u - \rho \frac{\alpha}{1 - \alpha - \beta - \gamma} \ln s_{pi} + \rho \frac{\beta}{1 - \alpha - \beta - \gamma} \ln s_{hi} + \rho \frac{\gamma}{1 - \alpha - \beta - \gamma} \ln s_{gi}.
\] (6)
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 equation (6). Note that we have included into the model productive public spending and taxes collected by government to finance *any kind* of public expenditure. This enables us to deal with the role of the public sector in a more extensive perspective and without conditioning both sides of public budget. The parameter \( \psi_{i0} \) let us to incorporate 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 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 considering unobservable individual-regional characteristics and it may imply biased coefficients from estimation. A panel data approach avoids this circumstance and the data time dimension is exploited in a better way\(^1\).

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

The term that symbolizes technical growth, \( x \left( t - e^{-\lambda T} (t - T) \right) \), depends on exogenous, constant variables, so it can be studied jointly with \( \ln \psi_{i0} \). This has been the chosen specification. We used a time trend previously, but as this alternative caused multicollinearity problems, mainly on the coefficient of \((1 - \tau_{it})\), and in 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.

Hausman (1978) test provides evidence on the existence of correlations between individual effects and regressors, that is, in favour of fixed effect model, for what we have taken a within-groups estimator. On the other hand, all the estimates have been carried out weighting the

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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 usual, is not a novelty in the literature (see, for example, Currais and Rivera, 1999a, 1999b).

3 Easterly and Rebelo (1993) point out the sensitivity 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.
observations in the cross-section to avoid heteroskedasticity caused by the different size of the units. Also we have used a White covariances matrix.

As is customary in empirical works on convergence, the results presented in Table 1 impose the restriction that the coefficients of demographic variables, private investment rate and public investment rate in infrastructure and human capital, sum to 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.

Table 1: Estimation of convergence equation. Spanish regions (1965 - 1995)

<table>
<thead>
<tr>
<th>Dependent variable: Per capita income growth rate for each span.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log(y_{it} - T)</td>
</tr>
<tr>
<td>-0.058 (-5.95)</td>
</tr>
<tr>
<td>-0.062 (-0.07)</td>
</tr>
<tr>
<td>-0.089 (-.80)</td>
</tr>
<tr>
<td>-0.086 (-.64)</td>
</tr>
<tr>
<td>-0.102 (-9.25)</td>
</tr>
<tr>
<td>-0.190 (-61)</td>
</tr>
</tbody>
</table>

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.

From Table 1 we can draw 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. 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 positive sign in all specifications but only when as variable stock is included (column (6)) or it is approximated through public investment in health (column (5)), it acquires statistical significance. 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. It maybe reinforces 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 Garcia, 1996).

Third, we see that productive public investment $s_{pi}$ 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 variable appears. It requires additional discussion since it is commonly admitted that public capital endowments play an important role in regional development.

Finally, income proportion available for private capital accumulation after discounting taxes $(1 - \tau)$ 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. 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 convergence equation may result in inconsistent estimations. This circumstance could explain, at least partially, the insignificance of public investment in infrastructure and even its negative sign. The literature about economic growth has shown that private investment rate depends on income growth rate; King and

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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.

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 Rebele (1993) also show the difficulties of isolating the influence of tax system on economic growth.
Levine (1994), Dolado et al. (1994) and Gorostiaga (1999) are samples of this. On the other hand, as is well known, an important shortcoming pointed out to 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 estimates.

We will offer additional empirical evidence carrying out an effort to take account the possible endogeneity of the rate of private and public investment (in infrastructure and social public capital). With this aim, convergence equation will be estimated using an instrumental variables (IV) estimator; we will enrich 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 to illustrate the implications of a likely endogeneity\(^6\). Since the estimator is within-groups, the use of 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 followed GMM.

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 a 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)

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6 Estimates of alternative specifications are available on request. They corroborate the results obtained for the equation that serves us as reference.
Table 2: GMM Estimation of convergence equation. Spanish regions (1965 - 1995). Dependent variable: Per capita income growth rate for each span.

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log(yi, t-T)</td>
<td>-0.096(-10.94)</td>
<td>-0.095(-12.69)</td>
<td>-0.094(-11.68)</td>
<td>-0.102(-0.16)</td>
<td>-0.092(-1.66)</td>
</tr>
<tr>
<td>Log(spit)-log(nit+x+δ)</td>
<td>0.028 (3.58)</td>
<td>0.034 (5.71)</td>
<td>0.029 (4.07)</td>
<td>0.039 (6.08)</td>
<td>0.029 (3.95)</td>
</tr>
<tr>
<td>Log(sgit)-log(nit+x+δ)</td>
<td>-0.009 (-2.13)</td>
<td>-0.009 (-1.89)</td>
<td>-0.007 (-1.90)</td>
<td>-0.020 (-2.98)</td>
<td>-0.003 (-1.14)</td>
</tr>
<tr>
<td>Log(ssit)-log(nit+x+δ)</td>
<td>0.003 (1.17)</td>
<td>0.005 (2.15)</td>
<td>0.006 (2.65)</td>
<td>0.008 (2.49)</td>
<td>0.003 (1.38)</td>
</tr>
<tr>
<td>Log(uit)</td>
<td>-0.005 (-2.88)</td>
<td>-0.004 (-2.80)</td>
<td>-0.004 (-2.74)</td>
<td>-0.005 (-2.79)</td>
<td>-0.004 (-2.76)</td>
</tr>
<tr>
<td>Log(1-τit)</td>
<td>-0.243 (-7.47)</td>
<td>-0.234 (-7.20)</td>
<td>-0.223 (-5.98)</td>
<td>-0.286 (-6.04)</td>
<td>-0.208 (-6.74)</td>
</tr>
<tr>
<td>λ</td>
<td>0.050</td>
<td>0.049</td>
<td>0.049</td>
<td>0.053</td>
<td>0.048</td>
</tr>
<tr>
<td>α</td>
<td>0.237</td>
<td>0.271</td>
<td>0.237</td>
<td>0.302</td>
<td>0.239</td>
</tr>
<tr>
<td>β</td>
<td>-0.076</td>
<td>-0.071</td>
<td>-0.057</td>
<td>-0.154</td>
<td>-0.024</td>
</tr>
<tr>
<td>γ</td>
<td>0.025</td>
<td>0.039</td>
<td>0.049</td>
<td>0.061</td>
<td>0.025</td>
</tr>
<tr>
<td>RSS</td>
<td>0.085</td>
<td>0.084</td>
<td>0.084</td>
<td>0.090</td>
<td>0.083</td>
</tr>
<tr>
<td>m1</td>
<td>2.999</td>
<td>3.186</td>
<td>3.081</td>
<td>3.163</td>
<td>3.313</td>
</tr>
<tr>
<td>m2</td>
<td>-2.008</td>
<td>-1.768</td>
<td>-1.853</td>
<td>-1.639</td>
<td>-1.839</td>
</tr>
<tr>
<td>Sargan</td>
<td>153.31 [78]</td>
<td>127.64 [26]</td>
<td>156.22 [52]</td>
<td>114.74 [26]</td>
<td>171.82 [78]</td>
</tr>
</tbody>
</table>

Notes: Instruments set in each specification: (1) Log(spit)-log(nit+x+δ) and Log(1-τit) with one lag, Log(spit) and Log(sgit) with one and two lags and remaining variables as exogenous. (2) Log(spit)-log(nit+x+δ) with one and two lags and remaining variables as exogenous. (3) Log(spit)-log(nit+x+δ) and Log(sgit)-log(nit+x+δ) with one and two lags and the remaining variables as exogenous. (4) Log(spit) with one and two lags and the remaining variables as exogenous. (5) Log(spit)-log(nit+x+δ), Log(sgit), Log(ssit) 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 around five percent; again, negative coefficients are obtained for public investment and positive ones for human capital, with a bigger statistical significance. The coefficients estimated for the unemployment rates and income share available for capital accumulation after taxes hold.

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 way.

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 to 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 regressors set.

Table 3: Estimation of convergence equation with multiplicative dummies. Spanish regions (1965 - 1995).

<table>
<thead>
<tr>
<th>Dependent variable: Per capita income growth rate for each span.</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log ($y_{it}$)</td>
<td>-0.084 (-6.53)</td>
<td>-0.081 (-.36)</td>
<td>-0.099 (-.10)</td>
<td>-0.099 (-.34)</td>
<td>-0.093 (-7.91)</td>
<td>-0.104 (-.21)</td>
</tr>
<tr>
<td>Log ($s_{pit}$)-log ($n_{it}$+$x$+$\delta$)</td>
<td>0.030 (4.90)</td>
<td>0.033 (5.30)</td>
<td>0.028 (4.84)</td>
<td>0.029 (4.54)</td>
<td>0.032 (4.98)</td>
<td>0.026 (4.36)</td>
</tr>
<tr>
<td>Log ($s_{sit}$)-log ($n_{it}$+$x$+$\delta$)</td>
<td>-0.005 (-0.22)</td>
<td>-0.003 (-0.80)</td>
<td>-0.007 (-0.68)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log ($s_{dit}$)-log ($n_{it}$+$x$+$\delta$)</td>
<td>0.0019 (0.60)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log ($u_{it}$)</td>
<td>-0.204 (-4.56)</td>
<td>-0.203 (-.49)</td>
<td>-0.226 (-.43)</td>
<td>-0.247 (-.68)</td>
<td>-0.236 (-5.33)</td>
<td>-0.241 (-.53)</td>
</tr>
<tr>
<td>Log (1- $\gamma_{it}$)</td>
<td>-0.204 (-4.56)</td>
<td>-0.203 (-.49)</td>
<td>-0.226 (-.43)</td>
<td>-0.247 (-.68)</td>
<td>-0.236 (-5.33)</td>
<td>-0.241 (-.53)</td>
</tr>
<tr>
<td>Multiplicative dummies</td>
<td>$s_{pit}$</td>
<td>$s_{pit}$</td>
<td>$s_{pit}$</td>
<td>$s_{sit}$</td>
<td>$s_{sit}$</td>
<td>$s_{dit}$</td>
</tr>
<tr>
<td>Andalucía</td>
<td>-0.003 (-0.30)</td>
<td>-0.002 (-.22)</td>
<td>-0.008 (-.90)</td>
<td>0.025 (2.79)</td>
<td>0.017 (1.30)</td>
<td>0.019 (4.42)</td>
</tr>
<tr>
<td>Aragón</td>
<td>0.006 (0.36)</td>
<td>0.009 (0.52)</td>
<td>0.001 (0.07)</td>
<td>0.001 (0.23)</td>
<td>-0.003 (-0.71)</td>
<td>0.010 (1.11)</td>
</tr>
<tr>
<td>Asturias</td>
<td>-0.005 (-0.38)</td>
<td>-0.003 (-.29)</td>
<td>-0.008 (-.63)</td>
<td>-0.003 (-.20)</td>
<td>-0.005 (-0.50)</td>
<td>0.006 (0.50)</td>
</tr>
<tr>
<td>Baleares</td>
<td>0.033 (2.00)</td>
<td>0.034 (2.04)</td>
<td>0.022 (1.34)</td>
<td>0.018 (1.36)</td>
<td>0.007 (0.67)</td>
<td>0.028 (2.10)</td>
</tr>
<tr>
<td>Canarias</td>
<td>0.007 (0.61)</td>
<td>0.008 (0.69)</td>
<td>0.000 (0.00)</td>
<td>0.007 (0.74)</td>
<td>0.003 (0.36)</td>
<td>0.011 (1.56)</td>
</tr>
<tr>
<td>Cantabria</td>
<td>0.004 (0.36)</td>
<td>0.005 (0.52)</td>
<td>0.000 (0.06)</td>
<td>0.016 (3.15)</td>
<td>0.009 (2.28)</td>
<td>0.016 (2.63)</td>
</tr>
<tr>
<td>Cataluña</td>
<td>-0.013 (-1.10)</td>
<td>-0.013 (-.06)</td>
<td>-0.019 (-.62)</td>
<td>-0.010 (-.69)</td>
<td>-0.013 (-1.00)</td>
<td>0.000 (0.01)</td>
</tr>
<tr>
<td>Castilla-La Mancha</td>
<td>0.003 (0.20)</td>
<td>0.005 (0.32)</td>
<td>0.001 (0.12)</td>
<td>0.002 (0.15)</td>
<td>-0.002 (-0.18)</td>
<td>0.011 (0.77)</td>
</tr>
<tr>
<td>Castilla-León</td>
<td>-0.004 (-0.23)</td>
<td>-0.002 (-.12)</td>
<td>-0.010 (-.65)</td>
<td>-0.014 (-.76)</td>
<td>-0.024 (-1.53)</td>
<td>0.012 (1.21)</td>
</tr>
</tbody>
</table>
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 (-0.23)  -0.030 (-0.50)  0.000 (0.04)  -0.002 (-0.30)  0.015 (1.73)
Murcia  -0.015 (-3.27)  -0.015 (-0.98)  -0.017 (-0.48)  -0.009 (-0.50)  -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)
Pais 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(nit+x+δ); column (2): Log(s git)-log(nit+x+δ); column (3): Log(s git)-log(nit+x+δ); column (4): Log(s git)-log(nit+x+δ); column (5): Log(s git)-log(nit+x+δ); column (6): Log(s git)-log(nit+x+δ). Source: IVIE and Foundation BBVA.

From 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 the growth rate or that 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; for the case of health investment, we should add Madrid and Valencia to previous group7.

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

Now we will consider 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 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:

\[
\ln y_{it} - \ln y_{it-T} = \beta_0 \ln y'_{t0} + x \left( t - e^{-\lambda T (t-T)} \right) - \beta_1 \ln y_{it-T} + \beta_2 \ln s_{git} + \beta_3 \left( \ln s_{git} \right)^2 + \beta_4 \left( \ln s_{lit} \right)^2 + \beta_5 \ln(\delta + n_t + x) + \beta_6 \ln(1 - \tau_t)
\]

7 A possible extension of this strategy could be the constitution of clubs of regions (Bajo et al., 1999). However, we would have to deal with the decrease in the number of observations.
Notice that 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) and when only one is defined for productive public investment.

Table 4: Estimation of convergence equation with non-linear relationships. Spanish regions (1965 - 1995).

<table>
<thead>
<tr>
<th>Dependent variable: Per capita income growth rate for each span.</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
</tr>
<tr>
<td>Log(y_{i,t-1})</td>
</tr>
<tr>
<td>Log(sp)</td>
</tr>
<tr>
<td>(Log(sp))^2</td>
</tr>
<tr>
<td>Log(se)</td>
</tr>
<tr>
<td>(Log(se))^2</td>
</tr>
<tr>
<td>Log(sit)</td>
</tr>
<tr>
<td>(Log(sit))^2</td>
</tr>
<tr>
<td>log(n_{i,x+δ})</td>
</tr>
<tr>
<td>Log(uit)</td>
</tr>
<tr>
<td>Log(1-r_{it})</td>
</tr>
<tr>
<td>RSS</td>
</tr>
<tr>
<td>Durbin-Watson</td>
</tr>
</tbody>
</table>

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 a slight difference. Productive public investment continues to be insignificant, although in this instance it acquires a positive sign that lacked before. Social public investment (education plus health) loses statistical significance now and even changes from positive sign to negative when entered in a quadratic way in the equation.

V.3 Time dummies

We do not present the values of other statistics such as Hausman or F; their values support the chosen specification. They are available on request.
In this subsection we include among the regressors time dummies to take account explicitly the 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, all of them including time dummies.

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

<table>
<thead>
<tr>
<th>Dependent variable: Per capita income growth rate for each span.</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \log(y_{i,t-T}) )</td>
<td>-0.057 (-3.60)</td>
<td>-0.061 (-3.53)</td>
<td>-0.054 (-3.40)</td>
</tr>
<tr>
<td>( \log(s_{gt}) - \log(n_{gt} + x + \delta) )</td>
<td>0.033 (6.45)</td>
<td>0.039 (8.33)</td>
<td>0.033 (6.41)</td>
</tr>
<tr>
<td>( \log(s_{gt}) - \log(n_{gt} + x + \delta) )</td>
<td>0.012 (2.28)</td>
<td>0.008 (1.20)</td>
<td>0.012 (2.36)</td>
</tr>
<tr>
<td>( \log(s_{lt}) - \log(n_{lt} + x + \delta) )</td>
<td>0.003 (1.53)</td>
<td>-0.001 (-0.55)</td>
<td>0.003 (1.32)</td>
</tr>
<tr>
<td>( \log(u_{it}) )</td>
<td>-0.001 (-1.64)</td>
<td>-0.001 (-2.01)</td>
<td></td>
</tr>
<tr>
<td>( \log(1-\tau_t) )</td>
<td>-0.037 (-0.79)</td>
<td>-0.064 (-1.22)</td>
<td>-0.031 (-0.63)</td>
</tr>
<tr>
<td>( \lambda )</td>
<td>0.029</td>
<td>0.031</td>
<td>0.027</td>
</tr>
<tr>
<td>( \alpha )</td>
<td>0.314</td>
<td>0.364</td>
<td>0.323</td>
</tr>
<tr>
<td>( \beta )</td>
<td>0.114</td>
<td>0.074</td>
<td>0.117</td>
</tr>
<tr>
<td>( \gamma )</td>
<td>0.028</td>
<td>-0.009</td>
<td>0.029</td>
</tr>
<tr>
<td>( \text{RSS} )</td>
<td>0.032</td>
<td>0.033</td>
<td>0.033</td>
</tr>
<tr>
<td>( m_1 )</td>
<td>2.543</td>
<td>2.739</td>
<td>2.494</td>
</tr>
<tr>
<td>( m_2 )</td>
<td>-0.087</td>
<td>-0.264</td>
<td>-0.027</td>
</tr>
<tr>
<td>Sargan</td>
<td>36.93 [26]</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: (1) Within groups estimation and no IV’s. (2) GMM; instruments: \( \log(s_{gt}) \) and \( \log(s_{lt}) \) 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.

Notice that goodness of fit improves, supporting the evidence of \( \beta \)-conditional convergence, with a convergence rate around 3 percent. The statistical significance of private investment rate has increased; instead, 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 one even shows indications that it affected negatively 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 appreciated that the chosen matrix of instruments is the appropriate one at an acceptable significance level and there are not clear symptoms of a bad specification (see statistics $m1$ and $m2$).

In short, and even recognizing that results we have just 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 theoretical framework proposed (time dummies affect other variables). Moreover, business cycle can be incorporated through unemployment rate; this last strategy offers a richer regional analysis.

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

The previous results have shown how productive public investment has not influenced positively the 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 when the bulk of regional policies stress on 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 by specialised literature.

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

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

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 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: $K = k^\beta h^{1-\beta}$. Public capital is accumulated according to the following movement equation:

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

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

$^9$ See previous footnote.
\[ \dot{K} = B(1-u)K - \delta K. \]  

(10)

*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 production\(^{10}\). Also, we can 
demonstrate that, under several assumptions, it is not required a nonnegative of gross investment 
constraint (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 has the *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:  
\[ Q = Y + pB(1-u)K, \]  

(11)

where *p* is shadow price of capital in units of *Y*\(^{11}\). 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 \( \gamma_x \) is growth rate of *x*, it is possible to 
demonstrate that \( \frac{\partial \gamma_Q}{\partial (G/K)} < 0 \). 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 
relatively 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 small.

Table 6 shows, in first column, a classification of the Spanish regions from bigger to smaller 
ratio \( \frac{G_i}{K_i} \) 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 share that public investment 
represents over private investment.

\(^{10}\) Notice that public capital has play no role in the accumulation of *K*, which is a restrictive assumption. If we incorporate *G* to 
equation (10), we will 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 hold when public capital enters into equation (10) 
(See Barro and Sala-i-Martin, 1999).
Table 6. Public capital endowments and private investment in the Spanish regions 1965-1995. (Average values for whole period)

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

Source: IVIE and Foundation BBVA

The evidence that table 6 shows 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 biggest resources in concept of public investment relative to private investment. Conversely, regions as Baleares, Madrid, Cataluña and Valencia (the worst endowed on average over the period) have registered -together with Galicia- the smallest public investment rates. This fact could be partially 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 relatively endowment of infrastructure, social return of the marginal public investment is minimal.

Formally, \( p \) is the ratio between Lagrange multipliers implied in household’s optimization problem.
capital was smaller. Public investment policy has not been focussed on maximizing total output of country but a redistributive objection.

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) for the richest regions in 1967, Moreno et al. (1997) and from a dual approach Boscá et al. (1999).

VII. Conclusions

In most of western economies, 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 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); also considered is the influence that tax system has on private capital accumulation. After presenting our theoretical framework, we derived a convergence equation estimated with Spanish regions data over 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.

From 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. We have also considered alternative specifications for the convergence equation. Only 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 smaller wealth of the specification give us doubts about 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
been directed especially to regions that present a higher public capital/private capital ratio. The return of public investment in these regions is smaller 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 is 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 impact of infrastructure on economic activity depends on factors 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 consider a miscellany of factors for measuring public capital effectiveness. And these circumstances do not seem have been taken account explicitly by policy-makers.

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

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 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 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: \( s_{ed} \) is public investment devoted to education as percentage of the regional GDP; \( s_{hl} \) is an equivalent concept but corresponding to investment in health; \( s_{el} \) 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 the Social Security.
In the group of demographic variables, \( n_d \) is the average growth rate of active population in each 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 the 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 and IVIE. Additional information about data can be found in that Internet site and in Mas et al. (1996).

The variable \( \tau \) is the share of tax resources collected by government over 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 \( h_k \) 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 and 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.

References


