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# Linking public investment to private investment

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**RESUMEN**
La literatura describe un efecto positivo de este tipo de gasto sobre la acumulación de capital privado. Este artículo proporciona nueva evidencia empírica sobre esta relación para las regiones españolas en el periodo 1965-1997. Se usa un modelo de *crowding-out* como base teórica y econometría de datos de panel para la parte empírica. Los resultados muestran un efecto positivo de la inversión pública productiva y social (especialmente en educación) sobre la inversión privada. Los efectos desbordamiento generados por infraestructuras productivas localizadas en otras regiones no parecen estimular a la inversión privada en las regiones vecinas. El consumo público y el tipo de interés ejercen una influencia negativa sobre la acumulación de capital privado. Estos resultados son robustos a cambios en la especificación econométrica.

**Palabras clave:** Efecto crowding-out, economía regional, inversión, datos de panel.

**ABSTRACT**
Literature describes a positive effect of public investment on private capital accumulation. This paper seeks to provide new empirical evidence on this latter relationship for the case of Spanish regions over period 1965-1997. We use a crowding-out theoretical framework and panel data methodology. The results show a positive effect of productive and social public investment (especially in education) on private investment. The spillover effects generated by productive infrastructures located in other regions do not seem to encourage private investment in neighbouring regions. Public consumption and interest rate exert a negative influence on private capital accumulation. These results are robust to changes in the econometric specification.

**Keywords:** Crowding-out, regional economics, investment, panel data
**JEL classification:** R53, H54, E62, C33.

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## I. Introduction

One of the most important instruments of regional policies is public investment. This is especially true since the end of the 70's, when other alternative mechanisms of interregional redistribution, such as development poles, subsidies to localization and so on, turned out not very effective and costly both in budgetary and efficiency terms. In such a way, the core of public intervention in processes of regional convergence has tried to ensure the necessary infrastructures for the poorest territories to increase their income per capita. There are at least two channels through which public investment affects regional economic growth. Firstly, the inclusion of public capital as an argument in the aggregate production function of the regions[1]; secondly, the effects of public expenditure in capital on regional income by means of its complementarity with private investment.

However, theoretical and empirical support for this second issue has been questioned from results provided by literature about the crowding-out effect that public spending may exert on the components of aggregated demand. Aschauer and Greenwood (1985), Aschauer (1988) or Barro (1989) are examples of this. Indeed, the relationship between public and private investment presents two opposite dimensions. On the one hand, when there is an increment of public spending in capital, private agents observe to what extent their time consumption pattern is modified. In order to adjust to the new situation, agents will reduce savings, and thus private investment. On the other hand, if public capital increases the productivity of private capital, public investment will raise the return of private investment and the disposition of the agents for saving; hence investment will go up. This last fact allows us to address the crowding-in effect of private investment by the public one, supporting regional policies based on public capital provision.

[1] For general surveys of these contributions, see Gramlich (1994) and Sturm (1998).

The empirical evidence is not unambiguous about the crowding-out hypothesis. Aschauer (1989), Erenburg (1993), Easterly and Rebelo (1993), Erenburg and Wohard (1995) and Argimon *et al*. (1997) detect, under different econometric specifications and samples, that public and private investment are positively related. For Spanish case, Flores de Frutos *et al*. (1998) obtain similar conclusions. However, we can find studies in which the opposite results are achieved. Pradhan *et al*. (1990), Monadjemi (1996), Nazmi and Ramírez (1997), Ghali (1998), and recently Voss (2002) show the existence of a crowding-out effect.

This paper seeks to add empirical evidence on the effects that public investment has on private capital accumulation in Spanish regions. On the basis of a simple overlapping generations model, public investment is studied through a variety of concepts that enlarge the interpretation of the results: productive public investment, in education and in health, and in bordering regions. A panel data approach has been used and we have dealt with specification problems. Our estimates find a positive effect of productive and social public investment (especially in education) on private investment, while public consumption and interest rate exert a negative influence on private capital accumulation. On the other hand, public investment located in bordering regions does not seem to encourage private investment in neighbouring regions.

The paper is organized as follows. Next section presents the theoretical framework and the model specification. Third section describes the data set we have used. Section IV shows the results obtained under different econometric specifications. Finally, section V supplies some concluding remarks.

## II. Theoretical framework and model specification

This section uses a very simple model for explaining causal links between public and private investment. Barro (1989), Aschauer (1988) or Aschauer and Greenwood (1985)

study how public spending affects private investment in infinitely lived agents models. However, we will adopt the approach followed by Argimón *et al*. (1997) that simplifies the way of reaching equilibrium relations. Our theoretical framework has been slightly modified in order to consider regional features.

We suppose an economy populated by overlapping generations of equal size. Each representative household lives two periods. In her first period, she offers a fixed amount of labour, pays taxes and saves. For her second period, she consumes what she has saved, taking the interest rate into account. Formally,

$$c_t = \omega_t - \tau_t - s_t, \qquad [1]$$

where $c_t$ is consumption of the household when young at *t*, $\omega_t$ is the wage rate, $\tau_t$ is a tax levied by government on young people, and $s_t$ is savings. Tax revenues are used to finance public spending, consisting of public consumption and public investment. For consumption at the second period, we have

$$c_{t+1} = (1 + r_{t+1}) s_t, \qquad [2]$$

where $r_{t+1}$ symbolizes the interest rate when the household is old. Utility function of a representative agent is given by

$$U = a\left(c_{gt}\right)\delta \ln c_t + (1-\delta)\ln c_{gt} + \frac{1}{1+\rho}\left[\delta \ln c_{t+1} + (1-\delta)\ln c_{gt+1}\right], \qquad [3]$$

where $c_g$ is public consumption, $\delta$ represents relative preference for private consumption, $\rho$ is the discount rate, and $a(.)$ is a function which captures substitutability or complementarity between $c$ and $c_g$ (when $a' < 0$, both types of consumption are substitutes and so on)[2].

[2] $a\left(c_{gt}\right): R^+ \to R^+$, *with* $a(0) = 1$. Although $a(c_{gt})$ only appears in the first period, an alternative specification with $a(c_{gt})$ also affecting in the second period would become rather cumbersome the resolution of the model, and nothing new would be added (assuming time-consistent preferences).

Our representative household maximizes the utility function [3] subject to [1] and [2]. This enables us to obtain the savings function:

$$s_t = (\omega_t - \tau_t)\sigma\,, \qquad [4]$$

where $\sigma = \frac{1}{1+(1+\rho)a} > 0$. For the firms we define the following production function per worker:

$$y_t = A k_t^{\alpha} k_{gt}^{\beta} k_{gst}^{\gamma}, \quad \alpha,\beta,\gamma > 0, \quad \alpha+\beta+\gamma < 1, \qquad [5]$$

where constant returns to scale in the three inputs are stated. *A* is a technological parameter, *k* the private capital stock, $k_{gt}$ the public capital stock, and $k_{gst}$ the public capital stock installed in other economies at period *t*. For the sake of simplicity, we assume that both private and public investment are fully depreciated in every period, such that for each type of capital stock the following movement equation is fulfilled: $k_t = i_t + (1-\phi)k_{t-1}$, where $i_t$ is the gross investment in *t*, and $\phi$ is the depreciation rate; as we set $\phi$=1, all the stock variables are replaced by investment hereafter. Final output per capita can be used as private or public consumption, or as private or public investment on a 1:1 basis. If factor markets are competitive, profit maximizing conditions are as follows:

$$1 + r_t = \alpha \mathrm{A} i_t^{\alpha-1} i_{gt}^{\beta} s_{gt}^{\gamma} = \alpha \frac{y_t}{i_t} \qquad [6]$$

$$\omega_t = (1-\alpha-\beta-\gamma)\mathrm{A} i_t^{\alpha} i_{gt}^{\beta} s_{gt}^{\gamma} = (1-\alpha-\beta-\gamma) y_t, \qquad [7]$$

where variables *i*, $i_g$ and $s_g$ refer to private investment, public investment and public investment located in other regions (spillover effects), respectively.

According to Walras' law, the next equilibrium conditions define the whole equilibrium of the economy:

$$i_t = \sigma(1-\alpha-\beta-\gamma)\mathrm{A} i_t^{\alpha} i_{gt}^{\beta} s_{gt}^{\gamma} - \sigma\,\tau_t \qquad [8]$$

$$\tau_t - \eta_t = \bar{c}_{gt} + \bar{i}_{gt} \qquad [9]$$

Expression [8] refers to equilibrium in capital market. Expression [9] is government budget constraint, where public spending variables with bar are the public consumption and investment that would be financed by taxes exclusively collected in the region, and $\eta_t$ is the (positive or negative) transfer that the regional economy receives/gives from/to central government[3]. This grant allows us to relate public spending variables with bar to actual values of these variables in the following way: $c_{gt} = \bar{c}_{gt} + \gamma \eta_t$ and $i_{gt} = \bar{i}_{gt} + (1-\gamma)\eta_t$, being $\gamma$ the share of the grant $\eta_t$ devoted to public consumption. Also it should be noted that public investment is bought by government at a price equal to one of the public consumption.

From [9] a value for $\tau_t$ can be obtained and used in equation [8] to yield $i_t\left(1-\sigma(1-\alpha-\beta-\gamma)Ai_t^{\alpha-1}i_{gt}^{\beta}s_{gt}^{\gamma}\right) = -\sigma\left(c_{gt}+i_{gt}\right)$, where actual values for public investment and consumption are considered hereafter. As profit maximizing condition [6] is taken into account, solving for $i_t$ yields the next expression for private investment (we drop time subscripts):

$$i = \frac{\sigma\left(c_g + i_g\right)}{\sigma\left[\frac{(1-\beta-\gamma)(1+r)}{\alpha} - f_i\left(i, i_g, s_g\right)\right] - 1}, \qquad [10]$$

where $f_i\left(i, i_g, s_g\right)$ is the productivity of private investment, which depends on the levels of private and public investment. Note that $f_i$ comes from the partial derivative of the production function with respect to $i$, which appears in [6].

[3] It is assumed that $\sum_j \eta_{jt} = 0$, where $j$ is the number of regions existing in the country.

On the basis of expression [10] and taken into account the above assumptions and features of the model, we obtain the following results to be checked: 1) Private investment has a positive relation with the productivity of private capital, as profit maximizing condition [6] states; 2) Impact of public consumption is ambiguous: an increase in non-productive public spending leads to bigger taxes that reduce savings (equation [4]), and thus investment (equation [8]); something similar would happen if public consumption is complementary to private consumption ($\sigma' < 0$). However, if public spending in consumption is substitute to private consumption ($\sigma' > 0$), the effect of government purchases would lead to a bigger private investment; 3) The effect of interest rate on private investment is unambiguously negative because a rise in *r* requires a bigger marginal productivity of private investment, that is, a smaller private investment as expression [6] states, ceteris paribus; 4) Public capital accumulation may affect private investment negatively or positively; on the one hand, a rise in government investment requires bigger tax revenues (equation [9]), which implies a negative effect on private savings (equation [4]), and hence on private investment; on the other hand, public investment is also complementary to the private one (given the production function [5]); in this case, infrastructure investment will affect positively the return of private investment; and 5) Public investment devoted to other regions should also have a positive impact on private investment, according to the production function (5); indeed, spillover effects may involve more resources for production without bearing the cost of more taxes to finance them.

In order to test these relationships between private investment and public investment (and other factors) for Spanish regions, we will estimate the following expression by means of panel data methodology:

$$i = i\left(f_i, c_g, r, i_g, s_g\right) \qquad [11]$$

Our empirical model is based on a linear representation of [10]. At this point, we must say that we are not interested in estimating exactly equation [10], but an ad hoc expression derived from the relationship between both sides of [10][4]. In such a way, theoretical model used in this paper only aims to be a simple but theoretically consistent motivation of the relationships to be involved between private investment and other variables, in line with the above comparative statics.

**III Data**

Our sample consists of biannual observations for Spanish regions over period 1965-1997. Dependent variable is the private investment rate, defined as the ratio between total regional private investment and private capital stock. Marginal productivity of private capital $f_i$ has been proxied by the average productivity, where the output is the regional GDP[5]. For public consumption $c_g$ there are no data over period 1965-1997. Then we have had to employ two proxy variables. The first one is the share of production of public services in a region over the value of total production, and the second one is the regional labour cost in public sector over regional GDP. Estimates are robust to the choice between both variables, and the former has been selected to be used.

The interest rate *r* is a national-level variable since capital market is common for overall Spanish regions. Due to the lack of data, this series has been constructed using three indexes according to the period (Molinas et al, (1991), and Bajo-Rubio et al, (2004), follow a similar strategy): before 1979, private bonds of public utilities; from 1979 to 1992, central government bonds at more than two years; and from 1993 to 1997, central government benchmark bond of ten years[6]. This variable has entered the regressions with

[4] Papers similar to this one usually estimate linear empirical models, although nonlinear relations among variables can be found in the underlying theoretical model (Tanzi and Zee, 1998).
[5] This is correct if we suppose that technology follows a Cobb-Douglas production function.

[6] Others papers concerned with the effects of government performance on private sector (see, for example, Ni, 1995), or with the relationships between public and private investment (see, for instance, Voss, 2002), also employ the return of the Treasury bonds to proxy the private borrowing cost.

one lag in order to avoid misspecification as a result of the likely endogeneity of the interest rate.

Different concepts for public investment have been used. Firstly, we have considered productive public investment (roads, hydraulic infrastructures, urban structures, ports, airports, railways) and social public investment ($i_{gs}$) as well, that is, in education and in health. Secondly, productive public investment has been split into capital accumulation by the general government *strictu sensu* ($i_g$) and a broad concept of productive public investment: by the general government and by the dependent agencies and corporations not classified as general government ($i_{gp}$). For government and social investment we consider public capital spending by central, regional and local governments. Thirdly, social public investment has been divided into investment in education ($i_{ge}$) and in health ($i_{gh}$). All these variables have been built as a ratio over the corresponding public capital stock.

Using only public *capital* spending has a clear problem: we ignore the effects of *current* public expenditures in education and in health on productivity, and therefore on private investment. This is a common drawback in the main branch of this type of literature caused by the lack of adequate data. Unfortunately, no regional data on these concepts are available over period 1965-1997, and it forces us to use only capital expenditure. Anyway, as a result of the relatively low capital/labor ratio existing in sectors such as education and health, one of the principal sources for increasing their productivity is investment in capital. This fact underlines the role of public investment over others forms of expenditure.

We also study the spillover effects that public investment located in other territories could have on regional private investment. With this aim we have distinguished between spillover effects generated by public investment in bordering regions, and those caused by public investment in overall nation (except, obviously, the region we consider). Both measures of the spillover effects take into consideration the network character of public infrastructures. We have used the former concept (bordering regions) because the latter variable caused multicollinearity problems in our estimates (although equal signs in the coefficients estimated were obtained). The variables referring spillovers are denoted by $s_{gp}$, $s_{ge}$, $s_{gh}$, $s_{gs}$, and mean public investment in productive capital, in education, in health and in social (education plus health) public capital in neighbouring regions, respectively.

All previous variables are measured at 1986 prices. These data can be found in Fundacion BBVA (1999, 2000); many of them are available in http://w3.grupobbva.com/TLFB/TLFBindex.htm), except interest rate, taken from Bank of Spain (2003).

We are aware that key assumptions of the theoretical model such as market-clearing conditions are not fulfilled by the data set used. As a result of this, our estimates may suffer from measurement errors. However, this fact is tackled in the paper by using several proxy variables and different instrumental variables estimators.

**IV Econometric estimation and results**

Estimation of expression [11] has been obtained using panel data techniques. Previously, we need to check some issues concerning econometric specification. First, initial estimates of the panel presented indications of first order serial correlations in the residuals, so that a formal test for serial correlation has been implemented. Table 1 reports the values obtained for the modified panel version of the Durbin-Watson statistic by Bhargava et al. (1982) in each one of the subsequent regressions listed in Tables 2 and

3. This statistic follows a similar but not identical distribution than DW under the null hypothesis of no serial correlation; lower and upper bounds on the critical values can be found in Bhargava et al. (1982). Also estimates for the AR(1) coefficient of the disturbances are given. Clearly, both results from the test and the magnitude of the autoregressive parameters show the need of controlling for serial correlation, what we have done.

INSERT TABLE 1 HERE

A second point to be considered refers to the likely correlation between unobservable individual effects and the remaining regressors. As data cover the total population of Spanish regions (i. e., the sample is determinist), fixed effects approach seems to be the most appropriate model. In any case, we have run a Hausman test for each specification and the results confirm evidence in favour of the fixed effects model, as can be seen in Table 1[7].

Thirdly, different sizes in the seventeen regions may result in groupwise heteroskedasticity. A likelihood-based test has been used in order to know whether this problem must be addressed. In particular, the null hypothesis of constant variance across units has been checked; the results are also reported in Table 1, showing a strong rejection of such a null hypothesis[8]. As a result of this, estimates reported later have been obtained weighting cross-section through a feasible GLS estimation, that is, carrying out a first-stage regression in order to have a consistent estimation of the covariance matrix, and then using it to weight more the observations with smaller variances in a second-

[7] As the Hausman test is sensitive to the presence of autocorrelation (Arellano, 1993), estimates of both fixed and random effects models for implementing the test have taken this issue into consideration.
[8] Greene (2000) gives more details on this test.

stage estimation[9]. Also a White covariance matrix has been employed so as to avoid heteroskedasticity in the individual series.

INSERT TABLE 2 HERE

Table 2 reports the coefficients for the expression [11] as several definitions of public investment are considered. Coefficients of the marginal productivity of private capital and interest rate appear with a highly significant value in all estimates, positive for the former and negative for the latter. These results are consistent with the theoretical model presented in section II. On the other hand, public consumption whose effect on the private investment was uncertain in the theoretical framework, presents an unambiguous negative value in our all estimates. It means that this kind of public spending does not encourage private investment, and this fact may be caused by the taxes needed to finance public consumption, and also because private and public consumption are complementary.

Productive public investment exerts a positive effect on private capital accumulation, bigger when a broad concept of infrastructure ($i_{gp}$) is taken into account rather than government investment solely ($i_g$). Conversely, in the case of social public investment, the results are not so unanimous; negative and significant coefficients are obtained for social and public investment in education, while investment in health appears as non significant. Anyway, these results must be interpreted with caution as long as an endogeneity problem can be involved in the estimates.

Table 3 shows estimates for the expression [11] when spillover effects are considered. Values and statistical significance for the coefficients of the productivity of private investment, public consumption and interest rate are very close to those obtained

[9] Although it is not reported here (but available upon request), when a modified Wald test is run to check whether the alternative, corrected specification through cross-section weighting is groupwise

previously. Magnitude of the effect of productive public investment on private capital accumulation increases in this new specification, just when a negative influence of public investment located in bordering regions is found. In fact, these two results can be interrelated. When a region has an adequate infrastructure endowment, it means that can attract resources for investment from other regions where public capital stock is lower or worse. At this point, our results move away from the theoretical predictions outlined above, because a positive impact coming from spillover effects was to be expected; it may be caused by a shortcoming of the theoretical model: it does not take into account private capital mobility across regions, which could be one of the main underlying explanations behind a negative influence of spillover effects.

In that case, public investment becomes a powerful instrument to modify the private investment allocation among territories: in a positive sense if it is placed inside the region, or in a negative way if productive public spending is invested in neighbouring regions. In such a way, fiscal competition processes can be developed among state governments by using public investment.

INSERT TABLE 3 HERE

However, the previous estimates may suffer from an endogeneity problem caused by both fiscal variables and productivity of private investment. In the case of public investment and consumption a reverse causality with private investment can be easily found in papers such as Sturm (1998) and Flores de Frutos at al (1998). In the case of productivity of private investment, equation [10] indicates that the return of private capital also depends on the level of private investment. Moreover, given the production function we have defined, a decreasing influence of the private investment on its marginal productivity is to

homoskedasticity, the statistics continue indicating that variations in the scales of variables affect estimates but in a smaller magnitude (see Greene (2000) again for further details).

be expected. Thus it seems to be justified using instrumental variables (IV) methods to estimate expression [11].

We have used a two-stage least squares (2SLS) estimator where variables have been transformed in orthogonal deviations. Previously, we employed others two alternative IV specifications: Generalised Method of Moments and 2SLS estimation with variables in first differences; several instruments sets were considered in both cases but the results suffered from problems of misspecification and serial correlation in the residuals as well as a non reasonable economic interpretation of the coefficients sometimes[10]. By contrast, our choice of a model in orthogonal deviations gives acceptable results and allows us to use lagged regressors as possible instruments[11]. Standard errors continue being robust to heteroskedasticity.

Table 4 reports estimates when this methodology is used. Columns [1] and [2] show the coefficients as total social public investment is included as regressor, while columns [3] and [4] present this variable split in education and health. Statistics m1 and m2 shows no evidence of serially correlated errors[12].

[10] These estimates are available upon request.

[11] Orthogonal deviations express each observation as the deviation from the average of future observations for the same individual, and weight each deviation to standardize the variance. Formally, each observation transformed is computed as: $x_{it}^{*}=\left(x_{it}-\frac{x_{i(t+1)}+\ldots+x_{iT}}{\mathrm{T}-t}\right)\left(\frac{\mathrm{T}-t}{\mathrm{T}-t+1}\right)^{1/2}$, for $t$ = 1,2, …, $T$-1. This strategy is based on the assumption that the regressors are independent of future errors; the appendix shows that this is true for our case. See Arellano (1988) and Arellano and Bover (1995) for further discussions.

[12] The *m* statistics report for the absence of first-order and second-order serial correlation in the first differenced residuals. If the disturbances in levels of the model are not serially correlated, there should be evidence of significant first-order serial correlation in the differenced residuals (we would expect m1 to be significant), and no evidence of second-order serial correlation in the differenced residuals (m2 to be insignificant). These tests are based on the standardized average residual autocovariances which are

INSERT TABLE 4 HERE

Under the new specification, the productivity of private investment and the interest rate lose statistical significance though their signs remain identical to the previous ones and consistent with the theoretical model. The coefficient of $f_i$ is smaller with IV estimators than before. On the other hand, the likely endogeneity of the interest rate was already taken into account, so this approach is redundant in this case. Public consumption holds a negative and significant coefficient under all specifications, although its magnitude is slightly smaller too.

The coefficients of productive and social public investment are positive and highly significant. Relevance of these two variables is now bigger, what means that endogeneity seems to be a relevant issue in the measurement of the effects of infrastructures on private capital accumulation. When public investment in education and in health are treated separately, we detect that public spending in health capital continues to be insignificant; otherwise, government investment in education changes its coefficient from an unrealistic negative sign to a significant positive value.

Finally, it is worthwhile to consider what happens as spillover effects are considered in this IV approach. Table 5 shows estimates of expression [11] with spillovers using 2SLS estimator. A first look on table 5 informs us that the coefficients of productivity of private investment, public consumption and interest rate keep their values and statistical significance when they are compared to those attained with IV and no spillovers (table 4). Again, the coefficients of productive public investment in a model with spillovers are

asymptotically *N(0, 1)* variables under the null of no autocorrelation. See Arellano and Bond (1991) for a further discussion.

more than two times those obtained without considering public investment in bordering regions. Also the magnitude of these negative spillover effects offset the positive influence of productive public spending invested inside the region. This circumstance may be related to the relevance of the free mobility of private capital, whose decisions about regional location may be very sensitive to infrastructure endowment. The estimated coefficient of social public investment is positive and significant at 10%, mainly due to the effect of public investment in education; conversely, public expenditure in health infrastructure continues being positive but non significant.

INSERT TABLE 5 HERE

**V. Conclusions**

Public investment is one of the main instruments for the design of regional policy. As is well-known, regional policy pursues income redistribution, favouring regional convergence processes among economies. The use of public investment for this aim is based on two reasons, namely: the existence of a direct relation between public spending in infrastructures and growth of income per capita, and the crowding-in effects of private investment by public capital accumulation. This last issue constitutes the object of study in this paper. In short, we have checked whether public sector investment has favoured private investment in Spanish regions over period 1965-1997.

We have used a crowding-out theoretical framework that has been estimated through panel data techniques. In addition, we have taken into account issues concerning with endogeneity of some regressors and specification problems. Most results are compatible with the underlying theoretical framework. The coefficients estimated show that there exists a positive influence of the productivity of private capital on private investment, while a negative effect is detected from public consumption and interest rate. Also we have found a positive effect of productive public investment on regional private

investment rate, showing that the crowding-in effect has prevailed versus the crowding-out. A similar conclusion is achieved when social public investment is considered, especially in education. Regarding the consequences of the spillover effects generated by infrastructures located in other regions, the results suggest the existence of a crowding-out effect of private investment by public investment in bordering regions; simultaneously, productive public spending inside a region presents a bigger influence on private capital accumulation when spillovers are considered.

Some policy implications can be guessed from this paper. One of them refers to the relevance that different types of public spending have on economic performance. Since public investment exerts a positive influence on private investment, government spending cuts should consider that if they are worried for a long-run economic growth. Other recommendation is related to the importance of public investment on the regional convergence processes. Government policies aimed at removing regional disparities may attract private investment to the poorest areas through a redistributive pattern in the allocation of public investment. It would allow reducing the differences in regional income per capita even in presence of agglomeration forces that probably favour the richest regions.

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**Table 1. Specification tests for equations [1]-[4] in Table 2 and [1]-[3] in Table 3**

| | Table 2 | | | | Table 3 | | |
|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (1) | (2) | (3) |
| Bhargava et al. statistic | 0.90 | 0.91 | 1.01 | 1.01 | 0.97 | 1.09 | 1.09 |
| AR (1) coefficient | 0.55 | 0.54 | 0.56 | 0.56 | 0.52 | 0.55 | 0.55 |
| Hausman | 36.99 [4] | 22.09 [4] | 24.11 [5] | 21.04 [6] | 21.61 [5] | 24.84 [7] | 26.10 [9] |
| LR (groupwise het.) | 47.03 [16] | 46.89 [16] | 47.44 [16] | 48.02 [16] | 53.56 [16] | 53.49 [16] | 54.41 [16] |

**Note:** Degrees of freedom between brackets.

**Table 2. Crowding-out effect. Spanish regions, 1965-1997.**

**Dependent variable: Private investment rate**

| | [1] | [2] | [3] | [4] |
|---|---|---|---|---|
| $f_i$ | 0.16*** (0.02) | 0.15*** (0.03) | 0.16*** (0.03) | 0.15*** (0.03) |
| $c_g$ | -0.28*** (0.04) | -0.28*** (0.04) | -0.32*** (0.04) | -0.30*** (0.04) |
| $r$ | -0.10*** (0.02) | -0.09*** (0.02) | -0.09*** (0.02) | -0.09*** (0.02) |
| $i_g$ | 0.04** (0.02) | | | |
| $i_{gp}$ | | 0.06** (0.03) | 0.07*** (0.03) | 0.06** (0.02) |
| $i_{gs}$ | | | -0.03** (0.01) | |
| $i_{ge}$ | | | | -0.04*** (0.01) |
| $i_{gh}$ | | | | 0.01 (0.01) |
| RSS | 0.03 | 0.03 | 0.03 | 0.03 |
| Observations | 272 | 272 | 272 | 272 |

**Notes**: ***, **, * Significant at a 1%, 5%, 10% level. Standard errors between parentheses.

**Table 3. Crowding-out effect with spillovers. Spanish regions, 1965-1997**

**Dependent variable: Private investment rate**

| | [1] | [2] | [3] |
|---|---|---|---|
| $f_i$ | 0.18*** (0.03) | 0.20*** (0.03) | 0.18*** (0.03) |
| $c_g$ | -0.23*** (0.05) | -0.29*** (0.05) | -0.28*** (0.05) |
| $r$ | -0.08*** (0.02) | -0.07*** (0.02) | -0.08*** (0.02) |
| $i_{gp}$ | 0.13*** (0.03) | 0.14*** (0.03) | 0.12*** (0.03) |
| $i_{gs}$ | | -0.01 (0.01) | |
| $i_{ge}$ | | | -0.01 (0.01) |
| $i_{gh}$ | | | 0.005 (0.01) |
| $s_{gp}$ | -0.16*** (0.04) | -0.15*** (0.04) | -0.12*** (0.04) |
| $s_{gs}$ | | -0.04** (0.02) | |
| $s_{ge}$ | | | -0.06*** (0.01) |
| $s_{gh}$ | | | 0.03* (0.02) |
| RSS | 0.03 | 0.03 | 0.03 |
| Observations | 272 | 272 | 272 |

**Notes**: ***, **, * Significant at a 1%, 5%, 10% level. Standard errors between parentheses.

**Table 4. Crowding-out effect. Spanish regions, 1965-1997.**

**IV Estimates. Dependent variable: Private investment rate**

| | [1] | [2] | [3] | [4] |
|---|---|---|---|---|
| $f_i$ | 0.12 (0.09) | 0.13* (0.07) | 0.10 (0.07) | 0.14* (0.08) |
| $c_g$ | -0.15** (0.06) | -0.14** (0.06) | -0.18*** (0.04) | -0.15*** (0.05) |
| $r$ | -0.07 (0.05) | -0.07 (0.05) | -0.05 (0.05) | -0.07 (0.05) |
| $i_{gp}$ | 0.11*** (0.04) | 0.11*** (0.04) | 0.11*** (0.04) | 0.12*** (0.04) |
| $i_{gs}$ | 0.05*** (0.02) | 0.05** (0.02) | | |
| $i_{ge}$ | | | 0.04** (0.02) | 0.04** (0.02) |
| $i_{gh}$ | | | 0.008 (0.01) | 0.008 (0.02) |
| RSS | 0.04 | 0.04 | 0.04 | 0.04 |
| m1 | 2.078 | 2.189 | 2.241 | 2.132 |
| m2 | 1.576 | 1.755 | 1.878 | 1.784 |
| Observations | 255 | 255 | 255 | 255 |

**Notes:** ***, **, * Significant at a 1%, 5%, 10% level. Standard errors between parentheses.
Instruments used: [1]: lagged levels of productivity of private investment, productive and social public investment; public consumption and interest rate expressed in orthogonal deviations. [2]: lagged levels of productivity of private investment, public consumption and productive and social public investment; interest rate expressed in orthogonal deviations. [3]: lagged levels of productivity of private investment, productive and education and health public investment, and interest rate; lagged orthogonal deviations of public consumption. [4]: lagged levels of productivity of private investment, productive and education public investment; lagged orthogonal deviations of public consumption; interest rate and public investment in health expressed in orthogonal deviations.

**Table 5. Crowding-out effect with spillovers. Spanish regions, 1965-1997.**
**IV Estimates. Dependent variable: Private investment rate**

| | [1] | [2] | [3] |
|---|---|---|---|
| $f_i$ | 0.15* (0.08) | 0.16* (0.09) | 0.15* (0.09) |
| $c_g$ | -0.15*** (0.06) | -0.13** (0.06) | -0.14** (0.06) |
| $r$ | -0.08* (0.05) | -0.07 (0.05) | -0.07 (0.05) |
| $i_{gp}$ | 0.34*** (0.12) | 0.31*** (0.10) | 0.31*** (0.10) |
| $i_{gs}$ | -0.01 (0.01) | 0.05* (0.03) | |
| $i_{ge}$ | | | 0.04** (0.02) |
| $i_{gh}$ | | | -0.01 (0.03) |
| $s_{gp}$ | -0.34** (0.15) | -0.31** (0.13) | -0.31** (0.13) |
| $s_{gs}$ | 0.03 (0.03) | -0.02 (0.04) | |
| $s_{ge}$ | | | -0.04 (0.03) |
| $s_{gh}$ | | | 0.03 (0.04) |
| RSS | 0.04 | 0.04 | 0.03 |
| m1 | 2.232 | 2.208 | 2.110 |
| m2 | 1.519 | 1.416 | 1.517 |
| Observations | 255 | 255 | 255 |

**Notes**: ***, **, * Significant at a 1%, 5%, 10% level. Standard errors between parentheses.

Instruments used: [1]: lagged levels of productivity of private investment and productive public investment; lagged orthogonal deviations of public consumption; interest rate, social public investment and spillovers from social and productive public investment expressed in orthogonal deviations. [2]: lagged levels of productivity of private investment and productive and social public investment; lagged orthogonal deviations of public consumption; interest rate and spillovers from social and productive public investment expressed in orthogonal deviations. [3]: lagged levels of productivity of private investment and productive, education and health public investment; lagged orthogonal deviations of public consumption; interest rate, and spillovers from productive, education and health public investment expressed in orthogonal deviations.

## Appendix

**Table A1. Correlations between future errors and regressors for specifications of Tables 4 and 5.**

| | [1]-[2] Table 4 | [3]-[4] Table 4 | [1]-[2] Table 5 | [3] Table 5 |
|---|---|---|---|---|
| | *Errors* $_{t+1}$ | *Errors* $_{t+1}$ | *Errors* $_{t+1}$ | *Errors* $_{t+1}$ |
| *Errors* $_{t+1}$ | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| $f_i$ | 0.0052 | 0.0050 | 0.0057 | 0.0034 |
| $c_g$ | 0.0950 | 0.0942 | 0.0796 | 0.0820 |
| $r$ | 0.0925 | 0.0908 | 0.0546 | 0.0621 |
| $i_{gp}$ | -0.0001 | 0.0020 | 0.0203 | 0.0099 |
| $i_{gs}$ | 0.0174 | | 0.0298 | |
| $i_{ge}$ | | 0.0943 | | 0.0974 |
| $i_{gh}$ | | -0.1466 | | -0.1200 |
| $s_{gp}$ | | | -0.0514 | -0.0641 |
| $s_{gs}$ | | | -0.0200 | |
| $s_{ge}$ | | | | -0.0356 |
| $s_{gh}$ | | | | -0.1101 |