ON THE REGIONAL IMPACT OF PUBLIC CAPITAL FORMATION IN SPAIN

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Abstract

The objective of this paper is to investigate, in a methodologically consistent manner, the regional effects of public capital formation and the possible existence of regional spillover effects in Spain. The empirical results are based on VAR estimates at both the aggregate and regional levels using output, employment, and private capital, as well as different measures of public capital. Empirical results suggest that public capital affects output positively at the aggregate level as well as in all but one region. For most regions, the effects of public capital installed in the region itself are important but the spillover effects induced from public capital installed elsewhere are also very important. In fact, the spillover effects account for over half of the total effects of public capital formation in Spain. Furthermore, these spillover effects have a clear geographical pattern in that they tend to be more important in the peripheral regions of the country. We also find that relative to their share of the Spanish output, the biggest beneficiaries of public capital formation are the largest regions in the country. This suggests that public capital formation has contributed to concentration of output in these regions. Finally, in terms of the effects of public capital formation on the private inputs we find that both private capital and employment are affected positively at the aggregate level as well as for most of the regions. Nevertheless, the effects on private capital seem to be larger. Also, the spillover effects are very important for private capital but not for employment. This reflects a great degree of dynamism and mobility in the capital markets as opposed to the labor markets.

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1. Introduction

The objective of this paper is to investigate the regional effects of public capital formation and the possible existence of regional spillover effects in Spain. The empirical results are based on VAR estimates at both the aggregate and regional levels using output, employment, and private capital, as well as different measures of public capital. Our analysis allows us to identify the regional distribution of the effects of public capital formation in a framework that is consistent with the evaluation of these effects at the aggregate level. Furthermore, not only it makes it possible to determine the existence of spillover effects, but also allows for their quantification and for the identification of their location. This means that we are able to identify which regions seem to benefit the most from not only public capital installed in their jurisdiction but also from public capital installed elsewhere.

The evaluation of the impact of public capital formation on private output was brought to the limelight by the work of Aschauer (1989a, 1989b) on the US. Aschauer's work inspired a large body of research, in particular, research with a regional focus. Earlier contributions used panel data at the state level to estimate nation-wide production functions for the US. They tend to provide evidence that points to the presence of important effects of public capital formation on private output [see, for example, Duffy-Deno and Eberts (1991), Munnell with Cook (1990), Eisner (1991), McGuire (1992) and Garcia-Mila and McGuire (1992)]. More recent studies, however, find little supporting evidence. Indeed, they suggest that after controlling for the state specific and unobserved characteristics, public capital variables are not significant within the aggregate production function framework [see, for example, Holtz-Eakin (1994), Evans and Karras (1994) and Garcia-Milà et al. (1996)].

One possible conjecture is that the inconclusive nature of the research with a regional focus is due to the fact that it ignores network effects [see, for example, Boarnet (1998) and Mikelbank and Jackson (2000)]. Indeed, it could be argued that network effects should be an integral part of the analysis of the regional impact of public capital formation. The positive effects of public capital formation in a region can be induced by public infrastructures installed in the region itself. However, the better accessibility of a region can be generated by a greater public capital formation installed in other regions. This leads us to the concept of spillover effects of public capital formation.

Paradoxically, maybe because of the inconclusive nature of the results on the impact of public capital on output at the regional level, the issue of the possible existence of the regional spillovers from public capital formation has received little attention. Munnell (1992) deals marginally with this issue. It addresses the fact that the elasticities of output with respect to public capital formation obtained with state-level data tend to be lower compared to those obtained with aggregate data. It conjectures that this fact is due to the existence of leakages, i.e., part of the

benefits generated from public capital formation are not captured with just state-level data. This issue is addressed directly by Holtz-Eakin (1994). The main finding is that regional level estimates are essentially identical to those from state data, suggesting no quantitatively important spillover effects across states. In turn, Holtz-Eakin and Schwartz (1995), focus on the case of state highway investment. Again, no evidence of quantitatively important regional spillovers is found. Clearly, the empirical relevance of spillovers of public capital formation across regions is largely an unresolved issue in the case of the US. Furthermore, little evidence is available for other countries. This is mostly due to the very basic reason that public capital data, in particular at the regional level, is either not available for other countries.

This paper is in the confluence of the empirical literature on the regional effects of public capital formation and the empirical literature on the relevance of regional spillovers. We focus on the case of the Spanish economy. The Spanish case is very interesting. First, the Spanish territory is organised in autonomous communities. These are not merely statistical regions but rather regions with substantial political power (although less than say the states in the US). Second, public capital formation data at the regional level for the last thirty years was just recently made available updating old data sets which ended in the late 1980s [see FBBVA (2001)]. This makes Spain the only country with such a rich and up-to-date regional public capital data set. Even for the US, state public capital data is currently available only until 1988 and it has not been updated [see, for example, Holtz-Eakin (1993) and Munnell (1990)].

Because of its regional make up and the existence of reliable regional data, the Spanish case is also interesting in that it is alone in having generated a literature investigating the effects of public capital which in many respects mirrors the literature for the US. Using Aschauer's production function approach at the aggregate level, Argimón et al. (1994), Bajo and Sosvilla (1993), Mas et al. (1993) and González-Páramo (1995) estimate positive output elasticities with respect to public capital [see De la Fuente (1996) for a review of this literature]. In terms of the research with a regional focus, using Munnell's panel data approach, Argimón and González-Páramo (1997), Garcia-Fontes and Serra (1994), and Mas et al. (1996), found substantially lower effects, often not statistically significant [see, Carames and Lago (1999) for a review of this literature]. Finally, also using panel data techniques, Mas et al. (1996), Moreno et al. (1997) and Rapun et al. (1999) find possible indirect evidence of regional spillovers along the lines suggested in Munnell (1992).

Although this paper focuses on the Spanish case its interest is not merely parochial. Indeed, the issue of the effects of public capital formation has been at the center of the policy debate in many countries, in many regions of the world. In particular, in the European Union, the development strategy of the less development countries, like Greece, Ireland, and Portugal, has been based largely on public investment projects. For these countries, public investment on infrastructures, through EU structural programs, has been the instrument of choice to induce real

convergence of the domestic economy to the EU standards of living. Furthermore, in the near future, the eastward expansion of the EU will bring into the fold countries with similar problems. For these Eastern European countries, economy recovery seems to depend, in large scale, on the reconstruction of obsolete infrastructures. For these countries joining the EU and, thereby, embarking in large public infrastructure projects seems to be the expected vehicle for vanquishing their relative backwardness.

Methodologically speaking, this paper departs in a substantial manner from the production function approach prevalent in the literature with a regional focus. Indeed, we follow the lead in Garcia-Mila et al. (1996), who suggest that the stage has been set in the regional literature for trying alternative methodological approaches. In this paper, we follow Pereira (2000) and adopt a multivariate time series framework, relating private output, private inputs (employment and capital), and public capital. In this context we develop separate vector auto regressive (VAR) models for the Spanish economy and for each one of the 17 autonomous communities. This approach allows us to identify the effects of public investment on each individual region as well as the regional distribution of the effects of public capital formation in a framework that is methodologically consistent with the evaluation of the effects of public capital formation at the aggregate level.

This multivariate time series approach brings a more precise conceptual focus to the debate about whether or not public capital is productive. In fact, the static single-equation framework so often used in the literature excludes the presence of feedbacks, in particular dynamic feedbacks, among the relevant variables. These, however, are essential to understand the impact of public capital on economic performance. Indeed, public capital formation affects output directly as an additional input in the production function. Public capital also affects aggregate production indirectly via its effects on the use of private inputs. It is conceivable that a greater availability of public capital could reduce the demand for private inputs. Higher availability of public capital, however, lowers the marginal costs of production, thereby potentially increasing the level of aggregate production and the demand for private inputs.

In turn, the evolution of private-sector variables can conceivably affect the evolution of public capital. Indeed, increasing output provides the government with a growing tax base and the potential for greater public capital. Furthermore, declining employment has often led to short-term policy packages that involve increased public investment. There is, therefore, a real possibility that reverse causality exists over time. By this we mean that it is possible that the evolution of private sector variables may be leading the evolution of public capital. In such a case the evolution of public capital follows a policy rule that relates the evolution of public to the evolution of the private sector variables.

Although our approach is exclusively empirical in nature it is not a-theoretical. Indeed, we have in the background of our analysis a dynamic model of the economy. In this model the

economy uses a production technology based on the use of private inputs, capital and labor, as well as public capital, to generate private output. For each region output is affected by public capital located in the region itself as well as public capital located elsewhere in the country. Given the market conditions and the availability of public capital, the private sector decides on the appropriate level of input demands. In turn, the public sector decides on the evolution of the public capital formation using a policy rule that relates public capital to the evolution of the private sector variables. The estimated VAR models can be thought of as a reduced form for the production function, input demands, and policy function.

This paper is organized as follows. In Section 2, we present the data set used in our analysis and the preliminary empirical results including univariate analysis and the specification of the vector auto-regressive models. In Section 3, we introduce and discuss some methodological issues in the identification and measurement of the effects of innovations in public capital. In Section 4, we analyze the effects on regional output of public capital, both installed in the region itself and located outside the region through the use of orthogonalized impulse response functions. In Section 5, we investigate the regional effects of public capital formation on private capital and employment as well as the evolution of labor productivity. Finally, in Section 6, we provide a summary and some concluding remarks.

2. Data and preliminary statistical analysis

2.1 Data: sources and description

We consider annual data on output, employment, and private capital, as well as public capital both at the aggregate and the disaggregated regional levels. In the regional disaggregation we consider the seventeen autonomous regions that make up Spain: Andalucia, Aragon, Asturias, Baleares, Canarias, Cantabria, Castilla-Leon, Castilla-Mancha, Cataluña, Extremadura, Galicia, Madrid, Murcia, Navarra, Rioja, Valencia, and Pais Vasco. Of these regions, fifteen are located in continental Spain in the Iberian Peninsula, while Baleares and Canarias are archipelagos off the coast of Spain in the Mediterranean and the Atlantic, respectively.

The data covers the sample period of 1970 to 1995. This is the longest available data set. This is primarily due to the unavailability of more recent data on the private and public capital stocks. All variables, except for employment, are in billion of constant 1986 pesetas. Employment is measured in thousands of workers. In the subsequent sections, all the variables are used in logarithmic form.

The data is obtained from several sources, although for each variable the same source is used for both aggregate and regional data. Output for the period 1980-1995 is obtained from the

regional account information, “Contabilidad Regional de España” (INE, 2000). Using this information and the regional information presented in FBBV (1999) and the national accouting information in “Contabilidad Nacional de España” (INE, 2000), we obtain the regional output for the period 1970-1979. In turn, employment is obtained from "Encuesta de Poblacion Activa" (INE, 2000). Finally, private capital and public capital are obtained from FBBVA (2001). The public capital stock is defined as infrastructures in the areas of transportation (including roads, ports, airports, and railroads) and communications. It is a comprehensive measure in that it includes infrastructures owned by the national, regional, and local administrations.

Some summary indicators for the regional data are provided in Table 1. One point that is immediately apparent is that most of these regions are very small economically. Indeed, Baleares, Cantabria, Extremadura, Murcia, Navarra, and Rioja, together account for just over 10% of the Spanish output, employment, and private and public capital. In turn, the regions of Andalucia, Castilla-Leon, Cataluña, Madrid, Valencia, and Pais Vasco, are the six largest in terms of the variables under consideration. These regions concentrate 70.4% of the Spanish output, 69.4% of the private capital stock, 66.3% of employment and 64.8% of the public capital stock.

It is also apparent that there are wide disparities among the regions in terms of their economic achievements. In fact, in 1996 Spain as a whole was at 78.7% of the EU average in GDP per capita in purchasing power standards. Nevertheless it is possible to place the Spanish regions in three different groups. Among the regions, Aragon, Baleares, Cataluña, Madrid, Navarra, Rioja, and Pais Vasco, are substantially above the Spanish average GDP per capita, between 89% and 100% of the EU average. In turn, Asturias, Castilla-Leon, Canarias, Cantabria, and Valencia, are close to the Spanish average. Finally, Andalucia, Castilla-La Mancha, Extremadura, Galicia, and Murcia, are substantially below the Spanish average with GDP per capita between 56 and 67% of the EU average. Therefore, of the largest regions in the country economically speaking, one is poor (Andalucia), two are moderate (Castilla-Leon and Valencia), and three are rich (Cataluña, Madrid and Pais Vasco).

Finally, it is also interesting to note that there seems to be clear regional differences in terms of the relative concentration of infrastructures. Indeed, for the sample period, regions like Aragon, Asturias, Castilla-Leon, Castilla-La Mancha, Navarra and Rioja have a disproportionately high concentration of infrastructures compared to their regional output. In turn, regions like Baleares, Madrid and Murcia have a disproportionately low concentration of infrastructures compared to their regional output.

2.2. Univariate analysis

In order to determine the order of integration of the different variables, we test the null hypothesis of a unit root on regional and aggregate output, employment, private capital, as well as

public capital in their logarithmic form. The results are based on the Augmented Dickey-Fuller (ADF) t-test. The optimal lag structure was chosen using the Box Information Criterion (BIC). A deterministic component was considered if statistically significant.

The analysis of the different series, which for the sake of brevity is not presented here, clearly suggests that output and employment in log-levels are I(1) variables at both the aggregate and disaggregated regional levels. In turn, the evidence for the private and public capital series is mixed, with the results suggesting that some of the disaggregated series are I(1) and others I(2). To clarify the order of integration of the capital stock series, we follow the procedure adopted in Pereira and Flores (1999). We apply the unit roots tests to the logarithms of the private and public capital to output ratios at both the aggregate and the regional levels. If these ratios are I(1) and since the output series in log-levels are I(1) it follows that the different private and public capital stock series are I(1) as well. The test results suggest that the logarithms of the ratios of private capital to output are I(1) at the aggregate level and for all the regions. In turn, the logarithms of the ratios of public capital to output are I(1) at the aggregate level and for 14 of the 17 regions. Furthermore, the ADF Z-test suggest public capital to output series to be I(1) in all cases. We take these results as strong evidence that stationarity in first differences is a good approximation for all time series under consideration, both at the aggregate and at the regional levels.

2.3 VAR specification and estimates

We now estimate VAR models for Spain and each of the 17 regions relating private output, employment, and capital, and public capital. Given the evidence of stationarity in first differences of all variables, and following the standard procedure in the literature, all the VAR estimates are in first differences of log-levels, i.e., in growth rates.

In our discussion below we estimate eighteen different VAR models. The first is a VAR model with aggregate variables for the whole country. It includes aggregate public capital, in addition to the private sector variables, output, private capital, and employment and is designed to give us the overall picture on the effects of public capital in Spain. Our ultimate objective is to provide a regional decomposition of the aggregate positive effects of public capital formation identified using the aggregate model. To do so, we estimate seventeen region-specific VAR models, which include, the three private sector variables - output, employment, and private capital as well as two measures of public capital. Naturally, for each region we consider the public capital installed in the region. However, in order to take into account the possible existence of spillover effects produced by the public capital installed in other regions we consider public capital installed in the rest of the country as well. Finally, we should mention that consistently with our conceptual arguments, public capital variables are endogenous variables throughout the estimation procedure.

The specification of the VAR models for the aggregate economy and for each of the 17 regions uses different criteria. Firstly, a deterministic component was considered if statistically significant. Secondly, the optimal lag structure was chosen taking into account the number of statistically significant coefficients of second order. Third, we take into account the number of statistically significant coefficients of both first and second order in the equations were public capital is the dependent variable. This is because we want to capture all the relevant feedbacks from the evolution of private sector variables into the evolution of public capital variables.

We started by determining the specification of the VAR model for the aggregate economy. A second order specification with constant and trend is suggested by the criteria above as well as by the BIC and likelihood ratio tests on the second order parameters and deterministic components. This is consistent with the fact that five of the eleven statistically significant coefficients are second order parameters, and three of the eight deterministic component parameters are statistically different from zero. The choice of the VAR specification for the different regions is in line with the choice of VAR specification at the aggregate level. In fact, for all regional models, a VAR specification with constants and trends is chosen. Furthermore, a second order specification was selected for 10 of the 17 regions. For the remaining seven regions, Andalucia, Baleares, Castilla-Leon, Castilla-La Mancha, Cataluña, Murcia, and Valencia, a VAR specification of first order was selected.

3. Identifying and Measuring the Effects of Innovations in Public Capital

We use the impulse-response functions associated with the estimated VAR models to examine the effects of innovations on public capital on output at both the aggregate and the regional levels. In this context, our methodology allows dynamic feedbacks among the different variables to play a critical role. This is true in both the identification of innovations in the public capital variables and the measurement of the effects of such innovations.

3.1 Identifying innovations in the public capital variables

While the public capital variables are endogenous in our econometric framework, the key methodological issue for the determination of the effects of public investment on the output is the identification of innovations on the public capital variables that are truly exogenous. This means that we need to identify shocks to public capital that are not contemporaneously correlated with shocks in the private sector variables. These shocks are not subject to the reverse causation problem. In dealing with this issue we draw from the approach typically followed in the literature

on the effects of monetary policy on the economy [see, for example, Christiano, Eichenbaum and Evans (1996,1998), and Rudebusch (1998)] and adopted in Pereira (2000).

Ideally, the identification of shocks to public capital which are not correlated with shocks in other variables would result from knowing what fraction of the Spanish central administration appropriations in each period is due to purely non-economic reasons. The econometric counterpart to this idea is to imagine a central administration policy function which relates the rate of growth of public capital to the information in the relevant information set; in our case, the past and current observations of the growth rates of the private sector variables. The residuals from this policy function reflect the unexpected component to the evolution of public capital and are not correlated with innovations in the private sector variables.

At the aggregate level we assume that the information set for the policy makers includes past values but not current values of the private sector variables. This is equivalent in the context of the standard Choleski decomposition to assuming that innovations in aggregate public capital lead innovations in aggregate private sector variables. This means that while innovations in aggregate public capital affect aggregate private sector variables contemporaneously, the reverse is not true. We have two reasons for making this our central assumption. First, it seems reasonable to assume that the private sector reacts within a year to innovations in public investment decisions. Second, it also seems reasonable to assume that the public sector is unable to adjust public investment decisions to innovations in the private-sector variables within a year. This is due to the time lags involved in information gathering and public decision making.

The same assumption and justifications are used at the regional level. Indeed, the bulk of the public investment decisions during the period analysed were made at the central administration level. Therefore, the assumption that innovations in regional public capital affect regional private sector variables contemporaneously, but the reverse is not true, seems even more justifiable at the regional level. The justifications for this assumption are also more plausible at the regional level. Indeed, one would expect the central administration to be completely unable to adjust public investment decisions to innovations in regional private-sector variables within a year.

The identification of exogenous innovations in public capital, however, has an additional layer of difficulties at the regional level. Indeed, we need to consider the contemporaneous relationship between innovations in the public capital in the regional and innovations in public capital installed outside the region. Here our assumption is that innovations in public capital outside any given region lead innovations in public capital in the region. This assumption is justified by the fact that the fraction of public capital installed in any given region is relatively small compared to the capital installed outside.

These arguments establish a very plausible central case for the identification of innovations in public capital formation that are not correlated with innovation in other variables. Nevertheless, to determine the robustness of our central case results we consider also all the

possible alternatives in terms of the definition of which observations are included in the central administration information set. This is equivalent to considering all the possible orderings of the variables within the Choleski decomposition framework. We report the corresponding range of results in Tables 2, 5 and 7 in parenthesis, together with the central case results.

The policy function at the aggregate level suggests that innovations in public capital are positively correlated with lagged changes in private output and private capital, and not correlated with lagged changes in employment. At the regional level, the positive correlation between the public capital variables and lagged private output and private capital is also present in 8 and 11 of the 17 regions, respectively. The regional evidence for employment is mixed in that the aggregate evidence hides some important regional patterns. Indeed, the correlation between public capital and lagged employment is positive in three regions and negative in three other regions.

Overall, the policy functions suggest a strong pattern of response of public capital decisions to lagged changes in the evolution of private-sector variables. A faster-growing private output generates greater tax revenues and allows for faster public investment growth. Also, the policy functions show a positive correlation between public and private capital, which suggests a virtuous cycle between the two types of capital. Finally, it seems that public investment has not been used as a counter-cyclical tool to promote job creation although it may have a role in attempting to correct some regional patterns. In general, and maybe even more importantly, the policy functions suggest that public capital cannot be considered an exogenous variable in either the aggregate or the regional levels.

Finally, it should be pointed out that the statistical evidence corroborates our assumptions on the identification of innovations in public capital that are not contemporaneously correlated with shocks in the private-sector variables. In fact, the matrices of contemporaneous correlations among the estimated residuals for the different VAR models show, in general, a block-diagonal pattern. This means that innovations in public capital variables tend to display a low contemporaneous correlation with innovations in the private sector variables. Indeed, for the aggregate model and for eleven of the seventeen regional models all the contemporaneous correlations between innovations in public capital and in private sector variables are under 0.50. This pattern suggests that the results from the impulse response functions to be presented below are very robust to our identification strategy.

3.2 The impulse-response functions

We consider the effects of one-standard deviation, one-time innovation in the rate of growth of the public variables on private output, capital and employment at both the aggregate and regional levels. We expect these one-time shocks to have temporary effects on the growth rates of the private-sector variables. They will, however, have permanent effects on the levels of these

variables. The accumulated impulse response functions for Spain as well as the three largest regions are reported in Figures 1-3.

There are a few interesting points worth mentioning in terms of the accumulated impulse-response functions. Let us start by acknowledging that all accumulated impulse-response function converge with a twenty-year period while most of them converge within a five to ten year period. This is consistent with the idea that public capital takes time to build before it really impacts the private sector performance. Notice, nevertheless, that our measures of public capital are aggregate measures, which are made of spending from a series of overlapping public investment projects. This being the case, in any given year a substantial part of the observed public investment corresponds to projects that have been concluded that year.

It should also be noted that the convergence path of the private sector variables is not only relatively fast but also very smooth. In turn, the convergence path of the public capital variables, although also relatively fast is less smooth in the early years. This pattern can easily be understood if one considers that the initial exogenous shock to the public capital variables is followed by an endogenous adjustment in public capital in response to the evolution of the private sector variables. This endogenous adjustment is dictated in the context of the VAR model by the policy functions discussed above.

3.3 Measuring the Effects of Innovations in the Public Capital Variables

We report the long-term accumulated elasticities of output with respect to each public capital variable considered. Long term is defined as the time horizon over which the growth effects of innovations disappear, that is the accumulated impulse-response functions converge. In our analysis, we assume that long term means twenty years, although most impulse response functions converge in between five and ten years. These elasticities represent the total percentage point changes in output for each long-term accumulated percentage-point change in public capital once all the dynamic feedback effects among the different variables have been considered.

We report also the results in terms of the long-term accumulated marginal productivity of public capital. These figures measure the long-term accumulated change in private output for every euro of long-term accumulated change in public capital. We obtain each figure by multiplying the long-term accumulated elasticity by the corresponding output to the public capital ratio. This ratio is in the original levels of the variables and is the average ratio for the last ten years of the sample. This allows us to interpret the marginal product figures as the long-term effects of policies implemented at the end of the sample measured under the conditions observed by the end of the sample period.

The marginal product figures at the regional level are weighted figures. This means that each raw regional marginal product figure has been multiplied by the share of public capital

installed in that region in total public capital in Spain. This allows us to interpret the sum on the regional marginal products as the combined effect of one euro invested in public capital in Spain. Therefore, this makes the sum of the disaggregate figures directly comparable to the marginal product obtained from the aggregate model for the whole country.

Finally, it should be noted that we use the term elasticity and marginal product in an unconventional way. In this paper, the term includes all the dynamic feedbacks among the variables. Therefore, the elasticities and marginal product figures that we calculate are total figures. That is, they measure both the direct effects of public investment on output and the indirect effects of public capital on output through changes in the evolution of private inputs. Of course, this is the relevant concept from a policy perspective.

4. On the Regional Effects of Public Capital Formation on Private Output

4.1 Aggregate effects of public capital formation on private output

We start by estimating the effects of public capital on output at the aggregate level for Spain. This is an important step since it gives us the benchmark for the overall effects of public capital formation aggregated across all regions. We obtain the aggregate results for Spain from the impulse response functions associated with the VAR model relating private output, employment, and capital, and public capital for the whole economy. The relevant results are reported in the top part of Table 2.

Estimation results suggest that the accumulated elasticity of output with respect to public capital is 0.523. This value is well within the range of estimates available for the Spanish case, which are somewhere between .19 and .71 [see De la Fuente (1996) for details]. This elasticity figure implies that the accumulated marginal productivity of public capital is 2.892, i.e., a one euro increase in public capital leads to a long-term accumulated increase in private output of 2.892 euros. Another way of interpreting this figure is by considering that if the average life expectancy of public capital assets is twenty years then public capital has an average rate of return of 5.5%. These results show that public capital has a significant positive effect on output in Spain as a whole.

4.2 Regional effects of public capital formation on private output

Our ultimate objective is to provide a regional decomposition of the aggregate positive effects of public capital formation we have just identified. To do so, we estimate for each region the accumulated elasticities and marginal products associated to shocks in the public capital

installed in the region itself as well as associated to shocks in public capital installed outside the region. The effects in each region of changes in the public capital installed outside give a measure of the spillover effects of public capital formation captured by each region. These results are reported in Tables 2 and 3.

Let us start with the regional effects of public capital installed in the region itself. The empirical results suggest that for thirteen of the seventeen regions the accumulated elasticities of output with respect to public capital in the region are positive. Accordingly, the positive aggregate effects of public capital on private output reflect positive regional effects of public capital installed in each region for most regions. Furthermore, the regional elasticities are in all but three cases lower than the aggregate elasticities. This tends to confirm Munnell's argument that a reduction in the public capital elasticity is expected when one descends to a regional level. These results have been also obtained in other empirical studies of the Spainsh case [see Carames and Lago (1999) for details].

A casual look at the accumulated marginal products suggests that Andalucia, Castilla-Leon, Cataluña, Madrid, Valencia, and Pais Vasco benefit substantially, in absolute terms, from public capital formation located in their jurisdiction. It is important to note that these are the six largest regions in the country, economically speaking. They represent 70.4% of Spanish GDP and 64.9% of the public capital stock is installed in their jurisdiction. Nevertheless, they capture 86.4% of the effects of public capital installed in each region. This suggests that, from the standpoint of the direct effects of public capital installed in the region itself, public capital formation has contributed to the regional concentration of output in Spain.

Consider now the effects for each region of changes in public capital installed elsewhere. Estimation results suggest that in all regions but one regional output is affected positively by innovations in public capital installed outside the region. Again this is consistent with the positive aggregate result obtained for the Spanish economy as a whole. A casual look at the accumulated marginal products suggests that five of the six largest regions in the country (the exception is Castilla-Leon) benefit substantially, in absolute terms, from public capital formation located outside their jurisdiction. These regions correspond to 64.1% of the Spanish GDP and 55.5% of the public capital is installed in their jurisdiction. They capture, however, 74.1% of the effects of public capital installed outside the region. Again, we find that also from the standpoint of the spillover effects of public capital installed outside the region, public capital formation has contributed to the regional concentration of output in Spain.

We are now in a position to consider the overall effect in each region - direct effects of public capital installed in the regions plus spillover effects for the region of public capital installed elsewhere - of public capital formation in Spain. To do so we just need to add across regions the marginal products of public capital installed in the region and public capital installed elsewhere in the country. The overall effects of public capital formation are positive for all but one region. The

exception is Extremadura. This confirms the idea that the positive aggregate results of public capital formation mirror widespread positive effects at the regional level. The regions that benefit the most are again Andalucia, Castilla-Leon, Cataluña, Madrid, Valencia and Pais Vasco (see Map 1). These regions are the six largest in the country and capture 80.3% of the total effects of public capital formation. Since their share of the benefits is well in excess of their share in the GDP or their share of the Spanish public capital, our results suggest very clearly that overall public capital formation tends to increase the concentration of economic activity in Spain.

Having identified the combined effects of public capital formation invested in the region and the spillover effects from capital installed elsewhere we now consider the relative importance for the Spanish economy of the spillover effects. Overall, the sum across all the regions of the marginal products of the public capital installed in the region itself is 50.1% of the aggregate marginal product estimated for Spain as a whole. In turn, when we consider the sum across all the regions of the accumulated marginal products with respect to innovations in the public capital installed outside the region, we obtain a figure that corresponds to 57.1% of the aggregate effects obtained for Spain as a whole. Therefore, the measure of the spillovers is comparable, and in fact slightly greater, than the direct effects of public capital installed in the region. Accordingly, an important conclusion of our empirical investigation is that the spillover effects for each region of public capital installed outside the region are very important in quantitative terms.

Finally it should be pointed out that, the sum across regions of the direct effects of capital installed in the region plus the spillover effects of capital installed outside the region is very close to the figures obtained for the total aggregate effect estimated for Spain. It corresponds to 107.2% of the aggregate value. This means that our disaggregation of the total effects of innovations in public capital in Spain is very precise. It should be pointed out, however, that a less closer fit of the aggregate results vis-à-vis the sum of disaggregated results would not be an indictment of our results. In fact, one should expect each of the regional models not to fully capture the general equilibrium effects induced by innovations in public capital formation. Indeed, the increase in output observed for each region individually would not be expected to reduce substantially the market output prices at the aggregate level. This is to say that it is as if each region has a horizontal output supply schedule. At the aggregate level, however, we would expect the simultaneous increase in output in most regions to lead to a reduction in the equilibrium output price. Our results suggest that in the product market these general equilibrium effects are not very strong and that the output supply schedule is relatively steep.

4.3 On the relative importance for each region of the direct versus the spillover effects

The results so far establish the relevance at the regional level of both the direct effects of public capital located in the region itself and the spillover effects of innovations in public capital

installed outside each region. Obviously, this general pattern has some interesting regional nuances. We are now interested in identifying which regions seem to benefit relatively more from the public capital formation within their borders relative to the spillover effects of public capital formation installed elsewhere. The relevant information is presented in Table 3.

Estimation results suggest that, for only six of the seventeen regions, including only four of the fifteen continental regions, are the direct effects of public capital installed in the region more relevant than the spillover effects from public capital installed outside the region. This is the case of Castilla-Leon, Castilla-La Mancha, Cantabria and Madrid. These regions form with Extremadura, for which public capital formation does not seem to have a positive impact on output, the interior spinal chord of the country. They are located in the central area of the Iberian Peninsula. The direct effects of public capital installed in the region are also dominant in the case of Baleares and Canarias. These are archipelagos off the coast of Spain in the Mediterranean and the Atlantic, respectively. Because of their geographically detached location, one would not expect substantial spillover effects from public capital installed in continental Spain.

Conversely, for the remaining ten regions, the spillover effects are relatively more important than the direct effects of public capital installed in the region. This is particularly true of Andalucia, Asturias, Galicia, Navarra, Rioja, and Valencia and to a lesser extent of Aragon, Cataluña, Murcia and Pais Vasco. All these regions are in the periphery of the country forming a belt around the regions for which the direct effects are more relevant.

This geographical pattern of results (see Map 2), with direct effects being relatively more important for central areas and spillover effects being relatively more important to peripheral areas is very interesting. It also lends itself to a very intuitive interpretation. Economic connections of each given region in Spain are mostly with other Spanish regions. This is true also of the peripherial regions adjacent to either Portugal or France. The accessibility of the peripheral regions to the rest of Spain depends critically on the network of public infrastructure installed in the rest of Spain. In turn, the central regions depend less on infrastrucutre located elsewhere for their accessibility to the rest of the country.

Interestingly enough, the negative results obtained for Extremadura are also consistent with this interpretation. Extremadura is the poorest region of Spain and is located in the center of the Iberian Peninsula adjacent to the poorest regions of Portugal. Extremadura does not have meaningful economic connections with either Portugal or the rest of Spain. In this case, neither public capital in the region or in the rest of Spain seem to have a positive impact in the region.

Overall our disaggregated results confirm the existence of spatial spillover effects coming from public capital formation in Spain. The existence of these effects had been conjectured or indirectly suggested by other empirical analysis of the Spanish case [see, for example, Mas et al. (1996), Moreno et al. (1997) and Rapun et al. (1999)]. Our approach, however, not only makes it possible to confirm the existence of these effects in the case of the Spanish economy, but also

allows for their precise quantification and the identification of their location. Furthermore, in a more general sense, our results support Hansen's conjecture that the economic impact of public capital depends on the characteristics of the region. In the case of Spain the geographical location seems to play an important role.

4.4 On the relative size for each region of the gains from public capital formation

So far we have been focusing on the effects on regional output of public capital - both public capital installed in the region and public capital installed elsewhere - in absolute terms. We want now to identify which regions seem to benefit the most in relative terms from either the public capital installed in the region itself or the spillover effects of capital installed elsewhere. To do so, we compare the size of the regional effects of public capital formation to the size of the region, as measured by its share of the Spanish GDP. The results are reported in Table 4.

Consider first, the effects on regional output of public capital installed in the region itself. We observe that besides the archipelagos of Baleares and Canarias, the regions of Castilla-Leon, Castilla-La Mancha, Cantabria, Madrid, Murcia, and Pais Vasco, display benefits that are relatively strong when compared to their share of the GDP. So, in continental Spain, the interior regions located in the central part of the Iberian Peninsula appear as the main beneficiaries, in relative terms, of public capital installed inside the region. When we consider the relative importance of the effects of the public capital located outside the regions we find the opposite pattern. In fact, the central regions do not appear now in the group of the ones that display a relatively strong benefit. These are Andalucia, Galicia, Murcia, Valencia, and Pais Vasco, all peripheral regions.

The combined direct and spillover effects of public capital formation determine that, in addition to the archipelagos of Baleares and Canarias, eight of the fifteen continental regions benefit from public capital formation more than proportionally to their share of the Spanish GDP. These regions are Andalucia, Cantabria, Castilla-Leon, Castilla-Mancha, Madrid, Murcia, Valencia, and Pais Vasco. These regions form the central spinal chord of the Iberian Peninsula, away from borders (see Map 3). Of these regions, Cantabria, Castilla-Leon, Castilla-Mancha, and Madrid are interior regions and benefit relatively more from public capital installed in the region itself. In turn, the other four regions are in the periphery and benefit relatively more from public capital installed outside the region.

It is interesting to highlight that the regions that benefit from public capital formation less than their share in the Spanish GDP are invariably peripheral regions. Of these, Extremadura and Galicia, are along the Portuguese border and Aragon, Asturias, Cataluña, Navarra, and Rioja, are Northern regions closer to the French border. In all cases one could conjecture that their

productive system would be relatively less dependent of transportation infrastructures located in the Spanish territory and more on public infrastructures in the surrounding countries

These results allow us to sharpen our discussion about the effects of public capital formation in terms of increased regional concentration of output in Spain. Indeed, five of the six largest areas benefit more than proportionally to their share of the Spanish GDP. This means that public capital formation has contributed to an increase in their share of the Spanish GDP. Among the largest regions the exception is Cataluña. In addition, public capital formation has tended to increase the relative importance of relatively small regions like Cantabria, Castilla-Mancha, and Murcia.

It could be conjectured that the relatively large gains captured by the largest regions could be a consequence of a disproportionately large public capital investment in these regions. In fact, the opposite is true. The share of the benefits for Andalucia, Madrid, Valencia, and Pais Vasco, are clearly in excess to their share of the Spanish public capital not just of their share of output. Among the smaller regions only Murcia seems to also benefit proportionally more than its share of public capital formation. This suggests that it is the very economic structure of these regions and their connections to other regions that allows them to benefit relatively more from public capital formation in the country.

5. Effects of Public Capital Formation on Private Capital and Employment

One of the advantages of the VAR approach adopted in this paper is that it allows us to identify the effects of public capital formation on private inputs, capital and employment, in a way that is methodologically consistent with the effects on output presented above. Indeed, in addition to affecting output directly as an additional input in the production function, public capital affects output indirectly through its effects on the use of private inputs. It is conceivable that a greater availability of public capital could reduce the demand for private inputs. Higher availability of public capital, however, also increases the marginal productivity of private inputs, thereby potentially increasing input demand. We do not have, therefore, a clear prior as to the sign of the effects of public capital on private inputs. In this section we analyse the empirical evidence on this matter.

5.1 On the effects of public capital formation on private capital

The empirical results on the effects of public capital on private capital are reported in Tables 5 and 6. When we estimate the effects of shocks to aggregate public capital on the evolution of private capital, we find a long-term elasticity of 0.270. This suggests that public

capital crowds in private capital at the aggregate level for Spain, i.e., public capital and private capital are complements. Furthermore, the figure for the elasticity implies a marginal product of 3.420 euros, or that one Euro invested in public capital tends to generate in the long term an accumulated 3.420 euros in private capital formation.

Let us consider now the disaggregated results obtained from the regional models. When we consider the effects of public capital installed in the region we find positive elasticities in twelve of the seventeen regions. Therefore, for most of the regions public capital located in the region crowds in local private capital formation. The regions with the largest marginal products are Andalucia, Baleares, Cataluña, Extremadura, Madrid, Valencia, and Pais Vasco, which include the five largest regions in Spain in terms of their share of the Spanish private capital stock. In turn, public capital installed elsewhere affects local private capital formation positively in fifteen of the seventeen regions. Again, we find that for most regions public capital installed outside the region crowds in local private capital formation. Again the largest effects in absolute terms occur in the largest regions in their share of the Spanish private capital stock.

One pattern that arises from the previous results is that for all regions private capital formation responds positively to either public capital in the region or public capital installed elsewhere or both. Therefore, not surprisingly, public capital formation in the country crowds in private capital in fourteen of the seventeen regions. The exceptions are the small regions of Asturias, Cantabria, and Navarra, which display negative albeit low effects. In turn, Andalucia, Cataluña, Madrid, Valencia, and Pais Vasco, the five largest regions, not only capture most of the effects of public capital on private capital formation but they do so in a disproportionate manner. In fact, while they represent 62.6% of the Spanish private capital stock they capture 79.9% of the effects of public capital formation in the country. Therefore, public capital formation in Spain has contributed to the regional concentration of the stock of private capital stock. In particular, Madrid and Pais Vasco, seem to benefit the most in relative terms. They capture 27.2% and 15.9% of the benefits respectively but only 12.2% and 6.6% of the Spanish private capital stock is located within their jurisdiction.

It is informative to consider the relevance of spillover effects in the context of private capital formation. Of the aggregate effect obtained by summing the marginal products across regions, the direct regional effects correspond to 42.6% and the spillover effects correspond to 57.4%. This suggests that the spillover effects are very important and account for more than half of the total effects on private capital formation. Furthermore, spillover effects are more important than the direct effects for twelve of the seventeen regions, although in the aggregate not by a substantial difference. The exceptions are Castilla-Mancha, Extremadura and Pais Vasco, besides the obvious cases of Baleares and Canarias.

A final comment of the relationship between the results from the aggregate Spanish model with the sum of the results obtained from the independent regional models. We observe that

the sum of the individual effects across regions is almost twice the value of the effect obtained with the aggregate model. This difference can be understood as the result of general equilibrium effects that are captured by the aggregate model but not the regional models. Indeed, when public capital is made available, more private capital is desired, simultaneously, by most of the regions. For each region it is as if the producers face a horizontal supply schedule for capital goods. This is because no single region is large enough to affect the aggregate nation-wide price of private capital goods. This simultaneous increase in demand, however, is limited by resource constraints in the economy. Therefore, at the aggregate level, the producers face an upward sloping supply schedule, and part of the increased demand for capital goods translates into higher capital good prices and a downward adjustment of the regional-specific demands. Thus, because of these general equilibrium price effects present in the aggregate model but not in the regional models, the sum of the regional marginal products should be expected to exceed the aggregate effects

5.2 On the effects of public capital formation on employment

The empirical results on the effects of public capital on employment are reported in Tables 7 and 8. At the aggregate level, employment responds to shocks in public capital formation with a long-term accumulated elasticity of 0.414. This means that at the aggregate level, public capital and the labor input are complements. This figure implies that a one million euros accumulated investment in public capital increases employment by 62.5 permanent long-term jobs.

Let us consider now the disaggregated results obtained from the regional models. When we consider the effects of public capital installed in the region on employment we find positive elasticities in twelve of the seventeen regions. Therefore, as at the aggregate level, local public capital and the labor input are complements in most regions. Moreover, the largest marginal products, or the largest number of long-term jobs created per one million euros in public capital are in Andalucia, Canarias, Madrid and Pais Vasco. In terms of the responsiveness of employment in a region to public capital installed elsewhere we also obtain positive, but clearly smaller effects, in twelve of the seventeen regions. The regions that benefit the most in terms of added employment are Madrid, Valencia, and Pais Vasco.

As to the total effect from shocks to the public capital installed in the region and public capital installed in the rest of the country we find that public capital and employment are complements in eleven of the seventeen regions. This despite the fact that for most regions private employment responds positively to either public capital in the region or to public capital installed elsewhere. In absolute terms the regions that benefit the most are Andalucia, Canarias, Madrid, Valencia, and Pais Vasco. These five regions plus Baleares, Cantabria, Murcia, Rioja benefit substantially in relative terms compared to their share of Spanish employment. Therefore, overall

it seems clear that public capital formation has contributed to a marked shift in regional employment patterns. It is important to note, in particular, that public capital formation seems to have shifted employment away from Castilla-Leon and Cataluña, two of the largest regions. In addition, Asturias, Castilla-La Mancha, Extremadura, and Galicia, some of the smallest regions are the biggest losers in terms of job creation.

Of the overall aggregate effects obtained by summing the marginal products across regions, the direct regional effects correspond to 74.5% and the spillover effects correspond to just 25.5%. Furthermore, spillover effects are more important than the direct effects for only four of the seventeen regions. This suggests that spillover effects are less important in the case of employment compared to the cases of output and private capital.

A final comment of the relationship between the results from the aggregate Spanish model with the sum of the results obtained from the independent regional models. We observe that the sum of the individual effects on employment across regions is close to the 60% the value of the effect obtained with the aggregate model. This is the opposite of what we observed for the effects on private capital. When we attempt to explain the difference in result for employment obtained with the aggregate model and the disaggregated regional models and, in particular, when we try to understand the difference between the results for employment and private capital, we need to consider the special characteristic of the labor input. Indeed, in some respects they are exactly the opposite of the private capital input. At the macro level the Spanish economy is characterised by very high unemployment rate and by nominal wage rigidity. This means that at the aggregate level, the productive sector is facing a virtually horizontal labor supply schedule. They can hire as much workers as they want at the current wage rate. The lower results at the regional level are consistent with a greater regional flexibility of nominal wages. Indeed, given the low intra-regional labor mobility that characterises the Spanish economy [see, for example, Castillo et al. (1998) and Bentolila (1997)], it is likely that in some regions producers face an upward labor supply schedule. This would be true in particular in regions with a relatively lower unemployment rate.

5.3 Labor productivity

Since our results allow us to identify the effects of public capital formation on both output and employment, it follows that we can determine its effect on labor productivity at both the aggregate and the regional levels. Our estimation results at the aggregate level suggest that public capital formation affects output with an elasticity of 0.523 and employment with an elasticity of 0.414. This implies that public capital formation affects output proportionally more than employment and, therefore, affects labor productivity positively.

The analysis of the regional results confirms that this finding also holds for most regions. In fact, if we compare the regional labor productivity before and after producing a shock in the public capital variables, we obtain that for twelve of the seventeen regions, public capital formation increases labor productivity. The exceptions are Canarias, Extremadura, Murcia, Navarra, and Rioja. Aside from Canarias, these are all very small regions. Therefore, their case does not have any bearing on the overall positive pattern at the national level. In turn, Canarias is less small but the negative effect on labor productivity seems to be induced by the very large positive effect of public capital formation on regional employment.

6- Summary and Concluding Remarks

The objective of this paper is to investigate the regional effects of public capital formation and the possible existence of regional spillover effects in Spain. The empirical results are based on VAR estimates at both the aggregate and regional levels using output, employment, and private capital, as well as public capital. This approach follows the conceptual argument that the analysis of the effects of public capital requires the consideration of dynamic feedback effects among the different variables. This approach allows us to identify the regional distribution of the effects of public capital formation in a framework that is consistent with the evaluation of the effects of public capital formation at the aggregate level. Furthermore, it allows us to identify at both the aggregate and regional levels the effects of public capital formation on private inputs that are behind the analysis of its impact on private output.

We start by estimating the effects of public capital formation on output at the aggregate level. The long-term marginal product of public capital is 2.892, which corresponds to a rate of return of 5.5%. This evidence suggests that public capital has been a powerful instrument to promote long-term output growth in Spain. Consequently, more public capital formation may be regarded as desirable as the Spanish economy strives to achieve EU standards of living.

In turn, the estimates at the regional level suggest that all of the Spanish regions benefit from either public capital installed in the region or from the spillover effects from capital installed elsewhere. Furthermore, our regional results suggest that most of the largest regions benefited from public capital formation well in excess of their share of the Spanish GDP. This suggests that public capital formation has contributed to increase the regional concentration of output in Spain.

Overall, the empirical results from the regional models suggest that the spillover effects of public capital formation are very important, this is because they account for over half of the aggregate effects of public capital formation. Naturally, different regions benefit from the internal and the spillover effects to different degrees. In fact, there is a clear geographical pattern of results. The central regions of Spain, in the middle of the Iberian Peninsula, tend to benefit

relatively more from the public capital located in their territory than from the spillover effects. Conversely, the peripheral regions, tend to benefit relatively more from the spillover effects, i.e., from shocks in the public capital located elsewhere, than from public capital formation in their own territory. This is consistent with the idea that accessibility to the Spanish markets by peripheral regions depend more on infrastructures installed outside the region while for central regions accessibility depends more on public infrastructures in the region itself.

In terms of the effects on private inputs the empirical results suggest that, at the aggregate level, public capital crowds in both private capital and employment. This is a pattern that is found as well for most, but not all regions. We find that spillovers account for 57.4% of the total effects of public capital formation in the case of private capital and for just 25.5% of the total effects on employment. This means that the spillover effects are very important in the case of private capital but not in the case of employment. This reflects a great degree of dynamism and mobility in the capital markets as opposed to the labor markets. In addition, our results suggest that public capital has led to increased regional concentration of both private capital and employment. Of the largest regions, Andalucia, Madrid, Valencia, and Pais Vasco benefit more than proportionally to their share of both private capital and employment while Cataluña only shows relatively high benefits for private capital. Finally, public capital formation seems to have crowded out either private capital or employment in some of the smallest regions.

This paper establishes the relevance of both capital installed in each region and of spillover effects in the understanding of the decomposition of the aggregate effects of public capital formation in a country. In doing so it opens the door to some tantalizing and potentially highly charged research issues. One is the determination of the optimal location of public investment projects. This paper allows us to identify which regions benefit the most from spillovers but not which regions generate the greatest spillover effects. Since, however, public infrastructures installed in a given region impact positively the economic performance of other regions and each region benefits from public infrastructures installed in the region and elsewhere in the country, then one would want to know which locations have the greatest effects on aggregate output.

Another interesting question, which is equally difficult to answer, is whether or not public capital formation has contributed to reduce regional asymmetries as measured by differences in the regional GDP per capita. Our results give us no guidance on this matter. This is, however, a critical question for Spain. Indeed, no one would want to see the convergence of the Spanish economy to EU patterns to be achieved at the cost of increasing regional disparities. In this context, we would also want to know which location for public infrastructure projects serve best the objective of reducing regional disparities. The conventional wisdom that you promote the development of a given region primarily by developing the public infrastructure in that region itself has been challenged by our results on the existence of important regional spillovers.

References

Aschauer, D. (1989a): "Is Public Expenditure Productive?", *Journal of Monetary Economics* 23, pp. 177-200.

Aschauer, D. (1989b): "Does Public Capital Crowd Out Private Capital?", *Journal of Monetary Economics* 24, pp. 171-188.

Argimón I.; J.M. González-Páramo ; M.J. Martín and J.M. Roldán (1994): "Productividad e Infraestructuras en la Economia Española", *Moneda y Crédito* 198, pp. 207-241.

Argimón I. and J.M. González-Páramo (1997): "Efectos de la Inversión en Infraestructuras sobre la Productividad y la Renta de las CC.AA.", in Pérez Toriño E. (dir.) '*Infraestructuras y Desarrollo Regional: Efectos Económicos de la Autopista del Atlántico',* Madrid, Civitas, pp. 141-182.

Bajo, O. and S. Sosvilla (1993): "Does Public Capital Affect Private Sector Performance ?. An Analysis of the Spanish Case 1964-1988," *Economic Modelling* 10 (3), pp. 179-185.

Bentolila, S. (1997): "Sticky Labor in Spanish Regions", *European Economic Review* 41, pp. 591-598.

Boarnet, M. G. (1998): "Spillovers and the Locational Effects of Public Infrastructure", *Journal of Regional Science* 38, pp. 381-400.

Caramés, L. and S. Lago (1999): "Capital Público y Crecimiento Económico en las Comunidades Autónomas", WP Fundación BBV – Economía Pública.

Castillo, S. J.F. Jimeno and O. Licandro (1998): "Employment Segmentation, Labour Mobility, and Mismatch: Spain 1987-1993", Working Paper, WP-98-04, FEDEA.

Christiano, L. J.; M. Eichenbaum and C. Evans (1996): "The Effects of Monetary Policy Shocks: Evidence from the Flow of Funds", *Review of Economics & Statistics* 78 (1), pp 16-34.

Christiano, L. J.; M. Eichenbaum and C. Evans (1998): "Monetary Policy Shocks: What Have We Learned and to What End?" National Bureau of Economic Research Working Paper: 6400.

Commission of the European Communities (1999): "Sixth Periodic Report on the Social and Economic Situation and Development of the Regions of the European Union," European Commission, Brussels.

De la Fuente, A. (1996): "Infraestructuras y Productividad: Un Panorama de la Evidencia Empirica", *Información Comercial Española* 757, pp. 25-40.

Duffy-Deno, K. and R. Eberts (1991): "Public Infrastructure and Regional Economic Development: A Simultaneous Equations Approach", *Journal of Urban Economics* 30, pp. 329-343.

Eisner, R. (1991): "Infrastructure and Regional Economic Performance: Comment," *New England Economic Review*, Sept/Oct, pp. 47-58.

Evans, P. and G. Karras (1994): "Are Government Activities Productive? Evidence From a Panel of U.S. States", *The Review of Economics and Statistics* 76 (1), pp. 1-11.

FBBV (1999): "Renta Nacional de Espana y su Distribucion Provincial. Serie Homogenea" Fundación Banco Bilbao Vizcaya.

FBBVA (2001): "Base de datos de conocimiento economico regional Sophinet". Fundación Banco Bilbao Vizcaya Argentaria (www.bancoreg.fbbv.es)

Garcia-Fontes, W. and D. Serra (1994) "Capital Público, Infraestructuras y Crecimiento", in Esteban, J.M and Vives X. (dirs.) '*Crecimiento y Convergencia Regional en España y Europa',* Barcelona, Instituto de Análisis Económico-CSIC, Vol 2, pp. 451-477.

Garcia-Milà, T. and T. McGuire (1992): "The Contribution of Publicly Provided Inputs to States' Economies", *Regional Science and Urban Economics* 22, pp. 229-241.

Garcia-Milà, T., T. McGuire and R. Porter (1996): "The Effect of Public Capital in State-Level Productions Functions Reconsidered", *Review of Economics and Statistics* 78 (1), pp. 177-180.

González-Páramo J. M. (1995): "Infraestructuras, Productividad y Bienestar", *Investigaciones Económicas* 19 (1), pp. 155-168.

Holtz-Eakin, D. (1993): "State-Specific Estimates of State and Local Government Capital", *Regional Science and Urban Economics* 23, pp. 185-209.

Holtz-Eakin, D. (1994): "Public Sector Capital and the Productivity Puzzle", *The Review of Economics and Statistics* 76 (1), pp. 12-21.

Holtz-Eakin, D. and A. E. Schwartz (1995): "Spatial Productivity Spillovers from Public Infrastructure: Evidence from State Highways", *International Tax and Public Finance* 2 (3), pp. 459-468.

INE (2000): "Base de datos TEMPUS". Instituto Nacional de Estadística (www.ine.es).

Jorgenson, D. (1991): "Fragile Statistical Foundations", *The Public's Capital* 6-7.

Mas, M., J. Maudos, F. Perez, and E. Uriel (1993): "Capital Público y Productividad de la Economia Española", Working Paper, WP-EC 93-08, IVIE.

Mas, M., J. Maudos, F. Perez, and E. Uriel (1996): "Infrastructures and Productivity in the Spanish Regions", *Regional Studies* 30 (7), pp. 641-649.

McGuire, T. J. (1992): "Higways and Macroeconomic Productivity: Phase Two", Federal Higway Administration, March 1992.

Mikelbank, B. A. and R. W. Jackson (2000): "The Role of Space in Public Capital Research", *International Regional Science Review* 23 (3), pp. 235-58.

Moreno R., M. Artís, E. López-Bazo and J. Suriñach (1997): "Evidence on the Complex Link Between Infrastructure and Regional Growth", *International Journal of Development Planning Literature* 12 (1-2), pp. 81-108.

Munnell, A. (1990): "Why Has Productivity Growth Declined? Productivity and Public Investment", *New England Economic Review*, January/February, pp. 3-22.

Munnell, A. (1992): "Infrastructure, Investment and Economic Growth", *Journal of Economic Perspectives* 6, pp. 189-198.

Munnell, A. and L. Cook (1990b): "How Does Public Infrastructure Affect Regional Economic Performance?", *New England Economic Review*, September/October, Federal Reserve Bank of Boston, pp. 11-33.

Pereira, A.M. (2000):"Is All Public Capital Equal", *The Review of Economics and Statistics* 82 (3), pp. 513-518.

Rapún, M.; P. Pascual and C. Gil (1999): "Public Capital, Regional Productivity and Spatial Spillovers" paper presented at *14th Annual Congress of European Economic Association,* Santiago de Compostela, Spain.

Rudebusch, G. D. (1998): "Do Measures of monetary Policy in a VAR Make Sense?", *International Economic Review* 39, pp. 907-931.

Table 1: Data description

	GDP per capita* (PPP) (UE15=100)	Regional GDP (% of Spain)	Regional Private Capital (% of Spain)	Regional Employment (% of Spain)	Regional Public Capital (% of Spain)
Reference period:	**1996**	**1970-1995**	**1970-1995**	**1970-1995**	**1970-1995**
Spain	78.7%	100.0%	100.0%	100.0%	100.0%
1. Andalucia	57.2%	13.3%	13.7%	14.2%	14.4%
2. Aragon	88.9%	3.4%	3.4%	3.4%	4.5%
3. Asturias	73.6%	2.7%	3.1%	3.1%	4.5%
4. Baleares	97.0%	2.2%	2.5%	1.9%	1.4%
5. Castilla Leon	75.9%	6.3%	6.8%	7.1%	9.4%
6. Castilla La Mancha	65.9%	3.7%	4.0%	4.3%	5.3%
7. Canarias	74.3%	3.5%	3.3%	3.4%	3.3%
8. Cantabria	76.9%	1.4%	1.6%	1.4%	1.7%
9. Cataluña	99.1%	19.0%	19.0%	16.9%	16.7%
10. Extremadura	54.6%	1.8%	2.2%	2.6%	2.2%
11. Galicia	63.0%	5.9%	6.1%	9.1%	6.5%
12. Madrid	100.6%	14.8%	12.2%	12.4%	8.9%
13. Murcia	67.2%	2.5%	2.4%	2.4%	1.4%
14. Navarra	98.1%	1.7%	1.4%	1.4%	2.7%
15. Rioja	89.0%	0.8%	0.7%	0.7%	1.7%
16. Valencia	73.8%	9.8%	11.1%	9.9%	8.0%
17. Pais Vasco	92.3%	7.2%	6.6%	5.8%	7.5%

* Source: Sixth Periodic Report on the social and economic situation and development of the regions of the European Union (Comission EU, 1999)

Figure 1. Accumulated impulse response functions with respect to shocks in aggregate public capital

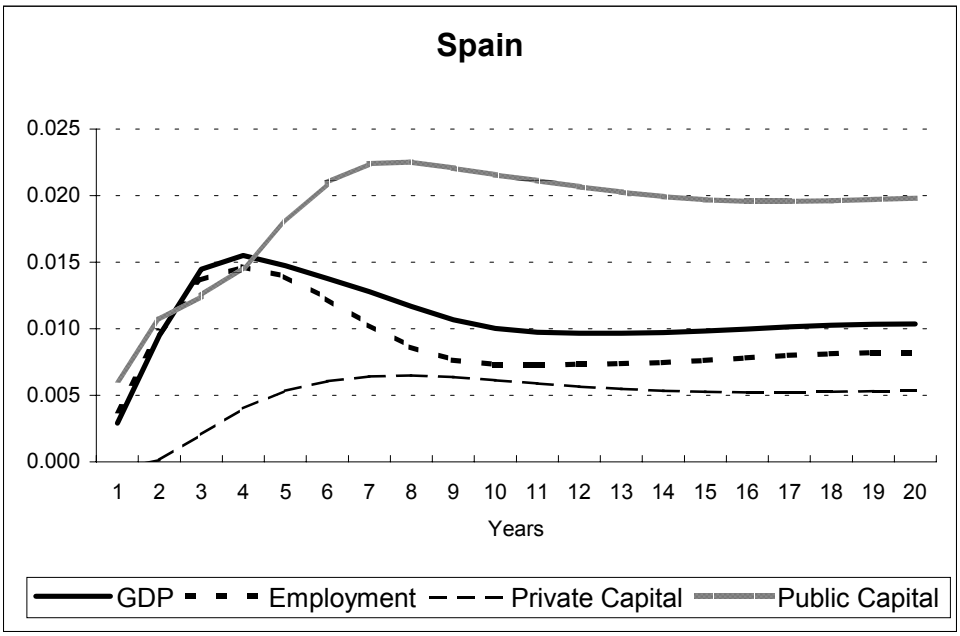
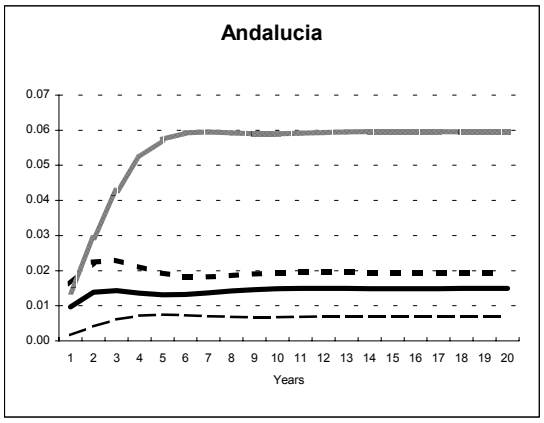
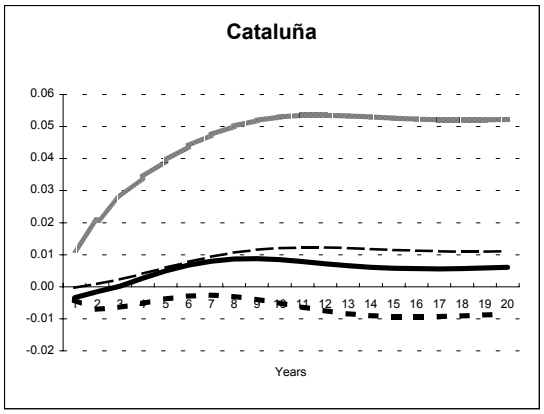


Figure 2. Accumulated impulse response functions with respect to shocks in public capital inside the region





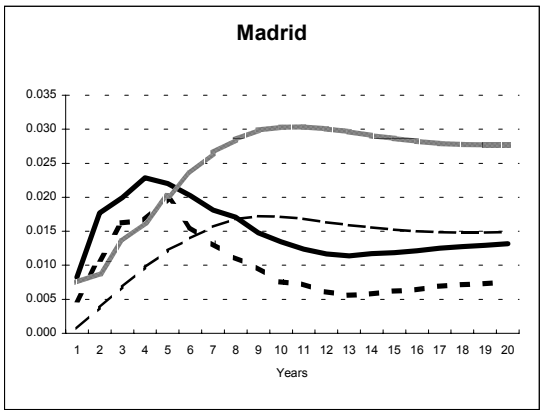
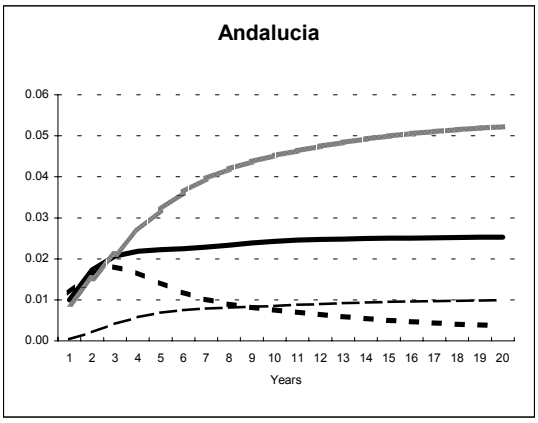
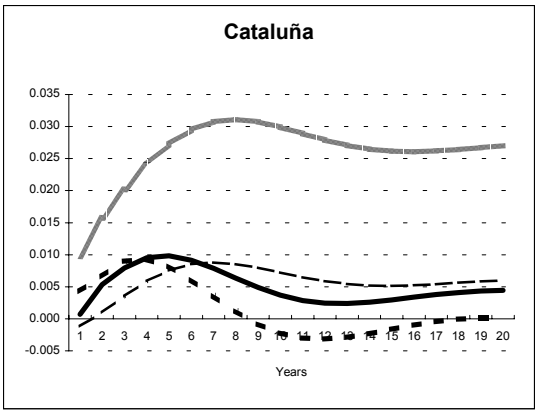


Figure 3. Accumulated impulse response functions with respect to shocks in public capital outside the region





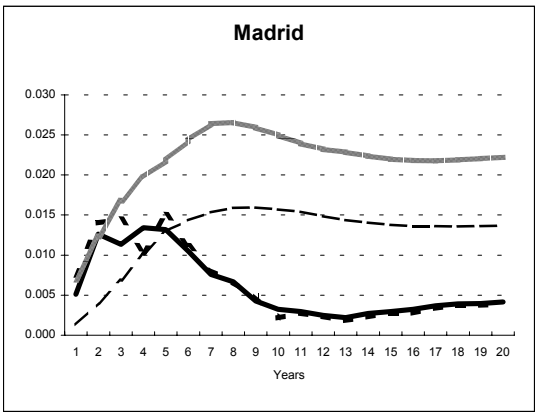


Table 2: Long-term accumulated elasticities and marginal products of output with respect to public capital installed inside and outside the region

	Elasticities with respect to		Marginal Products with respect to	
	PK inside	**PK outside**	**PK inside**	**PK outside**
Spain	0.523 [0.180, 0.625]		2.892 [0.997, 3.785]	
1. Andalucia	0.251 [-0.023, 0.251]	0.485 [0.257, 0.514]	0.187 [-0.017, 0.187]	0.362 [0.192, 0.384]
2. Aragon	0.155 [-0.036, 0.155]	0.197 [-0.067, 0.197]	0.030 [-0.007, 0.030]	0.037 [-0.013, 0.037]
3. Asturias	-0.364 [-0.364, -0.174]	0.016 [-0.238, 0.016]	-0.054 [-0.054, 0.026]	0.002 [-0.030, 0.002]
4. Baleares	0.583 [0.548, 0.619]	0.261 [0.243, 0.322]	0.078 [0.073, 0.083]	0.035 [0.033, 0.043]
5. Castilla Leon	0.604 [0.276, 0.604]	0.041 [-0.097, 0.082]	0.206 [0.094, 0.206]	0.014 [-0.033, 0.028]
6. Castilla La Mancha	0.443 [-0.034, 0.478]	0.201 [-0.559, 0.201]	0.091 [-0.007, 0.098]	0.041 [-0.114, 0.041]
7. Canarias	0.452 [-0.054, 0.452]	0.293 [-0.205, 0.350]	0.091 [-0.011, 0.091]	0.059 [-0.041, 0.070]
8. Cantabria	0.354 [-0.364, 0.493]	0.293 [0.079, 0.313]	0.026 [-0.027, 0.036]	0.022 [0.006, 0.024]
9. Cataluña	0.116 [0.116, 0.493]	0.164 [-0.175, 0.175]	0.122 [0.122, 0.519]	0.171 [-0.182, 0.182]
10. Extremadura	-0.263 [-0.422, -0.263]	-0.151 [-0.850, -0.151]	-0.028 [-0.045, -0.028]	-0.016 [-0.090, -0.016]
11. Galicia	-0.232 [-0.504, -0.232]	0.496 [0.320, 0.505]	-0.072 [-0.156, -0.072]	0.154 [0.099, 0.157]
12. Madrid	0.475 [0.277, 0.745]	0.187 [-0.042, 0.246]	0.402 [0.234, 0.631]	0.158 [-0.035, 0.208]
13. Murcia	0.341 [0.318, 0.482]	0.397 [0.278, 0.397]	0.046 [0.043, 0.065]	0.054 [0.038, 0.054]
14. Navarra	-0.118 [-0.118, 0.008]	0.173 [0.032, 0.376]	-0.011 [-0.011, 0.001]	0.016 [0.003, 0.035]
15. Rioja	0.032 [-0.029, 0.060]	0.237 [0.005, 0.237]	0.001 [-0.001, 0.002]	0.011 [0.000, 0.011]
16. Valencia	0.216 [0.209, 0.261]	0.415 [0.376, 0.422]	0.119 [0.115, 0.144]	0.228 [0.207, 0.232]
17. Pais Vasco	0.600 [0.596, 0.794]	0.851 [0.663, 0.946]	0.214 [0.213, 0.283]	0.304 [0.237, 0.338]

NB: In parenthesis are the ranges of variation from the sensitivity analysis exercises.

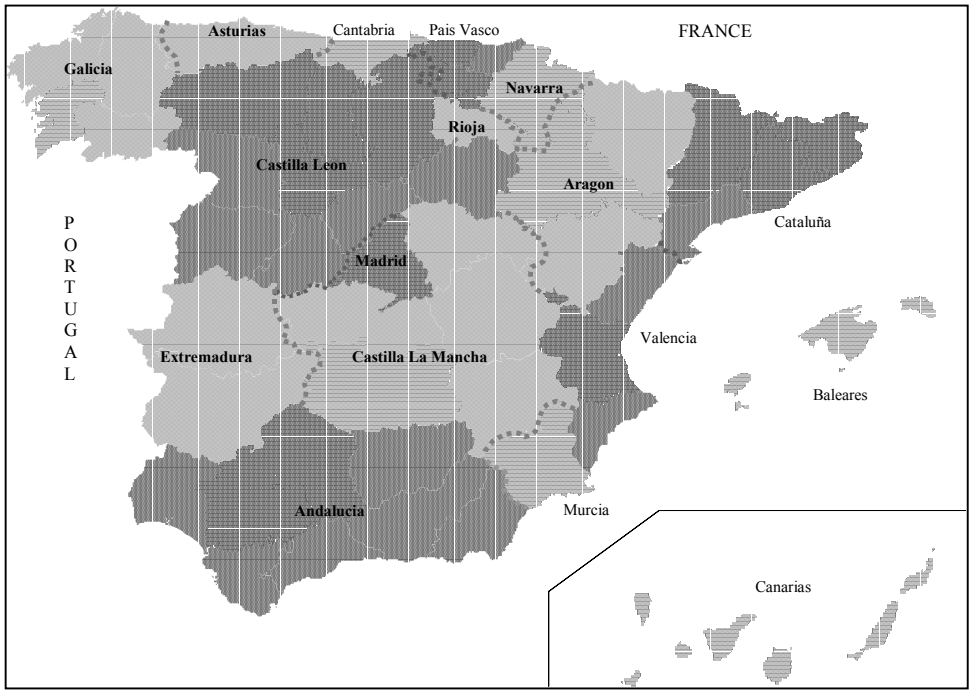
Table 3: On the importance of spillovers from public capital installed outside the region.

	Marginal Products with respect to			Spillovers
	PK inside (1)	**PK outside (2)**	**Total (3)=(1+2)**	**(2/3)**
Spain			2.892	
1. Andalucia	0.187	0.362	0.549	66 %
2. Aragon	0.030	0.037	0.067	56 %
3. Asturias	-0.054	0.002	-0.052	100 %
4. Baleares	0.078	0.035	0.113	31 %
5. Castilla Leon	0.206	0.014	0.220	6 %
6. Castilla La Mancha	0.091	0.041	0.132	31 %
7. Canarias	0.091	0.059	0.150	39 %
8. Cantabria	0.026	0.022	0.048	45 %
9. Cataluña	0.122	0.171	0.293	58 %
10. Extremadura	-0.028	-0.016	-0.044	-
11. Galicia	-0.072	0.154	0.082	100 %
12. Madrid	0.402	0.158	0.560	28 %
13. Murcia	0.046	0.054	0.100	54 %
14. Navarra	-0.011	0.016	0.005	100 %
15. Rioja	0.001	0.011	0.012	88 %
16. Valencia	0.119	0.228	0.347	66 %
17. Pais Vasco	0.214	0.304	0.518	59 %
Total all regions	1.447	1.651	3.098	
Total as % of Spain	50.1%	57.1%	107.2%	

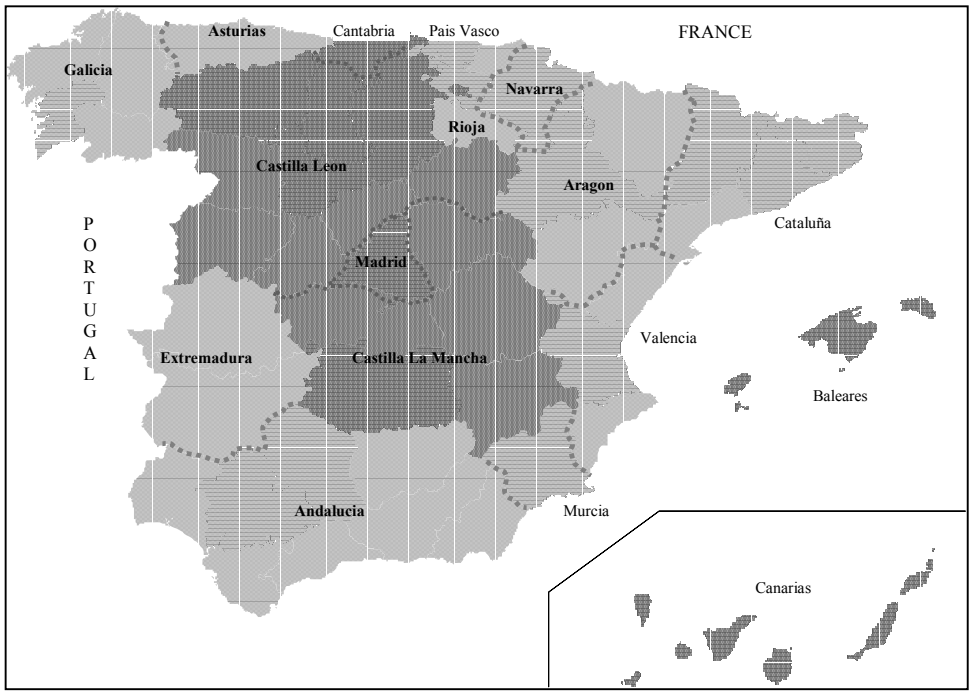
Table 4: Regional distribution of the marginal products of public capital formation

	Regional GDP	PK inside		PK outside		Total	
	% of Spain	% of effects	% effects/ % GDP	% of effects	% effects/ % GDP	% of effects	% effects/ % GDP
Spain	100.0%	100.0%	1.000	100.0%	1.000	100.0%	1.000
1. Andalucia	13.3%	12.9%	0.957	21.9%	1.624	17.7%	1.331
2. Aragon	3.4%	2.0%	0.590	2.3%	0.656	2.2%	0.647
3. Asturias	2.7%	-3.7%	-	0.1%	0.045	-1.7%	-
4. Baleares	2.2%	5.4%	2.226	2.1%	0.865	3.6%	1.636
5. Castilla Leon	6.3%	14.2%	2.308	0.8%	0.134	7.1%	1.127
6. Castilla La Mancha	3.7%	6.3%	1.693	2.5%	0.677	4.3%	1.162
7. Canarias	3.5%	6.3%	1.727	3.6%	0.986	4.8%	1.371
8. Cantabria	1.4%	1.8%	1.352	1.3%	0.975	1.5%	1.071
9. Cataluña	19.0%	8.4%	0.443	10.4%	0.548	9.5%	0.500
10. Extremadura	1.8%	-1.9%	-	-1.0%	-	-1.4%	-
11. Galicia	5.9%	-5.0%	-	9.3%	1.662	2.6%	0.441
12. Madrid	14.8%	27.8%	1.813	9.6%	0.626	18.1%	1.223
13. Murcia	2.5%	3.2%	1.304	3.3%	1.332	3.2%	1.280
14. Navarra	1.7%	-0.7%	-	0.9%	0.569	0.2%	0.118
15. Rioja	0.8%	0.1%	0.122	0.7%	0.778	0.4%	0.500
16. Valencia	9.8%	8.2%	0.826	13.8%	1.391	11.2%	1.143
17. Pais Vasco	7.2%	14.8%	2.285	18.4%	2.845	16.7%	2.319

Map 1. Marginal Products of Public Capital: regions with the largest absolute output gains (in dark)



Map 2. Marginal Products of Public Capital: regions in which the effects on output of public capital installed in the region is relatively more important (in dark)



Map 3. Marginal Products of Public Capital: regions with the largest gains in output relatives to their share of Spanish GDP (in dark)

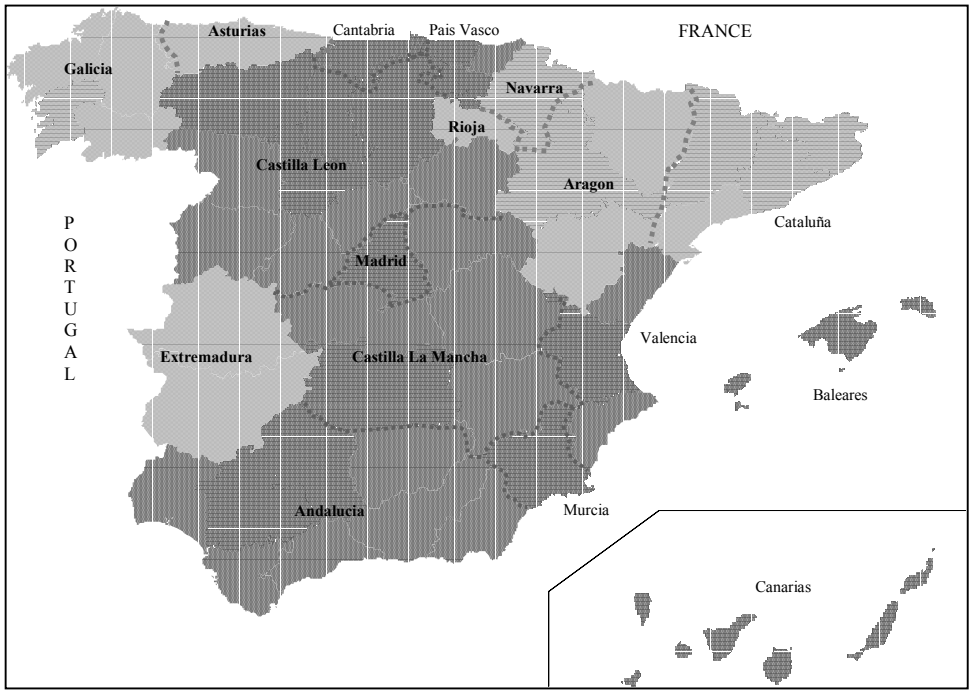


Table 5: Long-term accumulated elasticities and marginal products of private capital with respect to public capital installed inside and outside the region

	Elasticities with respect to		Marginal Products with respect to	
	PK inside	**PK outside**	**PK inside**	**PK outside**
Spain	0.270 [0.270, 0.366]		3.420 [3.420, 4.643]	
1. Andalucia	0.117 [0.116, 0.117]	0.189 [0.053, 0.189]	0.208 [-0.206, 0.208]	0.337 [0.095, 0.337]
2. Aragon	0.047 [-0.018, 0.047]	0.394 [0.237, 0.445]	0.020 [-0.008, 0.020]	0.166 [0.115, 0.187]
3. Asturias	-0.627 [-0.681, -0.453]	0.198 [0.081, 0.238]	-0.230 [-0.250, -0.166]	0.073 [0.030, 0.087]
4. Baleares	0.782 [0.420, 0.782]	-0.138 [-0.366, -0.138]	0.259 [0.139, 0.259]	-0.045 [-0.119, -0.045]
5. Castilla Leon	-0.025 [-0.025, 0.076]	0.220 [0.219, 0.238]	-0.021 [-0.021, 0.064]	0.188 [0.187, 0.203]
6. Castilla La Mancha	0.171 [0.117, 0.171]	0.044 [-0.038, 0.075]	0.091 [0.062, 0.091]	0.024 [-0.021, 0.041]
7. Canarias	0.406 [-0.199, 0.406]	0.407 [0.118, 0.414]	0.182 [-0.089, 0.182]	0.183 [0.053, 0.186]
8. Cantabria	-0.406 [-0.406, 0.183]	0.236 [-0.125, 0.282]	-0.077 [-0.077, 0.035]	0.045 [-0.024, 0.054]
9. Cataluña	0.211 [0.134, 0.275]	0.222 [0.162, 0.257]	0.497 [0.316, 0.648]	0.523 [0.382, 0.605]
10. Extremadura	0.776 [0.181, 0.776]	-0.376 [-0.376, 0.041]	0.220 [0.051, 0.220]	-0.105 [-0.105, 0.011]
11. Galicia	-0.113 [-0.229, -0.112]	0.296 [0.282, 0.327]	-0.087 [-0.176, -0.086]	0.227 [0.216, 0.251]
12. Madrid	0.538 [0.150, 0.538]	0.617 [0.356, 0.617]	0.830 [0.231, 0.830]	0.952 [0.549, 0.952]
13. Murcia	0.160 [0.160, 0.323]	0.329 [0.225, 0.329]	0.051 [0.051, 0.103]	0.105 [0.072, 0.105]
14. Navarra	-0.220 [-0.220, -0.028]	0.173 [0.079, 0.519]	-0.039 [-0.039, -0.005]	0.031 [0.014, 0.093]
15. Rioja	0.034 [-0.075, 0.034]	0.603 [0.531, 0.608]	0.003 [-0.007, 0.003]	0.054 [0.048, 0.054]
16. Valencia	0.227 [0.190, 0.239]	0.353 [0.286, 0.353]	0.332 [0.278, 0.350]	0.518 [0.420, 0.518]
17. Pais Vasco	0.750 [0.520, 0.750]	0.660 [0.260, 0.660]	0.553 [0.383, 0.553]	0.487 [0.192, 0.487]

NB: In parenthesis are the ranges of variation from the sensitivity analysis exercises.

Table 6: Regional distribution of the private capital effects of public capital formation and importance of the spillovers

	Marginal Products with respect to		Marginal Products		Spillovers
	PK inside (1)	PK outside (2)	Total (3)=(1+2)	Regional distribution	(2/3)
Spain			3.420	100.0%	
1. Andalucia	0.208	0.337	0.545	8.3%	62 %
2. Aragon	0.020	0.166	0.186	2.8%	89 %
3. Asturias	-0.230	0.073	-0.157	-2.4%	100 %
4. Baleares	0.259	-0.045	0.214	3.3%	0 %
5. Castilla Leon	-0.021	0.188	0.167	2.5%	100 %
6. Castilla La Mancha	0.091	0.024	0.115	1.7%	21 %
7. Canarias	0.182	0.183	0.365	5.6%	50 %
8. Cantabria	-0.077	0.045	-0.032	-0.5%	100 %
9. Cataluña	0.497	0.523	1.020	15.5%	51 %
10. Extremadura	0.220	-0.105	0.115	1.8%	0 %
11. Galicia	-0.087	0.227	0.140	2.1%	100 %
12. Madrid	0.830	0.952	1.782	27.2%	53 %
13. Murcia	0.051	0.105	0.156	2.4%	67 %
14. Navarra	-0.039	0.031	-0.008	-0.1%	100 %
15. Rioja	0.003	0.054	0.057	0.9%	95 %
16. Valencia	0.332	0.518	0.850	13.0%	61 %
17. Pais Vasco	0.553	0.487	1.040	15.9%	47 %
Total all regions	2.794	3.762	6.556		
Total as % of Spain	81.7%	110.0%	191.7%		

Table 7: Long-term accumulated elasticities and marginal products of employment with respect to public capital installed inside and outside the region

	Elasticities with respect to		Marginal Products* with respect to	
	PK inside	**PK outside**	**PK inside**	**PK outside**
Spain	0.414 [-0.084, 0.414]		62.50 [-12.69, 62.50]	
1. Andalucia	0.324 [0.243, 0.483]	0.071 [-0.248, 0.109]	7.04 [5.28, 10.50]	1.56 [-5.47, 2.40]
2. Aragon	0.189 [0.085, 0.206]	0.040 [-0.299, 0.040]	0.96 [0.43, 1.04]	0.17 [-1.30, 0.17]
3. Asturias	-0.759 [-0.807, -0.759]	-0.048 [-0.226, -0.003]	-3.22 [-3.42, -3.22]	-0.17 [-0.96, -0.01]
4. Baleares	0.841 [0.129, 0.849]	0.001 [-0.176, 0.006]	2.52 [0.39, 2.54]	0.00 [-0.46, 0.02]
5. Castilla Leon	0.183 [0.167, 0.352]	-0.234 [-0.381, -0.227]	1.83 [1.67, 3.51]	-2.35 [-3.82, -2.28]
6. Castilla La Mancha	0.056 [-0.167, 0.099]	-0.700 [-1.201, -0.700]	0.35 [-1.04, 0.61]	-4.43 [-7.61, -4.43]
7. Canarias	1.421 [-0.106, 1.421]	0.227 [-0.031, 0.370]	7.82 [-0.58, 7.82]	1.48 [-0.20, 2.41]
8. Cantabria	-0.111 [-1.228, 0.293]	0.626 [0.100, 1.113]	-0.26 [-2.89, 0.69]	1.30 [0.21, 2.32]
9. Cataluña	-0.163 [-0.163, 0.293]	0.006 [-0.587, 0.033]	-4.26 [-4.26, 7.66]	0.17 [-17.01, 0.96]
10. Extremadura	-0.329 [-0.758, 0.402]	-0.050 [-0.736, -0.026]	-1.22 [-2.80, 1.49]	-0.17 [-2.56, -0.09]
11. Galicia	-0.106 [-0.243, -0.097]	-0.046 [-0.205, -0.040]	-1.30 [-2.99, -1.19]	-0.61 [-2.71, -0.53]
12. Madrid	0.271 [-0.028, 0.290]	0.175 [-0.075, 0.186]	5.39 [-0.56, 5.77]	3.48 [-1.49, 3.70]
13. Murcia	0.571 [0.505, 0.621]	0.230 [0.150, 0.336]	2.17 [1.92, 2.36]	0.87 [0.57, 1.27]
14. Navarra	0.068 [0.068, 0.109]	0.012 [-0.118, 0.111]	0.17 [0.17, 0.28]	0.03 [-0.31, 0.29]
15. Rioja	0.132 [0.052, 0.156]	0.725 [0.518, 0.737]	0.17 [0.07, 0.21]	0.78 [0.56, 0.80]
16. Valencia	0.158 [0.146, 0.215]	0.217 [0.093, 0.217]	2.43 [2.25, 3.31]	3.39 [1.45, 3.39]
17. Pais Vasco	0.821 [0.274, 0.917]	0.477 [0.058, 0.477]	6.95 [2.32, 7.77]	4.00 [0.49, 4.00]

NB: In parenthesis are the ranges of variation from the sensitivity analysis exercises.
* Marginal Products measured as number of workers per one million 2001euros

Table 8: Regional distribution of the employment effects of public capital formation and importance of the spillovers

	Marginal Products* with respect to		Marginal Products		Spillovers
	PK inside (1)	PK outside (2)	Total (3)=(1+2)	Regional distribution	(2/3)
Spain			62.50	100.0%	
1. Andalucia	7.04	1.56	8.61	23.1%	18 %
2. Aragon	0.96	0.17	1.13	3.0%	15 %
3. Asturias	-3.22	-0.17	-3.39	-9.2%	0 %
4. Baleares	2.52	0.00	2.52	6.9%	0 %
5. Castilla Leon	1.83	-2.35	-0.52	-1.4%	0 %
6. Castilla La Mancha	0.35	-4.43	-4.09	-11.0%	0 %
7. Canarias	7.82	1.48	9.30	25.2%	16 %
8. Cantabria	-0.26	1.30	1.04	2.9%	100 %
9. Cataluña	-4.26	0.17	-4.09	-11.1%	100 %
10. Extremadura	-1.22	-0.17	-1.39	-3.6%	-
11. Galicia	-1.30	-0.61	-1.91	-5.1%	-
12. Madrid	5.39	3.48	8.87	23.9%	39 %
13. Murcia	2.17	0.87	3.04	8.3%	29 %
14. Navarra	0.17	0.03	0.20	0.4%	0 %
15. Rioja	0.17	0.78	0.96	2.5%	82 %
16. Valencia	2.43	3.39	5.82	15.6%	58 %
17. Pais Vasco	6.95	4.00	10.95	29.7%	37 %
Total all regions	27.56	9.51	37.05		
Total as % of Spain	44.1%	15.1%	59.3%		

* Marginal Products measured as number of workers per one million 2001 euros