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SPILLOVER EFFECTS OF PUBLIC CAPITAL FORMATION: EVIDENCE FROM THE SPANISH REGIONS

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Abstract

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. The objective of this paper is to provide evidence on the possible existence of such spillovers. We consider the case of Spain and its seventeen regions. Our methodological approach consists in estimating an aggregate VAR model for Spain as well as seventeen region-specific VAR models in which both capital installed in the region and capital installed outside the region are allowed to play a role in enhancing regional output. The estimation results can be summarized as follows. The aggregate effects of public capital formation in Spain are important. They cannot, however, be captured in their entirety by the direct effects in each region from public capital installed in the region itself. When for each region both the capital installed in the region and the capital installed outside the region are considered the total disaggregated effect from the seventeen regional models are very much in line with the aggregate results. Furthermore, the aggregate effect seems to be due in almost equal parts to the direct and spillover effects of public capital formation. Ultimately, this paper establishes the relevance of both capital installed in each region and spillover effects in the understanding of the regional decomposition of the aggregate effects of public capital formation. In doing so it opens the door to some tantalizing and potentially highly charged research issues in terms of the determination of the optimal location of public investment projects.

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1. Introduction

The evaluation of the impact of public capital formation on private output has received great attention in the literature. This issue was brought to the limelight by the work of Aschauer (1989a, 1989b). His results suggested that public investment would have such large effects that it would pay for itself close to three times in the form of additional tax revenues over the duration of the public capital assets [see Reich (1991)]. Such large effects induced a flurry of attention to the issue. Subsequent research, however, failed to replicate such large effects. Indeed, it often even failed to find meaningful positive results [see Gramlich (1994) and Munnell (1992) for detailed surveys of the literature and Hulten and Schwab (1993) for a detailed presentation on the infrastructure debate].

Aschauer's work has, in particular, inspired a large body of 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 [see, for example, Holtz-Eakin (1994), Evans and Karras (1994) and Garcia-Milà et al. (1996)]. The main conclusion of this literature seems to be, paraphrasing Garcia-Milà et al. (1996), that no clear evidence of a positive linkage between public capital and private output has been found at the regional level for the US within the aggregate production function framework.

One possible conjecture as to the inconclusive nature of the research with a regional focus is that this is due to the fact that this research 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. Indeed, 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 Spanish case is a very interesting case. 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 [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)].

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 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 seventeen 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 allows us to address much of the econometric criticisms of some of the previous literature, in a rigorous and comprehensive manner. These concerns related to simultaneity issues, to the non-stationarity of variables, and to the implicit assumption of exogeneity of public capital, [See Jorgenson (1991) and Munnell (1992) for

comprehensive discussion of these econometric problems.] It also 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.

Dynamic feedbacks are essential to understand the relationship between public capital and economic performance. Indeed, public capital affects output directly as an additional input in the production function. Moreover, as a positive externality to aggregate production, public capital should, *ceteris paribus*, lead to higher aggregate production. Public capital also affects aggregate production indirectly via its effects on the use of private inputs, capital and labor. It is conceivable that a greater availability of public capital could reduce the demand for private inputs (a substitution effect). Higher availability of public capital, however, also increases the marginal productivity of private inputs. This lowers the marginal costs of production, thereby potentially increasing the level of aggregate production (a scale effect).

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. By this we mean that it is possible that the evolution of private sector variables may be leading the evolution of public capital.

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 capital installed in the region itself and capital located outside the region through the use of orthogonalized impulse response functions. Finally, in Section 5, we provide a summary and some concluding remarks

2. Data and Preliminary Results

2.1 Data: sources and description

We consider annual data on private 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 17 autonomous communities 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. 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 and public capital series 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.

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 use three different sets of VAR models. First, we use a VAR with aggregate variables for the whole country. This model is designed to gives us the overall picture on the effects of public capital in Spain. Second, we use VAR models with region-specific variables. These models are designed just to suggest that focusing only on the effects of public capital installed in the regions may miss part of the picture. Third, we use VAR models public including capital installed in the other regions in addition to region-specific variables. These models yield the central results in the paper. Because of the nature of the different sets of models we have decided to focus on the VAR specification for the first and third sets of models and adopt for the second set the same specification as in the third. This way, the results in the second, and less important, set of results more readily comparable with the rest of results in the paper.

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 ten of the seventeen regions. For the remaining seven regions, Andalucia, Baleares, Castilla-Leon, Castilla-La Mancha, Cataluna, 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

The central issue for the determination of the effects of public investment on the output is the identification of shocks to public capital that are not contemporaneously correlated with shocks in the private sector variables, i.e., shocks that 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 relevant information set for the policy makers includes past values but not current values of the aggregate 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 shocks to public capital that are not contemporaneously correlated with shocks in the private sector variables, 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 means that innovations in public capital outside the region affect contemporaneously innovations of public capital in the region but the reverse is not true. 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 2-4 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 3 regions and negative in 3 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.

3.2 Measuring the Effects of Innovations in the Public Capital Variables

We consider the effects of one-percentage point, one-time innovation in the rate of growth of public capital on private output 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.

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 20 years, although most impulse response functions converge in between 5 and 10 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 disaggregated figures directly comparable to the marginal product obtained from the aggregate model for the whole country.

4. On the Regional Effects of Public Capital Formation

4.1 On the aggregate effects of public capital formation in Spain

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 at the aggregate level of the whole economy. The relevant results are reported in Table 2.

Estimation results suggest that the accumulated elasticity of output with respect to public capital is 0.523. This 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 On the regional decomposition of the aggregate effects in the absence of spillovers

Our ultimate objective is to provide a regional decomposition the aggregate positive effects of public capital formation we have just identified. A natural starting point in pursuing this objective is to consider the results of the impulse-response function analysis associated with region-specific VAR models relating regional output, employment, and private capital, and public capital located in the region itself. We estimate, therefore, a total of seventeen regional models. The corresponding elasticities and marginal products are reported in Table 3.

The empirical results obtained from these regional models confirm the positive effects of public capital on output. In fact, in fourteen of the seventeen regions the accumulated elasticities of output with respect to public capital are positive. A casual look at the accumulated marginal products of public capital suggests that Andalucia and Madrid and to a lesser extent Castilla-Leon, Canarias, Cataluna, Valencia, and Pais Vasco seem to benefit substantially from public capital formation located in their jurisdiction.

A critical question, however, is to what extent the empirical results obtained form these seventeen regional models capture the aggregate effect of public capital in Spain in its entirety. Consider first that, in all but two the accumulated elasticity of output with respect to public capital is lower than the accumulated elasticity of output at the aggregate Spanish level. This result is along the lines of the evidence for the US in Munnell (1992). It suggests that the regional models

are not capturing the aggregate effect of public capital on output in its entirety. The regional estimates of the long-term accumulated marginal productivity of public capital make this point abundantly clear. In fact, the sum across regions of the effects induced by the public capital installed in the region itself, accounts for only 44% of the total effects of public capital identified at the aggregate level.

These results are consistent with the conjecture that the effects of public capital cannot be fully captured with the use of strictly regional data. They indicate the possible existence of important spillover effects for each region from public capital installed in the other regions. Naturally, these spillovers cannot be captured in the regional models estimated in this sub-section. This is because these models include exclusively public capital installed in the region itself.

4.3 On the importance of spillover effects from public capital installed in other regions

In order to take into account the possible existence of spillover effects produced by the public capital installed in other regions, we now estimate more general region-specific VAR models. These more general region-specific models include, in addition to the four variables as in the previous sub-section, a fifth variable reflecting the public capital installed in the rest of the country. We now 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 Table 4.

The new estimates of the elasticities of regional output with respect to public capital installed in each region generally have the same sign and the same order of magnitude as the ones reported in the previous sub-section. Furthermore, the sum across all the regions of the marginal products of the public capital installed in the region itself is now 50.1% of the aggregate marginal product estimated for Spain as a whole. It is therefore of the same order of magnitude of the sum estimated in the previous sub-section, which was 44.0% of the total. This suggests that these new measures of the effects of public capital installed in each region are in line with the measures presented in the previous sub-section.

More importantly, estimation results suggest that in all but one region the regional output is affected positively by innovations in public capital installed outside that region. This result suggests very strongly the existence of spillover effects for each region from capital installed in other regions. Furthermore, 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.

There are three important corollaries of these results. First, these results suggest that the public capital installed in each region have an important positive effect on output in that region. These direct regional effects, however, account for only 50.1% of the aggregate effects of public capital installed in the country. Second, these results show that that the spillover effects of public capital installed outside each region are also very important in quantitative terms. Indeed, the measure of the spillovers - 57.1% of the aggregate effect, is comparable, in fact slightly greater, than the direct effects of public capital installed in the region. Third, 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 indeed.

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

The results so far establish the overall relevance of the spillover effects of innovations in public capital installed outside each region in addition to the direct effects of capital installed in the region itself. Obviously this general pattern has some interesting regional nuances. We are now interested in identifying which regions seem to benefits 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 5.

Estimation results suggest that, for six of the seventeen regions, the direct effects of public capital installed in the region are more relevant than the spillover effects from public capital installed outside the region. This is the case of Baleares, Castilla-Leon, Castilla-La Mancha, Canarias, Cantabria and Madrid. In the case of Baleares and Canarias this is hardly surprising since 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. The other four regions, form with Extremadura, for which public capital formation does not seem to have a positive impact, the interior spinal chord of the country, located as they are in the central area of the Iberian Peninsula.

In turn, for 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, Cataluna, 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, 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.

5. Summary and Concluding Remarks

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. Indeed, 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 private output, employment, and 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. Moreover, 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.

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 is a powerful instrument to promote long-term output growth in Spain. To identify the regional effects of public capital formation we first estimate region-specific VAR models relating private sector variables in a region to public capital located in the region. In doing so we find that public capital has positive effects for most regions. More importantly we find that the sum of the regional marginal products is well below the estimated marginal product estimated for Spain at the aggregate level. This suggests the possible existence of spillover effects from capital located in other regions.

To capture the spillover effects of public capital formation we estimate region-specific VAR models relating private sector variables to both public capital installed in the region itself as well as public capital located outside the region. This approach allows us to estimate the marginal products for each region of public capital located in the regions. In addition, it allows us to

estimate the marginal product of public capital located outside the region, which we take as a measure of the spillover effects of public capital formation. Empirical results from these more general regional models suggest that spillover effects are very important. In fact, spillovers account for over half of the aggregate effects of public capital formation previously estimated, the remainder being accounted for by the effects of public capital installed in the region itself.

In general, the estimation results suggest that the different regions of Spain benefit from either public capital installed in the region or from spillover effects from capital installed elsewhere, or from both. The same empirical results, however, also suggest that 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 infrastrures installed outside the region while for central regions accessibility depends more on public infrastructures in the region itself.

This paper establishes the relevance of both capital installed in each region and spillover effects in the understanding of the regional decomposition of the aggregate effects of public capital formation. In doing so it opens the door to some tantalizing and potentially highly charged research issues in terms of the determination of the optimal location of public investment projects. Since 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. If the major concern of a country is to promote catching up of its standards of living to some international paradigm this may be of critical relevance. Also, we would want to know which locations would serve best the objective of reducing regional disparities. If is its quest for aggregate growth the country wants also to reduce regional asymmetries this is a critical question. Our results suggest that the answer to the two questions is not necessarily the same. Furthermore, our results challenge the conventional wisdom that the best way of promoting the development of a given region is by developing the public infrastructure installed in the region itself.

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Table 1: Data description - averages for 1970-1995

	Regional Output (% of Spain)	**Regional Public Capital (% of Spain)**
Spain	100.0%	100.0%
1. Andalucia	13.3%	14.4%
2. Aragon	3.4%	4.5%
3. Asturias	2.7%	4.5%
4. Baleares	2.2%	1.4%
5. Castilla Leon	6.3%	9.4%
6. Castilla La Mancha	3.7%	5.3%
7. Canarias	3.5%	3.3%
8. Cantabria	1.4%	1.7%
9. Cataluña	19.0%	16.7%
10. Extremadura	1.8%	2.2%
11. Galicia	5.9%	6.5%
12. Madrid	14.8%	8.9%
13. Murcia	2.5%	1.4%
14. Navarra	1.7%	2.7%
15. Rioja	0.8%	1.7%
16. Valencia	9.8%	8.0%
17. Pais Vasco	7.2%	7.5%

Table 2 - Aggregate effects of public capital formation on output

	Elasticity	**Marginal Product**
Central case	0.523	2.892
Range of results	[0.180, 0.625]	[0.997, 3.785]
Mean of all results	0.447	2.471

Table 3: Long-term accumulated effects on output of regional public capital in the absence of spillovers

	Elasticities	**Marginal Products**
Spain	0.523 [0.180, 0.625]	2.892 [0.997, 3.785]
1. Andalucia	0.347 [0.187, 0.404]	0.259 [0.140, 0.302]
2. Aragon	0.098 [-0.013, 0.105]	0.019 [-0.003, 0.020]
3. Asturias	-0.237 [-0.237, -0.016]	-0.035 [-0.035, -0.002]
4. Baleares	0.593 [0.554, 0.598]	0.079 [0.074, 0.080]
5. Castilla Leon	0.294 [0.083, 0.373]	0.100 [0.028, 0.127]
6. Castilla La Mancha	0.324 [0.145, 0.324]	0.066 [0.030, 0.066]
7. Canarias	0.457 [0.135, 0.457]	0.092 [0.027, 0.092]
8. Cantabria	0.703 [0.156, 0.703]	0.052 [0.012, 0.052]
9. Cataluña	0.123 [0.106, 0.208]	0.129 [0.111, 0.218]
10. Extremadura	-0.560 [-0.670, -0.276]	-0.059 [-0.071, 0.029]
11. Galicia	0.161 [-0.064, 0.161]	0.050 [-0.020, 0.050]
12. Madrid	0.325 [0.190, 0.412]	0.275 [0.161, 0.349]
13. Murcia	0.272 [0.266, 0.342]	0.037 [0.036, 0.047]
14. Navarra	-0.102 [-0.102, 0.023]	-0.009 [-0.009, 0.002]
15. Rioja	0.017 [-0.066, 0.028]	0.001 [-0.004, 0.002]
16. Valencia	0.216 [0.198, 0.217]	0.118 [0.108, 0.119]
17. Pais Vasco	0.265 [0.070, 0.337]	0.095 [0.025, 0.121]
Total all regions Total as % of total Spain		1.269 44%

Table 4: Long-term accumulated effects on output of public capital installed in the region and outside the region

	Elasticities with respect to		**Marginal Products with respect to**	
	PK inside	**PK outside**	**PK inside**	**PK outside**
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]
Total all regions Total as % of total Spain			1.447 50.1%	1.651 57.1%

Table 5: On the importance for each region 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%	