PUBLIC INVESTMENT IN TRANSPORTATION INFRASTRUCTURES AND ECONOMIC PERFORMANCE IN PORTUGAL

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Abstract - This paper uses a VAR approach to investigate the effects of aggregate and disaggregate measures of public investment in transportation infrastructures on private investment, employment, and output in Portugal. Estimation results suggest that public investment in transportation infrastructures crowds in private investment and employment and, therefore, has a strong positive effect on output. Indeed, we estimate that one euro invested in public investment increases output in the long-term by 9.5 euros. This figure suggests that public investment pays for itself 3.3 times in the form of tax revenues over the life span of the public capital asset. Furthermore, this figure corresponds to a rate of return of 15.9%, which is clearly higher than the rate of return expected on private investment activities. A close look at the effects of different types of public investment is very informative, since it shows which types of public investments are the most productive. In terms of marginal productivities, the highest effects on private investment come from public investment in ports, airports and national roads. In terms of job creation, the highest effects come from public investment in ports, municipal roads, and national roads. Finally, in terms of the effects on output the largest effects come from investment in ports followed by national roads, municipal roads, airports, and railroads. The results in this paper are very important from a public policy perspective. This is because they suggest that public investment in transportation infrastructures has been a powerful instrument to promote long-term growth and that the strategy followed by the Portuguese authorities of investing in public infrastructures is justified both from a long-term development perspective as well as from a public budgetary perspective.

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I. Introduction

One of the nagging aspects in the Portuguese economic performance is the relative backwardness of the Portuguese economy vis-à-vis the European Union partners. From the 1970s until around the late 1980s the Portuguese GDP per capita in purchasing power parity was just approximately around 55% of the EU average. The magnitude and persistence of the relative backwardness of the Portuguese economy has been explained by the lack of domestic long-term growth fundamentals. Historically serious distortions in the financial markets lead to lagging private investment while a narrow domestic tax base hindered the development of a modern infrastructure. These difficulties justified the EU structural funds programs after 1989. The cornerstone of these structural transfer programs was the development of a modern transportation infrastructure network. Therefore, over the last decade, the strategy of development in Portugal has been largely based on transportation infrastructure development.

Interestingly enough, despite the central role of public infrastructure development and the intuitive knowledge of the relative scarcity of public infrastructures in Portugal, no information was available on the actual impact of this development strategy. While the impact of infrastructure development on private investment, employment and output has been assumed to be positive and important, there has been complete ignorance as to what the actual effects might be. In particular, no estimates exist of the rates of return on different types of infrastructure investment. Therefore no information exists on relationship between the rates of return on public investments and the rate of return on private investment projects. This information, however, is crucial to determine the appropriateness of the development strategy followed in Portugal.

The most important reason for the absence of estimates of the rates of return to public infrastructure investment in Portugal, as indeed for most other countries of comparable or lower levels of development, has been the absence of the most basic data on public investment itself. This is because of the highly decentralized nature of the institutions in charge of the different types of public investment as well as the constant shifting in jurisdictions in public investment activities. In the case of Portugal, however, the problem of the absence of a data set has now been solved. The authors concluded recently the construction of a detailed database of public investment in transportation infrastructures, under the auspices of the Portuguese

Ministry of Planning [see Pereira and Andraz (2001)].

In this paper we estimate empirically the impact of infrastructure investment in the area of transportation on aggregate economic performance in Portugal. We focus on aggregate public investment as well as on different types of transportation infrastructure - roads and highways, ports, airports, and railways - to evaluate the effects of such public investments on private investment, employment and, ultimately, on output. We seek to estimate the marginal products and the rates of return of public investment in different types of transportation infrastructures.

Although this paper focuses on the Portuguese case and deals with issues that are of great importance for policy making in Portugal, its interest is not merely parochial. Indeed, the issue of the effects of public investment on private sector performance 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.

The empirical evaluation of the effects of public capital formation on private output was brought to the limelight by the work of Aschauer (1989a, 1989b). Using a single-equation static production function approach based on aggregate measures of public capital, Aschauer (1989a, 1989b) suggests that public capital has been a powerful engine for growth in the United States. In fact, his results suggest that public investment 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)]. Subsequent analysis applying the same methodology to regional and sector-specific data in the United States as well as international data, 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].

The work of Aschauer inspired an important body of literature on the impact of infrastructure development for other countries. This includes contributions that are country-specific and others that have a multi-country focus. In the first case one could mention, for example, the work of Otto and Voss (1996) for Australia, Seitz (1994) for Germany, Sturm and de Haan (1995) for Holland, Merriman (1990) for Japan, Shah (1992) for Mexico, Pereira and Roca (1999) for Spain, Berndt and Hansson (1992) for Sweden, and Lynde and Richmond (1993) for the UK. In the second case one could mention, for example, the work of Aschauer (1989c), Evans and Karras (1993), Ford and Poret (1991), and Mittnik and Newman (1998), all focusing on developed OECD countries. The magnitude and significance of the empirical results varies greatly among countries. Furthermore, international comparisons are rendered very difficult by the use in the literature of different measures of public capital, different levels of aggregation, and different methodologies.

The approach used in Aschauer (1989a, 1989b) and much of the literature that followed focuses on measuring the effects of public investment on private output using a single equation, static production function approach. In this approach, private output is regressed on public capital and private inputs – employment and capital. This approach has been criticized on econometric grounds. It has been observed that the estimation of static, univariate production functions in levels (or log-levels) is based on non-stationary variables. Therefore, OLS estimates are spurious in the absence of cointegration. Moreover, OLS estimates suffer from simultaneity bias. Even if this bias is corrected, conclusions about causality still cannot be drawn. [See Jorgenson (1991) and Munnell (1992) for comprehensive discussion of these econometric problems.]

In this paper, we follow Pereira (2000) and adopt a vector auto-regressive/error correction mechanism approach. This multivariate time series approach allows us to address the aforementioned econometric criticisms in a rigorous and comprehensive manner. 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. This exclusion is of paramount importance for it is likely that feedbacks exist. If they do, a zero elasticity of private output with respect to public capital, as obtained from a single-equation static production function approach, is neither a necessary nor a sufficient condition for public investment to be ineffective in influencing output.

Dynamic feedbacks are essential to a conceptual understanding of the relationship between public investment and aggregate economic performance. Indeed, public investment affects output directly as an additional input in the production function. Moreover, as a positive externality to aggregate production, public investment should, *ceteris paribus*, lead to higher aggregate production. Public investment 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 inputs and aggregate output can conceivably affect the evolution of public investment. Indeed, increasing aggregate output provides the government with a growing tax base and the potential for greater public investment. 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 aggregate output and private inputs may be leading the evolution of public investment.

This paper is organized as follows. In Section II, we present the data set used in our analysis. In particular, we present in some detail the new public investment data for Portugal (see also the Appendix). We also report preliminary empirical results including univariate and cointegration analysis and report on the specification of the vector auto-regressive/error correction mechanism models. In Section III, we introduce and discuss some methodological issues in the identification and measurement of the effects of innovations in public investment. In Section IV, we analyze the effects on economic performance - output, employment, and private investment - of aggregate and disaggregate measures of public investment through the use of orthogonalized impulse response functions. Finally, in Section V, we provide a summary and some concluding remarks.

II. Data and Preliminary Empirical Results

A. Data: sources and description

We use annual data for the period 1976 to 1998. We consider output (gdp), employment (emp), private investment (inv), in addition to public investment in transportation infrastructures (pinv). The data on output, employment, and private investment in presented in Table 1. This data was obtained from the Bank of Portugal/Banco de Portugal (1997), Commission of the European Communities (1999), and Ministry of Finance/Ministério das Finanças (2000). Output and private investment are measured in millions of constant 1995 Portuguese escudos while employment is measured in full-time equivalent employees.

The data for public investment in transportation infrastructures (pinv) is obtained from Pereira and Andraz (2001). This database is the result of a long and meticulous investigation, sponsored by the Portuguese Ministry of Planning. This database includes data on public investment, both at current and constant 1995 prices deflated by the GDP as well as the private investment deflators. It includes public investment in national roads, municipal roads, highways, ports, airports, and railways. It covers the period from 1974 to 1998, despite some failures of information regarding the two first years, due to lost data at the source. Since this database has not been published before and is used in this article for the first time, it is provided here in Table 2 and we discuss some of its main features below. For the same reason we also included in an Appendix to this paper the executive summary of Pereira and Andraz (2001). All of the data is in 1995 Portuguese escudos deflated using the GDP price deflator. The use of the private investment deflator would lead to only marginal changes in the empirical results in this paper.

To talk about the main features of the public investment data in Portugal one has immediately to recognize the existence in the second half of the sample period of EU sponsored structural transfer programs in the form of Community Support Frameworks for Portugal. The first Community Support Framework program covered the period from 1989 to 1993 and the second covered the period from 1994 to 1999. Therefore, our sample includes 13 years prior the programs and 10 years of with the programs.

In what follows we consider an aggregate measure of public investment in transportation infrastructures, as well as six disaggregated measures pertaining to public investment on roads, ports, airports and railways. We present the evolution of each type of investment as a percentage of the GDP and as a percentage of private investment in Tables 3 and 4, respectfully, and in Figures 1-7. We present the evolution of the composition of public investment in transportation infrastructures in Table 5 and Figure 8.

The first type of public investment (pinv1) is core infrastructure investment in national roads. It averages 0.48% of the GDP for the sample period. It experiences a strongly increasing trend during the sample period, from 0.34% of the GDP in the early years of the sample to 0.76% by the end of the sample period. The second type of public investment (pinv2) is core infrastructure investment in municipal roads. It averages 0.40% of the GDP for the sample period and shows less of a variation in that it averages 0.35% in the first part of the sample and 0.45% in the second. The third type of public investment (pinv3) is core infrastructure investment in highways. It represents an average of 0.21% of the GDP over the sample period, although the average in the early years is just 0.13% and in the second part of the sample is 0.32%. The fourth type of public investment (pinv4) is core infrastructure investment in ports. It represents on average 0.12% of the GDP and has experienced a decline from 0.15% in the 1970s and 80s to about 0.08% in the last decade. The fifth type of public investment (pinv5) is infrastructure investment in airports, and has remained stable over the sample period at about 0.05% of the GDP. Finally, the sixth type (pinv6) is core infrastructure investment in railways. It averages 0.29% of the GDP for the period and it only shows an upward trend in the last few years of the sample.

Overall, aggregate public investment (pinv) averages 1.55% of the GDP for the sample period. It changes, however, from an average of 1.24% for 1976-88 to an average of 1.96% for 1989-1998. The data suggests that the increase through the 1990s in the overall figures is due mostly to increases in public investment in national roads (pinv1) and highways (pinv3) and, more recently, in railroad investment (pinv6).

All of the considerations above suggest that the data fully reflect the conventional wisdom that the EU structural transfer programs brought a greater dynamism to the public investment in infrastructures. They are also very informative about the effects of the EU Community Support Frameworks in terms of the composition of public investment in transportation infrastructures. In fact, core investment in national roads (pinv1) is one of the greatest beneficiaries of these programs. Its share on total public investment increased from 27.4% in the 1980s to 33.7% in the 1990s. Core investment in highways (pinv3) also increased its share, from 10.1% to 16.5%. Core investment in railways (pinv6), was also positively affected by EU programs. During the period between 1989 and 1998, it represents 19.3% of total public investment after having accounted for about 17% until 1988. On the other side of the spectrum are the other types of public investment whose shares decreased during the period covered by EU programs. The share of public investment on municipal roads (pinv2) declined from 29.2% to 23.3%, while the share of investment on airports (pinv5) declined from 3.7% to 2.9%. However, the greater losses occurred in public investment on ports (pinv4). From a share of 12.1% in the period before 1989, it represents only 2.9% of total public investment during the 1990s.

Besides the changes in magnitude and composition of public investment before and after the Community Support Frameworks, it is also possible to detect some changes from the first program (1989-93) and second (1994-98). The shares of public investment on national roads (pinv1) and on railways (pinv6) show an increasing trend during the two structural programs. Their shares to total public investment during the second program are higher than the average share for the 1990s. The share of public investment on highways (pinv3), decreased from 17.4% to 15.7% to total public investment during the second program. Public investment on municipal roads (pinv2) shows a continuous decreasing pattern during the 1990, from 29.2% before the structural programs, to 25.9% and 20.6% during the first and the second programs, respectively. Public investment on ports (pinv4), whose share to total was 12.1% in the period until 1988, suffered a sharp decline during the first program to 5.3%. During the second program, its share still decreased to 3.5%. Finally, the share of public investment on airports (pinv5) decreased to 3.4% during the first program, and to 2.4% thereafter.

We conclude this discussion of the public investment data with some brief international comparisons. International data comparisons are very difficult. This is mostly due to the fact that the definition of the public investment data and its scope vary greatly across countries. Furthermore, detailed disaggregated public investment data sets are not readily available for most countries. Despite these cautionary words we provide a tentative comparison of aggregate public investment in transportation infrastructures in Portugal, Spain and the United States. For the Spanish data sources and specific definitions see Pereira and Roca (1999) and for the US case see Pereira (2000). We present the evolution of public investment in transportation infrastructures as a percentage of the GDP for these three countries in Figure 9.

There are two aspects that are worth mentioning. First, aggregate public investment in transportation infrastructures in Portugal is of the same order of magnitude as in Spain. In both countries public investment in transportation infrastructures tends to be somewhat above the levels for the US, in particular after the late 1980s. This is an obvious implication of the EU structural programs, which have been in effect for both countries since 1989. Second, the upward trend that can be detected after the late 1980s in both Portugal and Spain is much less pronounced in the Spanish case after 1993. This can also be explained by the characteristics of the EU structural programs. Indeed, the EU structural programs for Spain became less important after 1994, with the inception of the second Community Support Framework.

B. Univariate and cointegration analysis

We start by using the Augmented Dickey-Fuller (ADF) t-test to test the null hypothesis of a unit root in the different variables. We use the Bayesian Information Criterion (BIC) to determine the optimal number of lagged differences to be included in the regressions, and we include deterministic components, a constant and/or a trend, in the regressions if they are statistically significant.

The results of the ADF t-tests applied to the different variables in log-levels, are presented in the top part of Table 6. In all the cases, the t-statistics are lower, in absolute levels, than the 5% critical values. Therefore, the ADF tests cannot reject the null hypothesis of a unit root in these variables. In turn, the results of ADF t-tests applied to the first differences of the log-levels, i.e., the growth rates of the original variables, are presented in bottom part of Table 6. All critical values are greater, in absolute value, than the 5% critical value. Therefore, we can reject the null hypothesis of unit roots in the growth rates of the variables. We take this evidence as an indication that stationarity in first differences is a good approximation for all the time series under consideration.

We also test the null hypothesis of a unit root in the different variables using the Phillips-Perron test, which takes into consideration the possible existence of structural breaks in the evolution of the variables. This is an important step since due to the different EU structural programs structural breaks are likely to exist. We follow the same strategy as above in the determination of optimal lags and deterministic components in the tests. The test results are reported in Table 7. The results from the Phillips-Perron unit roots tests completely confirm the previous unit root test results. Again the strong evidence is that stationarity in first differences is a good approximation for all the time series under consideration.

It should be pointed out that this empirical evidence is consistent with the conventional wisdom in the macroeconomics literature that aggregate public investment, output, employment, and private investment are stationary in first differences. Although our public investment series is more disaggregated, the same pattern of stationarity in first differences is not surprising.

We now test for cointegration among output, employment, aggregated private investment, and aggregated public investment as well as each one of the six public investment variables. We use the standard Engle-Granger approach to test for cointegration. We have chosen this procedure over the often-used Johansen approach for two reasons. First, since we do not have any priors that suggest the possible existence of more than one cointegration relationship, the Johansen approach is not strictly necessary. More importantly, however, for small samples, Johansen's tests are known to induce strong bias in favor of finding cointegration when it does not exist. [See, for example, Gonzalo and Lee (1998).] Therefore, our relatively small sample size suggests that the standard Engle-Granger approach will lead to more accurate results.

Following the standard Engle-Granger approach, we perform four tests in each case. This is because it is possible that one of the variables will enter the cointegrating relationship with a statistically insignificant coefficient. We do not know, a priori, whether or not this will happen. If it does happen, however, a test that uses such a variable as the endogenous variable will not pick up the cointegration. Therefore, a different variable is endogenous in each of the four tests. We apply the ADF t-test to the residuals from the regressions of each variable on the remaining variables. In all of the tests, the optimal lag structure is chosen using the BIC, and a deterministic component is included if it is statistically significant.

The results of the cointegration tests at the aggregate level are reported on the top part of Table 8.

The value of the t-statistics is lower, in absolute value, than the 5% critical values for at least three of the four cases considered. Moreover, all the test statistics are lower, in absolute value, than the 1% critical values. Thus, the ADF tests cannot reject the null hypothesis of a random walk, and we cannot reject that the variables are not co-integrated at this aggregated level.

Cointegration tests were also performed with aggregate output, employment and private investment, together with each of the six different types of public investment. Results are also reported in Table 8. For all six public investment variables, the value of the t-statistics is lower, in absolute value, than the 5% critical values for all but four of the twenty-four cases considered. We take this as strong evidence that, consistently with the results at the aggregate level, the variables are not cointegrated at the more disaggregated level.

C. VAR specifications and estimates

We have now determined that all of the variables have the same order of integration and, in particular, that they are stationary of first order. We have also determined that the variables do not seem to be cointegrated, either at the aggregate level or at the more disaggregated level. Accordingly, we follow the standard procedure in the literature and determine the specifications of the VAR models using growth rates of the original variables (denoted by ggdp, gemp, ginv, gpinv, etc).

We estimate seven VAR models. All VAR models include aggregate output, employment, and private investment. In addition, each of the seven VAR models includes a different public investment variable - one for aggregate public investment and one for each of the six different types of public investment. This means that, consistently with our conceptual arguments, the public investment variables are endogenous variables throughout the estimation procedure. For the sake of brevity, the details on the model selection for the different VAR models are not reported here. They are available from the authors upon request.

The specifications of the different VAR models are determined using the BIC. The test results are reported in Table 9. The VAR specification has two dimensions, which were determined jointly - the specification of the deterministic components and the consideration of the possibility of structural breaks. In all cases a first order specification were selected. A higher order was not considered due to relative small size of sample. The BIC selects a specification with constant and trend for the disaggregated models for national roads, municipal roads, highways, and ports. For the aggregate model, as well as the disaggregated models for airports and for railways, the BIC selects a specification with only a constant.

In order to consider the possible structural changes due to the two Community Support Frameworks, different VAR specifications were considered. One could possibly distinguish three periods in which there might have been structural changes: the period before 1989, the period of first program, i.e., 1989-93 and the period of the second program, i.e., 1994-98. Therefore, we consider three alternatives in terms of the VAR specification. The first is the case of no structural break/no dummies. The second is the case of one structural break/one dummy distinguishing the periods before and after the EU structural programs. Finally, we consider the possibility of two structural breaks/two dummies reflecting the possibility of the three different periods mentioned above. We find that the BIC criterion leads to the selection of VAR with two structural breaks/two dummies for aggregate public investment as well as for each one of the six types of public investment. This suggests that in addition to considering the differences before and after the EU structural programs, there are also important changes associated with each of the EU structural programs.

III. Identifying and Measuring the Effects of Innovations in Public Investment

We use the impulse-response functions associated with the estimated VAR models to examine the effects of the different types of public investment on the performance of output, employment and private investment variables. 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 investment variables and the measurement of the effects of such innovations.

A. Identifying innovations in the public investment variables

While the public investment variables are endogenous in our econometric framework, the key methodological issue for the determination of the effects of public investment on the other variables is the identification of innovations in the public investment variables that are truly exogenous. This means that we need to identify shocks to public investment variables that are not contemporaneously correlated with shocks in the remaining variables. These exogenous 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 Rudebush (1998).]

Ideally, the identification of shocks to public investment which are uncorrelated with shocks in other variables would result from knowing what fraction of the government appropriations in each period is due to purely non-economic reasons. The econometric counterpart to this idea is to imagine a government policy function which relates the rate of growth of public investment to the information in the relevant government information set; in our case, the past and current observations of the growth rates of the output, employment and private investment variables. The residuals from this policy function reflect the unexpected component to the evolution of public investment and are uncorrelated with other innovations.

In the central case, we assume that the relevant information set for the government policy function includes past values but not current values of the other variables. This is equivalent in the context of the standard Choleski decomposition to assuming that innovations in public investment lead innovations in the other variables. This means that we allow innovations in public investment to affect the other variables contemporaneously, but not the reverse.

We have two reasons for making this our central case. First, it seems reasonable to believe 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. Nevertheless, to determine the robustness of our central case results, we also consider all the possible alternatives in terms of the definition of which observations of the private sector variables are included in the government 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 for the variance decomposition in Table 10 and for the impact indicators in Table 11.

It should be pointed out that the sensitivity analysis efforts could conceivably be generalized in two different directions. First, we could consider the effects of innovations in the private sector variables, for example a supply shock, under our current sensitivity analysis framework. To do so, however, would require a great deal of assumptions as to the ordering of the private sector variables. Our approach has the advantage of providing a measure of the effects of innovations in public investment variables on private sector variables that is independent of the ordering of the private sector variables. We can, therefore, remain agnostic about the issue of the order of these variables. Second, we could generalize the sensitivity analysis framework to consider non-recursive or signal extraction schemes. This would reflect, however, an econometric more than an economic concern. It would only be justified if we had less strong priors about what the central case should be and it would entail alternatives of less clear economic interpretation. Because of these reasons we have not pursued either path in this paper.

B. Policy functions

The policy functions for aggregate public investment as well as the different types of public investment are reported in Table 12. These policy functions relate the evolution of the public investment variables to the evolution of the private sector variables lagged one year, according to the selected VAR specification. For the aggregate model, there is no feedback from the other variables to public investment. This means that public investment is truly an exogenous variable.

It is interesting to note that the exogeneity of public investment in Portugal is in contrast with the findings for the US, for example. In fact, Pereira (2000) shows that changes in public investment in the US are positively correlated with lagged changes in output and negatively correlated with lagged changes in employment. Therefore, changes in private-sector variables affect the evolution of public investment in the US, which is not an exogenous variable. The exogeneity of public investment decisions in Portugal, however, is easily explained by the fact that for long public investment decisions have been closely related with the Portuguese participation in the EU. This is particularly true after 1989, when the bulk of the public investment in transportation infrastructures in Portugal has been conducted under the two Community Support Frameworks. These programs are typically negotiated between the recipient economies and the EU, focusing on long-term goals and deliberately avoiding short-term considerations.

It should be pointed out that while public investment seems to be an exogenous variable at the aggregate level, the aggregate results hide some important effects on the evolution of different types of public investment. This means that although the magnitude of public investment seems to be truly exogenous there may be some effects from the economy on the composition of public investment.

In fact, the policy functions suggest that changes in the evolution of public investment in national roads (pinv1) respond positively to changes in output while the evolution of public investment in municipal roads (pinv2) depends positively on the evolution of private investment. In turn, the evolution of investment in highways (pinv3) depends positively on the evolution of employment and negatively on the evolution of private investment. Public investment in ports (pinv4) depends positively on lagged changes in output and negatively on lagged changes in private investment. Finally, the evolution of public investment in airports (pinv5) and in railroads (pinv6) does not seem to respond to lagged economic performance.

C. The impulse-response functions

We consider the effects of one-percentage point, one-time random shocks in the rates of growth of the different types of public investment on output, employment, and private investment. We expect these temporary shocks in the growth rates of the different types of public investment to have temporary effects on the growth rates of the other variables. They will, however, have permanent effects on the levels of those variables. The accumulated impulse response functions are reported in Figures 10-16.

There are a few interesting points worth mentioning in terms of these accumulated impulse-response functions. Let us start by acknowledging that all accumulated impulse-response functions converge within approximately a five-year period. This is not inconsistent with the idea that public investment takes time to build before it really impacts the private sector performance. This is because our measures of public investment 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 investment variables, although fast, is less smooth in the early years. This pattern can easily be understood if one considers that the initial exogenous shock to public investment variables is followed by an endogenous adjustment in public investment in response to the private sector variables. This endogenous adjustment is dictated in the context of the VAR model by the policy functions presented in Table 12 and discussed above.

These policy functions suggest a negative recursive pattern in the evolution of public investment in addition to their response to private sector variables. This negative recursive pattern dominates in the early years while the effects on the private sector variables are relatively small. This explains the dip in the impulse-response function in the early years. In later years, however, the positive feed back from the evolution of the private sector variables seems to dominate, although in some cases it is not strong enough to bring the accumulated long-term change in public investment to its initial level on impact. Hence, for aggregate public investment (pinv), for example, the long-term change in public investment associated with a 1.0 percentage point change on impact is 1.2 approximately, while for national roads (pinv1) is about 1.0, and for municipal roads (pinv2) is about 0.8.

D. Measuring the effects of innovations in public investment variables

In this paper we estimate the long-term accumulated elasticities of the different variables with respect to each type of public investment. Long-term is defined as the time horizon over which the growth effects of innovations disappear, i.e., the accumulated impulse-response functions converge. These elasticities represent the total percentage point changes in the different variables for each long-term accumulated percentage point change in public investment once all the dynamic feedback effects among the different variables have been considered.

We report the long-term accumulated marginal productivity of public investment in terms of the other variables in Tables 13 to 15. These figures measure the change, in million euros, in output and private investment for every million euros accumulated change in public investment. In Table 14, we report the effects in terms of the number of jobs created in the long-term per one million euros in public investment.

We obtain the marginal product of private investment reported in Table 15, by multiplying the output to public investment ratio for the last ten years by the elasticity of output with respect to public investment.

The choice of the output to public investment ratio for the last ten years is designed to reflect the relative scarcity of public investment of the different types. We consider the relative scarcity at the margin of the sample period without letting these ratios be overly affected by business cycle factors or by the different priorities established by EU structural programs.

It should be noted that we use the term marginal product in a way that departs from the conventional definition of the word. This is because these elasticities and marginal products are not based on ceteris paribus assumptions. In this paper, the term marginal product includes all of the dynamic feedbacks among the variables. Therefore, the marginal product that we calculate is a total marginal product. That is, it measures both the direct effects of public investment on output, and the indirect effects of public investment on output through changes in the evolution of inputs. Of course, this is the relevant concept from the standpoint of policy making.

Finally, the annual rates of return, also reported on Table 15, are calculated from the marginal product figures by assuming a life horizon of twenty years for all types of public capital assets. That is, the rate of return applied to one euro over a twenty-year period yields the value of the accumulated marginal product. These rates of return are adjusted to accommodate for a public capital depreciation rate of 5%, which is implicit in the life horizon of twenty years for the public capital assets.

IV. On the Economic Effects of Public Investment

A. Aggregate effects of public investment in transportation infrastructure

The effects on employment and private investment of public investment at the aggregate level are reported on the top part of Tables 13 and 14. The results from the impulse response analysis at the aggregate level suggest that in Portugal, public investment in transportation infrastructure crowds in both private investment and employment. Indeed, when we estimate the effects of shocks to aggregate public investment in transportation infrastructures on the evolution of the other variables, we find that the elasticity of private investment with respect to aggregate public investment is 0.639, which corresponds to a marginal product of

8.1. This means that at the aggregate level, public investment crowds in private investment and that one euro of additional public investment will induce, in the long-term, an accumulated total of 8.1 euros of private investment. In turn, the elasticity of employment with respect to aggregate public investment is 0.079. This figure suggests that 230 additional jobs will be created in the long-term for each additional one million euros in public investment in transportation infrastructures.

In turn, the long-term effects of innovations in investment in transportation infrastructures on output are reported on the top part of Table 15. We find that aggregate public investment has a positive effect on output with an elasticity of 0.183, which corresponds to a marginal product of 9.5. This implies that the increase of one euro in public investment leads to a total accumulated increase of 9.5 euros in output.

One possible way of interpreting the marginal product figures is by calculating the corresponding average rate of return. The estimated annual rate of return over a twenty-year period of public investment in transportation infrastructures is 15.9%. This figure suggests that the rate of return of public investment in transportation infrastructures is well above the range one would expect for the rate of return on private investment. From this perspective, the reliance on public investment in transportation infrastructures as the cornerstone of a development strategy in Portugal seems to have been justified.

Another possible way of interpreting this figure is by calculating the value of the tax revenues generated by this increase in output. Since tax revenues tend to hover around the 35% of the GDP, then the marginal product of public investment in transportation infrastructures suggests that over the life expectancy of the public capital assets, the public sector would collect 3.3 euros. Therefore, the public sector collects an additional 3.3 euros in tax revenues for each euro spent in public infrastructure. According to this evidence, the public investment assets in transportation infrastructures pay for themselves over their life span and still generate additional funds, which can be used for other public activities.

B. Effects of public investment in different types of transportation infrastructure

In the discussion above, we have established empirically that public investment in transportation infrastructure makes a positive and significant contribution to private-sector performance. We are ready to determine which types of public investment are the most productive. The positive crowding in effects of public investment in transportation infrastructures on private investment and employment observed at the aggregate level are also present at the disaggregated level. All types of public infrastructure in transportation affect private investment and employment positively in the long-term. Not surprisingly, the same pattern can be found in terms of the effects on output.

The effects of public investment in transportation infrastructures on private investment are reported in Table 13. In terms of the effects of public investment on private investment, the strongest effect comes from public investment in national roads (pinv1) with an elasticity of 0.766. It is followed, by the investments in municipal roads (pinv2), ports (pinv4), and railways (pinv6) with elasticities of 0.254, 0.281 and 0.264, respectively. Finally, public investment in highways (pinv3) and in airports (pinv5) display the lowest elasticities, 0.110 and 0.079, respectively.

In terms of marginal productivities, a better measure of relative scarcity, the highest marginal effects on private investment come from public investment in ports (pinv4) and airports (pinv5) with marginal products of 84.4 and 39.1 respectively. The marginal products of public investment in national roads (pinv1), municipal roads (pinv2), and railroads (pinv6) are still relatively large – 29.6, 14.1, and 18.8, respectively. The lowest effects on private investment come from public investment in highways (pinv3) with a marginal product of 9.2.

The effects of public investment in transportation infrastructures on employment are reported in Table 14. The strongest effect comes now from shocks to ports (pinv4) with an elasticity of 0.070, followed by municipal roads (pinv2), with an elasticity of 0.054, national roads (pinv1), with an elasticity of 0.045. In turn, the elasticities of public investment in highways (pinv3) and railways (pinv6) are substantially smaller, 0.009 and 0.012, respectively. Finally, the effect on employment of public investment in airports (pinv5) is only marginally different from zero.

In terms of job creation, one million euros invested in ports (pinv4) will create, in the long-term, about 4800 new jobs. This number reduces sharply to 692, 404, 204, and 164 new jobs per million euros invested in municipal roads (pinv2), national roads (pinv1), railways (pinv6), and highways (pinv3) respectively. Finally, public investment in airports (pinv5) actually eliminates about 500 jobs per million euros.

The effects of public investment in transportation infrastructures on output are reported in Table 15. The effects of shocks to the different public investment variables on output are all positive. In terms of the long-term accumulated elasticities, the strongest effect comes from shocks to public investment in national roads (pinv1) with an elasticity of 0.198. This is followed by the effect of shocks in public investment in municipal roads (pinv2), with an elasticity of 0.098, in ports (pinv4), with an elasticity of 0.087, and railways (pinv6), with an elasticity of 0.062. In turn, the elasticities of output with respect to public investment in highways (pinv3) and airports (pinv5) are the smallest, respectively 0.024 and 0.009.

Let us now consider the marginal product figures. These figures are a better measure of the relative effects of different types of public investment. This is because they reflect the relative scarcity of the different types of public investment at the margin of the sample period. The marginal product figures suggest that all types of public investment are productive. Although there is a wide range of effects, four of the six types of transportation infrastructure have marginal products within a relatively small range, between 18.5 and 31.4. This is the case of public investment in national roads (pinv1), municipal roads (pinv2), airports (pinv5) and railroads (pinv6), with marginal products of 31.4, 21.3, 19.2, and 18.5, respectively. The two extremes are given by public investment in highways (pinv3) with a marginal product of just 8.2 and public investment in ports (pinv4) with a marginal product of 107.1.

Another way of interpreting these results is by considering the rates of return on the different types of public investment. Again, all rates of return for all different types of public investment in infrastructures are above the expected ranges for private investment. Over a twenty-year period, the average rate of return to public investment in ports (pinv4), is 30.8%, and is the highest. It is closely followed by the rate of return to public investment in national roads (pinv1) of 23.0%, municipal roads (pinv2) of 20.9%, airports (pinv5) of 20.0%, and railroads (pinv6) of 19.7%. The lowest rate of return, although still high, is for public investment in highways (pinv3) with 15.0%.

It is important to highlight the importance of considering both the direct and the indirect effects of innovations in public investment. The explicit consideration of the indirect effects of public investment on private investment and employment allows us to highlight the mechanisms through which the different types of public investment tend to affect output. Indeed, the strong effects of public investment in ports (pinv4) on output, seems to be related to strong effects on both employment and private investment. The converse is true for public investment in highways (pinv3) in which case the less strong effects seem to be related to less strong effects on also both private investment and employment. In turn, the effects on output of public investment in municipal roads seems to be due mostly to the important effects on employment while the effects of public investment in airports (pinv5) seem to be mostly related to the effects on private investment.

C. Comparison with the international evidence

The comparison of the results in this paper with the international evidence available in the literature is not easy. This is primarily because the international literature has used a variety of econometric techniques, which makes similar terms, like elasticity or marginal product not always comparable with the way such terms are used in this paper. Also, most of the literature on the effects of public infrastructures considers public investment as an exogenous variable and focuses on the effects of public investment on private output and is not designed to address the impact on private inputs. Furthermore, the definitions of public investment used in the literature vary wildly.

Although comparisons are difficult they are not impossible. The results in this paper are most directly comparable with the results in Pereira and Roca (1999) for Spain and in Pereira (2000) for the US. Pereira and Roca (1999) consider for Spain the effects of public capital in transportation infrastructures. The empirical results suggest a marginal product of private investment with respect to public investment of 10.2 and that one million euros in public investment create 129 jobs in the long-term. Moreover, the results indicate that the marginal product of public investment in Spain is 5.5. This corresponds to a rate of return of 8.9%. Accordingly, the results obtained in this paper for Portugal, 230 new jobs created per million euros in public investment and a rate of return of 15.9%, tend to be higher than the ones for Spain.

In turn, Pereira (2000) finds that public investment, although under a much broader definition, crowds in private investment with a marginal product of 0.8 while it seems to have a negligible effect on private employment. The results in this paper for Portugal show much larger figures for the marginal effects of public investment in transportation infrastructures on private investment – about ten times, while the effects on employment in Portugal are substantial - 230 jobs per one million euros in public investment. More importantly, Pereira (2000) suggests that the marginal product of public investment in the US is 4.5. This corresponds to a rate of return of 7.8%, compared to a rate of return of 15.9% in the Portuguese case. Again, the results in this paper tend to be substantially higher than the results for the US. This is understandable given the relatively greater scarcity of public infrastructures in the Portuguese economy.

International comparisons in terms of the disaggregated effects of different types of public investment are even more difficult. Again, probably the closest comparisons can be made with Pereira (2000). In Pereira (2000) there is a core infrastructure variable, which represents highways and streets and that closely resembles the aggregate of national roads, municipal roads, and highways. Another variable in Pereira (2000), core infrastructure in ports, airports, etc, seems to be close to the aggregate of ports and airports in this paper. The results indicate that the marginal products of these two types of public investment are 1.97 and 19.79, respectively. The correspondent rates of return are 3.4% and 16.1%, respectively. In this paper, the range of rates of return is from 15.0% to 23.0% for public investment in roads and highways, and 30.8% and 20.0% for public investment in ports and airports, respectively. Again, the figures for Portugal tend to be substantially higher than the ones for the US.

An important feature of the empirical results in this paper is that in Portugal public investment in transportation infrastructures would more than pay for itself in the form of added tax revenues over the life span of the public investment assets. This is reminiscent of the supply-side Laffer-curve effect found for the United States by the early literature. Indeed, the seminal contribution of Aschauer (1989a) has been interpreted as suggesting that [see, for example, Reich (1991)]. This result was disputed by subsequent research for the United States case. For example, Pereira (2000) suggests that the marginal product of public investment would just pay for itself over time. Furthermore, Pereira and Roca (1999) show that the same is true for Spain while the results in Mittnik and Newman (1998) for Canada, France, Germany, Japan, The Netherlands, and the United Kingdom, in a time series context not incompatible with the approach in this paper, seem to imply the same. Interestingly enough, however, the same type of result seems to resurface in the case of Portugal. This leaves open the question as to whether a supply-side Laffer-curve effect while not present in more developed economies could be a fixture of less developed countries.

V. Summary and Concluding Remarks

This paper analyzes empirically the effects of public investment in transportation infrastructure on economic performance in Portugal. To do so, we use a new data set on public investment in transportation infrastructures in Portugal for the period 1976-98, recently published by Pereira and Andraz (2001). We follow a VAR approach, which is consistent with the argument that the analysis of the effects of public investment on output, employment and private investment variables requires the consideration of dynamic feedback effects among the different variables.

We can summarize the empirical results as follows. We find that in the long-term, aggregate public investment in transportation infrastructures crowds in private investment as well as employment. More importantly, we find that it has a positive effect on output. Indeed, we estimate that one euro invested in public investment increases output in the long-term by 9.5 euros. This figure suggests that public investment pays for itself 3.3 times in the form of tax revenues over the life span of the public capital asset. Furthermore, the marginal product figure corresponds to a rate of return of 15.9%. This rate of return is clearly higher than the rate of return expected on private investment activities.

The importance of the effects of public investment in transportation infrastructures at the aggregate level opens the door to the next stage of our analysis: the study of the effects of different types of public investment on economic performance. Consistent with the aggregate results, we find that all types of public investment crowd in the other variables. Nevertheless, a close look at the effects of different types of public investment on the remaining variables suggests that the disaggregation of public investment is very informative, since it shows which types of public investments are the most productive. In terms of marginal productivities, the highest effects on private investment come from public investment in ports, airports and national roads. In terms of job creation, the highest effects come from public investment in ports, municipal roads, and national roads. Finally, in terms of the effects of output the largest effects come from investment in ports followed closely by national roads, municipal roads, airports, and railroads.

The results in this paper are very important and timely from a public policy perspective in Portugal.

From a retroactive perspective, the empirical evidence suggests strongly that public investment in transportation infrastructures has been a powerful instrument to promote long-term growth in Portugal. Moreover, it suggests that the strategy followed by the Portuguese authorities of investing in public infrastructures has been justified both from a long-term development perspective as well as from a public budgetary perspective.

More importantly, from a prospective perspective, the results in this paper provide broad guidelines for the country's future development strategies. This is very important due to the still relative backwardness now. As a matter of fact, Portuguese GDP is still at about 75% of EU average while sources of outside financing are being reduced and the country faces a great budgetary restraint in the context of EMU. This requires greater attention to relative benefits and much more fine-tuned development policies. It is also important to highlight the fact that given current budgetary constraints in the context of the Stability and Growth Programs, the tendency for achieving budgetary consolidation through reduction in public investment is a mistake from the standpoint of long-term growth. It is also a mistake from the standpoint of long-term budgetary situation.

Although the results in this paper are important from the perspective of policy making in Portugal, its interest is far from parochial. In fact, there is a number of Eastern European waiting to join the EU. These countries have levels of development and infrastructure scarcities that are not unlike the Portuguese case by the end of 1980s. Furthermore, there are already structural transfer programs in place to smooth the transition of these countries into the EU and they are expected to benefit from large EU structural funds upon accession, much like Greece, Ireland, Portugal, and Spain currently do. From this paper we learn that the general strategy of investing in public infrastructure may be very effective in promoting real convergence of these economies to EU standards. Furthermore, given the difficulties of data gathering one would encourage data collection and coordination of policies and implementation agencies from early stages is critical to provide info to help design basic programs.

Despite all the considerations above it is appropriate to conclude on a cautionary note. Although we have established empirically the importance of public investment in transportation infrastructure for economic development in Portugal, we have done so with a relatively small data set. This places some limitations on the statistical analysis in the paper. More importantly, maybe, is the fact that establishing that public investment has been important in the past does not establish that it will be important in the future. Indeed, one could easily conjecture a pattern of decreasing marginal returns to public investment. Finally, even if we could legitimately conjecture, based on the relatively high rates of return we estimated, that these public investments will continue to be important, we did not address the issue of which types of investment are the most important. Indeed, just showing that public investment in infrastructures is productive does not mean that it is more productive than private investment or investment in human capital, for example.

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Table 1 - Data set for Portugal

Years	Output	Employment	Private investment	Public investment
1976	9.023.294	3.624	2.033.225	113.212
1977	9.519.412	3.671	2.265.797	103.305
1978	9.788.215	3.770	2.427.918	123.781
1979	10.341.059	3.862	2.376.059	134.398
1980	10.813.624	3.943	2.577.030	122.724
1981	10.991.600	3.939	2.728.533	159.585
1982	11.224.467	3.965	2.770.359	162.976
1983	11.205.164	3.878	2.579.592	137.623
1984	10.991.821	3.937	2.137.447	114.935
1985	11.305.010	3.932	2.071.879	127.688
1986	11.768.296	3.900	2.293.706	144.316
1987	12.518.244	4.006	2.677.251	155.751
1988	13.451.070	4.096	3.102.701	178.492
1989	14.144.498	4.236	3.236.613	198.425
1990	14.759.562	4.279	3.501.980	247.907
1991	15.104.553	4.335	3.624.977	295.401
1992	15.483.749	4.359	3.801.235	269.922
1993	15.311.404	4.295	3.585.621	306.278
1994	15.651.492	4.449	3.701.556	324.773
1995	16.102.000	4.416	3.880.582	311.933
1996	16.584.869	4.445	4.067.238	335.804
1997	17.260.447	4.530	4.545.614	433.520
1998	17.866.194	4.740	4.952.094	404.936

Units: Output, private investment, and public investment – millions of 1995 escudos.
Labor – thousand workers.

Sources:
Output, employment and private investment: the Bank of Portugal/Banco de Portugal (1997), Commission of the European Communities (1999), and Ministry of Finance/Ministério das Finanças (2000)
Public investment: Pereira and Andraz (2001).

Table 2 - Public investment in transportation infrastructures

Years	Aggregate public investment	National roads	Municipal roads	Highways	Ports	Airports	Railways
1976	113.212	28.538	20.900	16.216	7.110	3.365	37.083
1977	103.305	20.773	24.829	12.310	8.476	2.595	34.322
1978	123.781	26.976	33.694	16.570	13.350	1.535	31.657
1979	134.398	30.532	49.580	9.823	14.878	2.411	27.174
1980	122.724	38.032	29.789	16.553	24.567	1.359	12.424
1981	159.585	41.197	49.274	25.381	25.381	3.442	14.911
1982	162.976	40.038	50.851	19.051	24.853	6.567	21.616
1983	137.623	43.451	41.734	9.760	21.032	5.078	16.568
1984	114.935	32.908	43.160	1.283	17.412	6.839	13.333
1985	127.688	35.674	43.418	11.159	15.543	4.469	17.425
1986	144.316	45.205	39.258	10.393	16.489	10.473	22.497
1987	155.751	52.960	43.753	13.288	12.834	8.702	24.215
1988	178.492	55.360	51.542	18.243	12.324	11.686	29.336
1989	198.425	56.892	57.549	35.603	10.185	11.041	27.156
1990	247.907	78.109	56.034	56.980	13.917	10.923	31.945
1991	295.401	84.248	67.958	67.331	18.409	8.936	48.518
1992	269.922	100.680	74.192	24.851	13.544	5.718	50.937
1993	306.278	100.777	83.302	43.571	13.326	5.207	60.095
1994	324.773	119.079	66.098	59.462	12.297	5.336	62.500
1995	311.933	128.160	54.440	57.847	12.730	6.146	52.610
1996	335.804	139.065	71.566	37.089	9.983	8.126	69.975
1997	433.520	126.036	90.559	75.553	12.059	10.502	118.811
1998	404.936	118.974	93.988	52.518	16.675	14.217	108.563

Units: Millions of 1995 escudos.
Source: Pereira and Andraz (2001).

Table 3 – Public investment as a share of GDP (%)

Public investment	1976-80	1981-85	1986-88	1989-93	1994-98	Averages 1976-88	Averages 1989-98	Sample Average
pinv: Aggregate public investment	1.21	1.26	1.27	1.76	2.16	1.24	1.96	1.55
pinv1: National roads	0.29	0.35	0.41	0.56	0.76	0.34	0.66	0.48
pinv2: Municipal roads	0.32	0.41	0.36	0.45	0.45	0.36	0.45	0.40
pinv3: Highways	0.15	0.12	0.11	0.31	0.34	0.13	0.32	0.21
pinv4: Ports	0.14	0.19	0.11	0.09	0.08	0.15	0.08	0.12
pinv5: Airports	0.02	0.05	0.08	0.06	0.05	0.05	0.05	0.05
pinv6: Railways	0.30	0.15	0.20	0.29	0.49	0.22	0.39	0.29

Table 4 – Public investment as a share of Private Investment (%)

Public investment	1976-80	1981-85	1986-88	1989-93	1994-98	Averages 1976-88	Averages 1989-98	Sample Average
pinv: Aggregate public investment	5.13	5.72	5.95	7.40	8.56	5.55	7.98	6.60
pinv1: National roads	1.24	1.58	1.91	2.35	3.02	1.53	2.69	2.03
pinv2: Municipal roads	1.35	1.87	1.67	1.91	1.77	1.63	1.84	1.72
pinv3: Highways	0.62	0.52	0.51	1.29	1.35	0.55	1.32	0.89
pinv4: Ports	0.57	0.84	0.53	0.39	0.30	0.67	0.35	0.53
pinv5: Airports	0.10	0.22	0.39	0.24	0.20	0.21	0.22	0.22
pinv6: Railways	1.25	0.69	0.94	1.22	1.91	0.96	1.57	1.23

Table 5 - Shares of total public investment (%)

Public investment	1976-80	1981-85	1986-88	1989-93	1994-98	Averages 1976-88	Averages 1989-98	Sample Average
pinv1: National roads	24.2	27.7	32.1	31.8	35.5	27.4	33.7	30.1
pinv2: Municipal roads	26.2	32.8	28.1	25.9	20.6	29.2	23.3	26.6
pinv3: Highways	12.1	8.9	8.7	17.4	15.7	10.1	16.5	12.9
pinv4: Ports	11.3	14.8	8.9	5.3	3.5	12.1	4.4	8.7
pinv5: Airports	1.9	3.9	6.5	3.4	2.4	3.7	2.9	3.4
pinv6: Railways	24.4	12.0	15.9	16.3	22.2	17.6	19.3	18.3

Figure 1: Aggregate public investment in transportation infrastructures (pinv)
as % of GDP and private investment

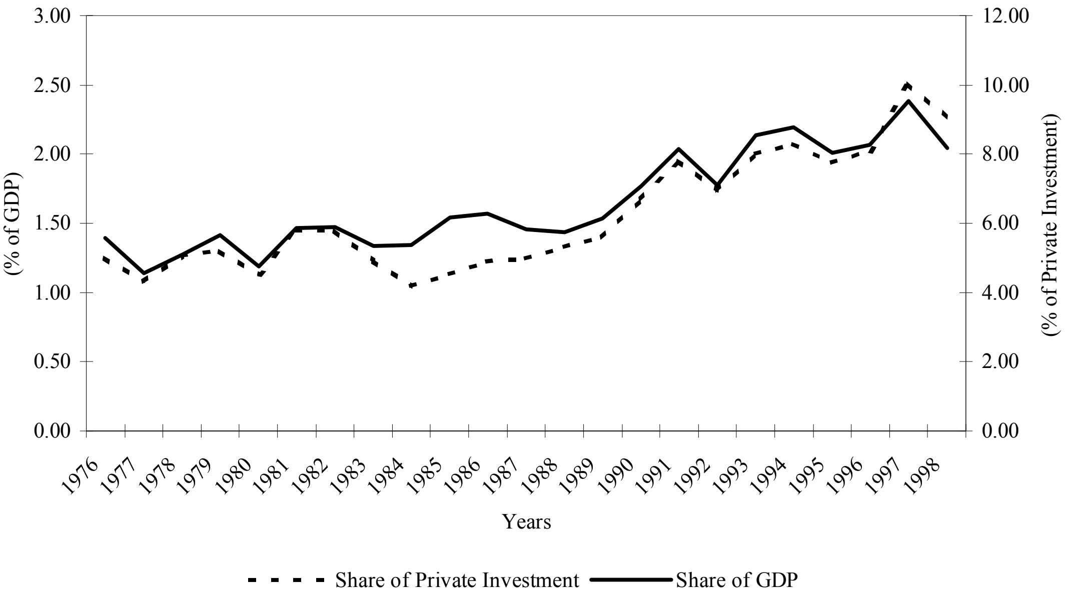


Figure 2: Public investment in national roads (pinv1)
as % of GDP and private investment

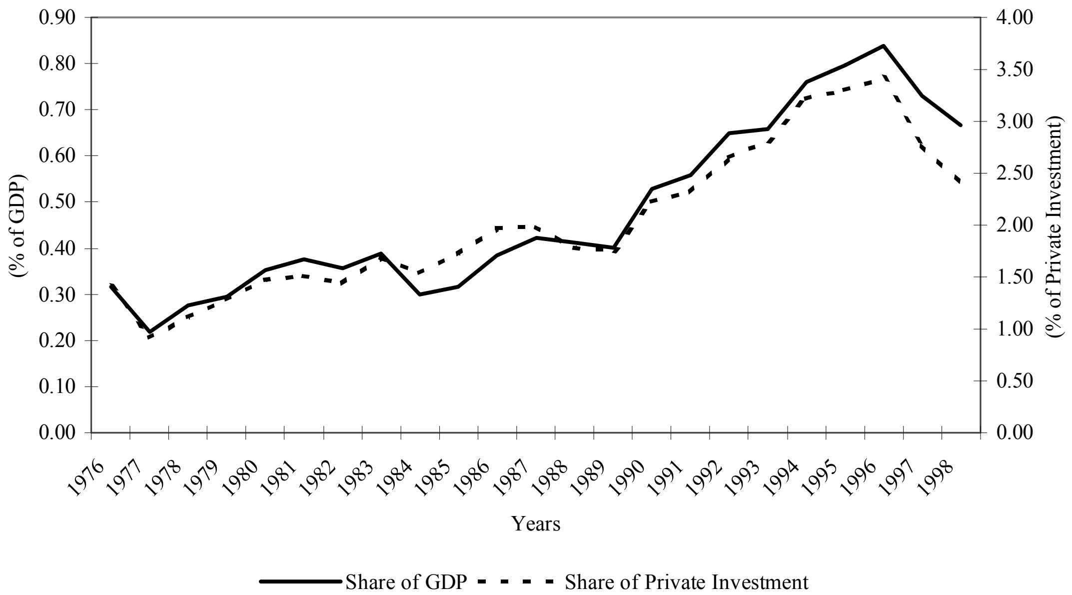


Figure 3: Public investment in municipal roads (pinv2)
as % of GDP and private investment

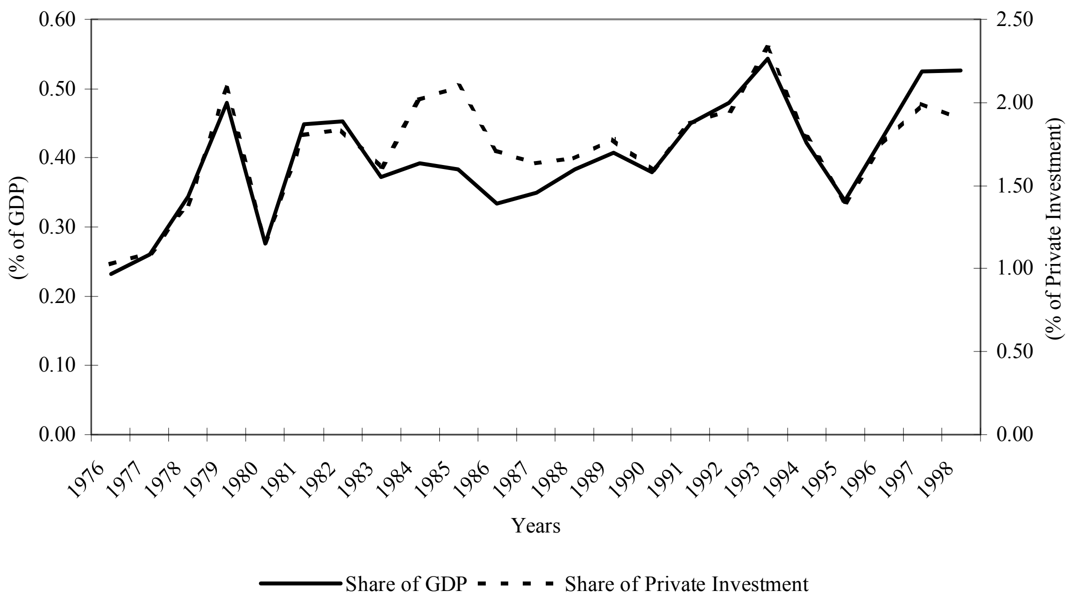


Figure 4: Public investment in highways (pinv3)
as % of GDP and private investment

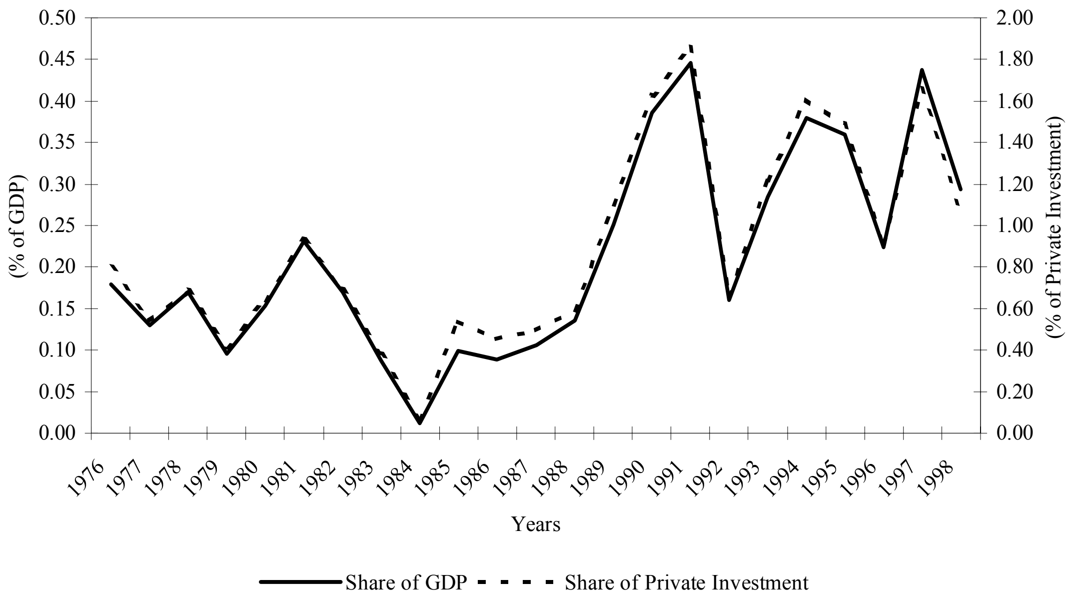


Figure 5: Public investment in ports (pinv4)
as % of GDP and private investment

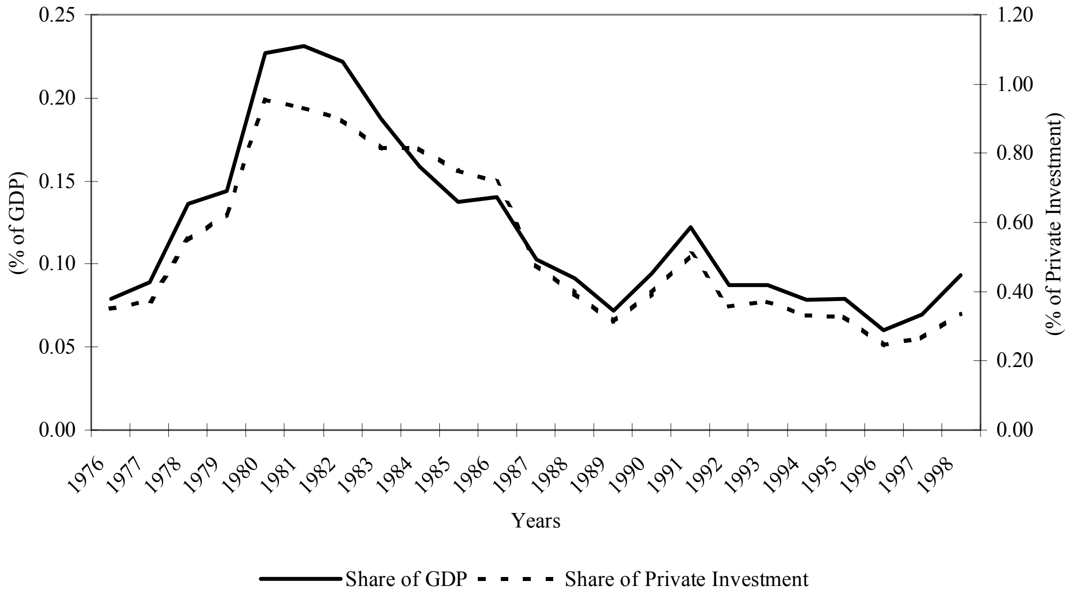


Figure 6: Public investment in airports (pinv5)
as % of GDP and private investment

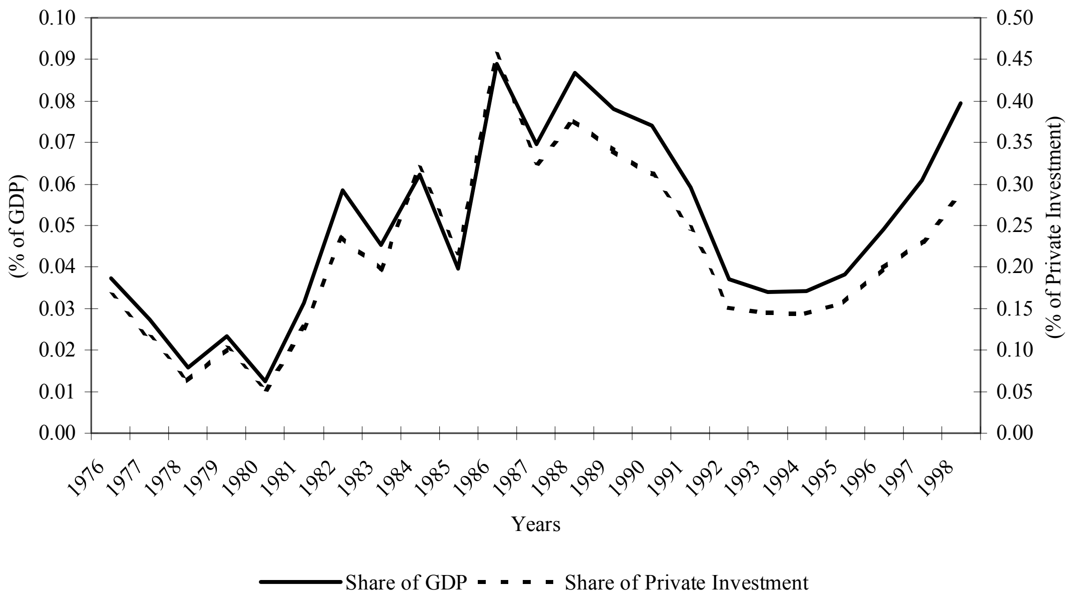
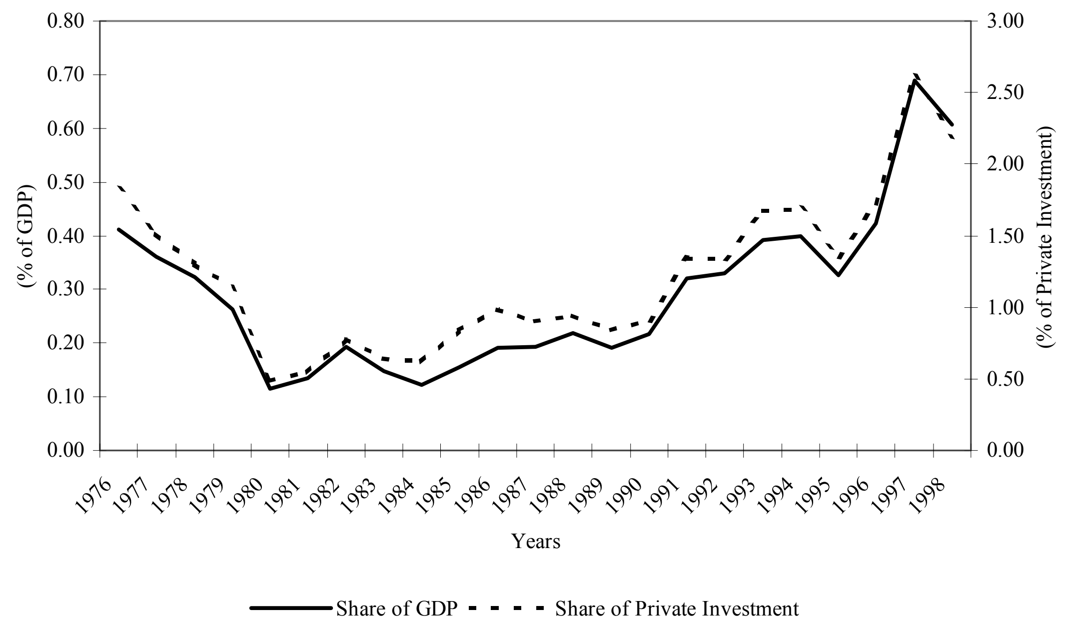


Figure 7: Public investment in railways (pinv6)
as % of GDP and private investment



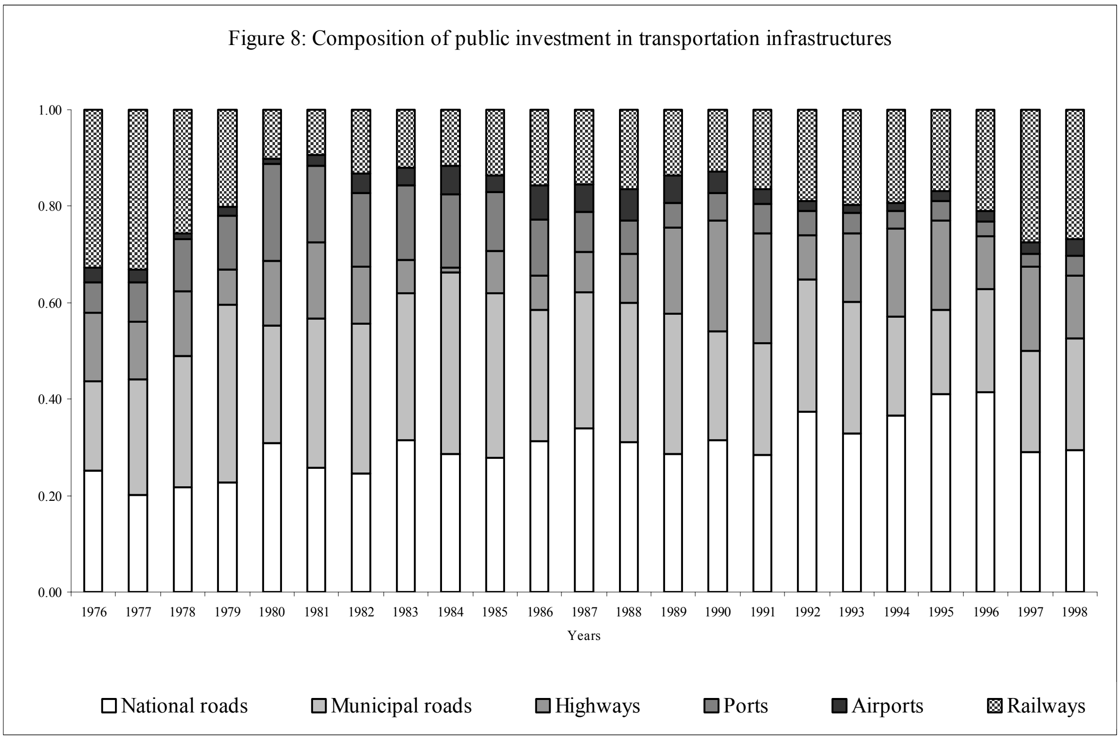


Figure 8: Composition of public investment in transportation infrastructures
1.00
0.80
0.60
0.40
0.20
0.00
1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998
Years
National roads
Municipal roads
Highways
Ports
Airports
Railways

Figure 9: Aggregate public investment in transportation infrastructures as % of GDP in Portugal, Spain and in the U.S.A.

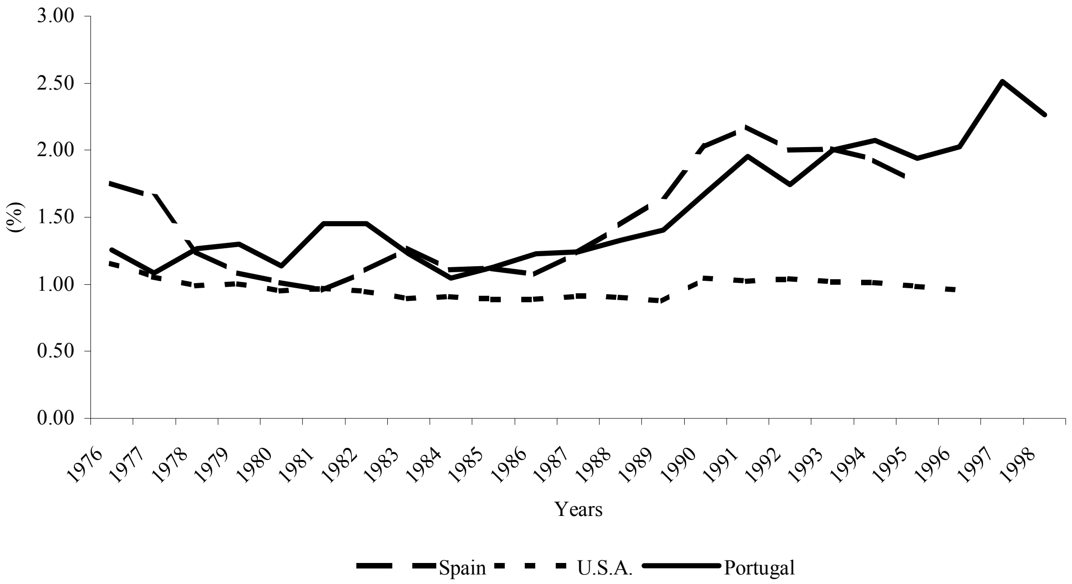


Table 6 – Testing for the null hypothesis of unit roots using the ADF test

	Deterministic components	Order (BIC)	Test statistic	Critical values 5%	1%
Variables: log levels					
gdp: Output	CT	2	-3.0118	-3.60	-4.38
emp: Employment	CT	0	-1.6349	-3.60	-4.38
inv: Private investment	CT	1	-2.0732	-3.60	-4.38
pinv: Aggregate public investment	CT	0	-1.8699	-3.60	-4.38
pinv1: National roads	CT	0	-1.9461	-3.60	-4.38
pinv2 : Municipal roads	CT	1	-3.2594	-3.60	-4.38
pinv3: Highways	CT	0	-3.4357	-3.60	-4.38
pinv4: Ports	C	0	-2.1310	-3.00	-3.75
pinv5: Airports	CT	2	-2.7925	-3.60	-4.38
pinv6. Railways	CT	2	-0.9072	-3.60	-4.38
Variables: growth rates					
gdp: Output	C	3	-4.6470	-3.00	-3.75
emp: Employment	C	0	-3.9231	-3.00	-3.75
inv: Private investment	N	0	-2.2950	-1.95	-2.66
pinv: Aggregate public investment	C	0	-4.8404	-3.00	-3.75
pinv1: National roads	C	0	-5.5086	-3.00	-3.75
pinv2 : Municipal roads	C	1	-4.1368	-3.00	-3.75
pinv3: Highways	N	0	-4.9659	-1.95	-2.66
pinv4: Ports	N	0	-3.3923	-1.95	-2.66
pinv5: Airports	N	0	-4.7955	-1.95	-2.66
pinv6. Railways	CT	1	-5.8943	-3.60	-4.38

Table 7 – Testing for the null hypothesis of unit roots using the Phillips-Perron test

	Deterministic components	Order (BIC)	Test statistic	Critical values 5%	1%
Variables: log levels					
gdp: Output	C	1	-0.1828	-12.5	-17.2
emp: Employment	CT	0	-8.3216	-17.9	-22.5
inv: Private investment	CT	1	-22.4939	-17.9	-22.5
pinv: Aggregate public investment	CT	0	-8.0042	-17.9	-22.5
pinv1: National roads	CT	0	-11.7611	-17.9	-22.5
pinv2 : Municipal roads	CT	1	-17.4691	-17.9	-22.5
pinv3: Highways	CT	0	-13.6992	-17.9	-22.5
pinv4: Ports	C	0	-8.3041	-12.5	-17.2
pinv5: Airports	CT	2	-9.1929	-17.9	-22.5
pinv6. Railways	CT	2	-6.0600	-17.9	-22.5
Variables: growth rates					
gdp: Output	C	0	-10.1261	-12.5	-17.2
emp: Employment	C	0	-21.0370	-12.5	-17.2
inv: Private investment	N	0	-8.4164	-7.3	-11.9
pinv: Aggregate public investment	C	0	-23.0084	-12.5	-17.2
pinv1: National roads	C	0	-23.3204	-12.5	-17.2
pinv2 : Municipal roads	C	1	-36.6651	-12.5	-17.2
pinv3: Highways	N	0	-23.1967	-7.3	-11.9
pinv4: Ports	N	0	-16.1431	-7.3	-11.9
pinv5: Airports	N	0	-22.5798	-7.3	-11.9
pinv6. Railways	CT	1	-113.4204	-17.9	-22.5

Table 8 – Testing the null hypothesis of no cointegration

Variables	Deterministic Components	Optimal Lag (BIC)	Test Statistic	Critical Values 5%	1%
gdp: Output	CT	0	-1.4347	-4.16	-4.65
emp: Employment	C	0	-3.9402	-4.11	-4.73
inv: Private investment	CT	0	-3.1888	-4.16	-4.65
pinv: Aggregate public investment	CT	0	-4.5880	-4.16	-4.65
gdp: Output	CT	0	-1.3356	-4.16	-4.65
emp: Employment	C	0	-3.9385	-4.11	-4.73
inv: Private investment	CT	1	-2.8594	-4.16	-4.65
pinv1: National roads	N	2	-3.5147	-3.74	-4.30
gdp: Output	CT	0	-1.4802	-4.16	-4.65
emp: Employment	C	0	-4.3649	-4.11	-4.73
inv: Private investment	CT	0	-2.0492	-4.16	-4.65
pinv2 : Municipal roads	C	1	-4.8360	-4.11	-4.73
gdp: Output	CT	0	-2.1859	-4.16	-4.65
emp: Employment	C	0	-4.0019	-4.11	-4.73
inv: Private investment	CT	0	-1.9255	-4.16	-4.65
pinv3: Highways	CT	1	-5.3735	-4.16	-4.65
gdp: Output	CT	0	-1.7135	-4.16	-4.65
emp: Employment	C	2	-5.2319	-4.11	-4.73
inv: Private investment	CT	0	-1.6549	-4.16	-4.65
pinv4: Ports	C	0	-3.3592	-4.11	-4.73
gdp: Output	CT	0	-1.3165	-4.16	-4.65
emp: Employment	C	0	-4.0143	-4.11	-4.73
inv: Private investment	CT	0	-1.8647	-4.16	-4.65
pinv5: Airports	N	2	-2.9691	-3.74	-4.70
gdp: Output	CT	0	-2.0721	-4.16	-4.65
emp: Employment	C	0	-4.0632	-4.11	-4.73
inv: Private investment	CT	0	-3.6027	-4.16	-4.65
pinv6. Railways	CT	0	-3.7113	-4.16	-4.65

Table 9 – VAR specification (BIC)

Public investment	Model order	Deterministic components	No dummy	One dummy (1989)	Two dummies (1989,1994)
pinv: Aggregate public investment	1	N	-24.79172	-24.89442	-25.11975
	1	C	-25.05496	-25.46241	**-25.69166**
	1	CT	-25.09007	-25.58873	-25.69035
pinv1: National roads	1	N	-24.85156	-24.94396	-25.52282
	1	C	-25.07617	-25.52986	-26.10160
	1	CT	-25.24993	-26.45380	**-26.77999**
pinv2 : Municipal roads	1	N	-23.64226	-23.68089	-23.73939
	1	C	-23.92128	-24.30213	-24.36215
	1	CT	-24.11397	-24.51930	**-24.59061**
pinv3: Highways	1	N	-20.04118	-20.08434	-20.13513
	1	C	-20.32396	-20.75705	-20.81506
	1	CT	-20.37029	-20.87376	**-21.01449**
pinv4: Ports	1	N	-23.77836	-23.84164	-23.89150
	1	C	-24.06601	-24.45286	-24.51007
	1	CT	-24.31672	-24.93027	**-25.28925**
pinv5: Airports	1	N	-21.64709	-21.68944	-21.81481
	1	C	-21.96905	-22.52255	**-22.66662**
	1	CT	-22.11673	-22.50320	-22.62232
pinv6. Railways	1	N	-22.95706	-23.30818	-23.35772
	1	C	-23.47973	-23.91985	**-23.97603**
	1	CT	-23.57522	-23.87059	-23.92901

NB: In bold face is the selected specification.

Table 10 – Variance decomposition: percentage of long-term variation in the variables due to variations in public investment

Variable		Output	Employment	Investment	Public Investment
pinv: Aggregate public investment					
	central case	37.6%	18.7%	37.2%	88.7%
	range of variation	[9.8%;37.6%]	[8.8%;19.2%]	[6.9%;37.2%]	[69.2%;88.7%]
pinv1: National roads					
	central case	33.5%	3.3%	43.9%	76.7%
	range of variation	[0.2%;35.6%]	[0.6%;24.8%]	[0.1%;45.3%]	[24.9%;76.7%]
pinv2: Municipal roads					
	central case	11.2%	11.0%	5.8%	64.1%
	range of variation	[3.8%;11.2%]	[7.9%;11.0%]	[1.8%;5.8%]	[57.9%;64.1%]
pinv3: Highways					
	central case	7.8%	3.9%	17.0%	53.7%
	range of variation	[0.9%;7.8%]	[2.5%;3.9%]	[2.2%;17.0%]	[38.4%;55.0%]
pinv4: Ports					
	central case	16.7%	32.1%	12.8%	65.7%
	range of variation	[0.8%;16.7%]	[1.9%;32.1%]	[0.5%;12.8%]	[28.7%;65.7%]
pinv5: Airports					
	central case	0.6%	7.1%	6.1%	90.5%
	range of variation	[0.6%;5.5%]	[0.4%;9.4%]	[0.9%;11.6%]	[80.7%;90.5%]
pinv6: Railways					
	central case	12.4%	10.8%	22.3%	90.5%
	range of variation	[0.9%;23.4%]	[0.7%;16.1%]	[2.9%;30.5%]	[64.4%;90.5%]

Table 11 – Long-term accumulated elasticities of private sector variables with respect to public investment

Variable		Output	Employment	Investment
pinv: Aggregate public investment				
	central case	0.18264	0.07860	0.63871
	range of variation	[0.105;0.183]	[0.045;0.079]	[0.356;0.639]
pinv1: National roads				
	central case	0.19807	0.04524	0.76549
	range of variation	[-0.133;0.202]	[-0.206;0.049]	[-0.259;0.772]
pinv2: Municipal roads				
	central case	0.09839	0.05441	0.25396
	range of variation	[0.054;0.098]	[0.032;0.054]	[0.111;0.254]
pinv3: Highways				
	central case	0.02416	0.00865	0.11013
	range of variation	[0.000;0.024]	[0.000;0.009]	[0.010;0.110]
pinv4: Ports				
	central case	0.08736	0.07025	0.28102
	range of variation	[-0.057;0.087]	[0.005;0.070]	[-0.075;0.281]
pinv5: Airports				
	central case	0.00937	-0.00438	0.07858
	range of variation	[-0.014;0.030]	[-0.005;0.009]	[0.002;0.137]
pinv6: Railways				
	central case	0.06247	0.01221	0.26418
	range of variation	[0.014;0.090]	[-0.010;0.031]	[0.080;0.341]

Table 12 – Policy functions for different types of public investment

GPINV	Constant	Trend	D1989	D1994	GGDP(-1)	GEMP(-1)	GINV(-1)	GPINV(-1)
pinv: Aggregate public investment	0.01652 (0.22)	----	0.08141 (1.02)	0.00836 (0.10)	1.06899 (0.38)	0.91162 (0.37)	0.43275 (0.55)	-0.31825 (-1.18)
pinv1: National roads	0.08439 (0.79)	-0.01174 (-1.10)	0.20328 (1.76)**	0.08463 (0.53)	3.98963 (1.59)*	0.98707 (0.43)	-0.78891 (-1.16)	-0.18631 (-0.96)
pinv2: Municipal roads	0.43479 (2.37)**	-0.02938 (-1.62)*	0.16555 (0.86)	0.28084 (1.04)	-5.38487 (-1.28)	-0.20668 (-0.05)	2.93549 (2.63)**	-0.34957 (-1.72)
pinv3: Highways	-0.85095 (-0.74)	0.24811 (2.13)**	-2.78687 (-2.25)**	-3.82736 (-2.21)**	-0.53118 (-0.02)	53.91315 (2.19)**	-15.56848 (-1.61)*	-0.29846 (-2.25)**
pinv4: Ports	0.19952 (1.00)	-0.05471 (-2.69)**	0.54009 (2.68)**	0.82740 (2.98)**	9.67703 (2.40)**	0.24936 (0.07)	-1.66084 (-1.46)*	-0.12838 (0.56)
pinv5: Airports	0.60145 (1.97)**	----	-0.60197 (-1.91)**	-0.10877 (-0.32)	-8.35899 (-0.77)	-4.37766 (-0.45)	2.86747 (1.00)	-0.38275 (-1.57)*
pinv6: Railways	0.12489 (0.75)	----	0.17389 (1.00)	0.17051 (0.87)	-3.33996 (-0.54)	-3.75863 (-0.69)	1.32406 (0.79)	-0.12572 (-0.46)

NB: t-statistics in parenthesis.
* Significant at 10% level.
** Significant at 5% level.

Figure 10: Accumulated impulse response function for aggregate public investment (pinv)

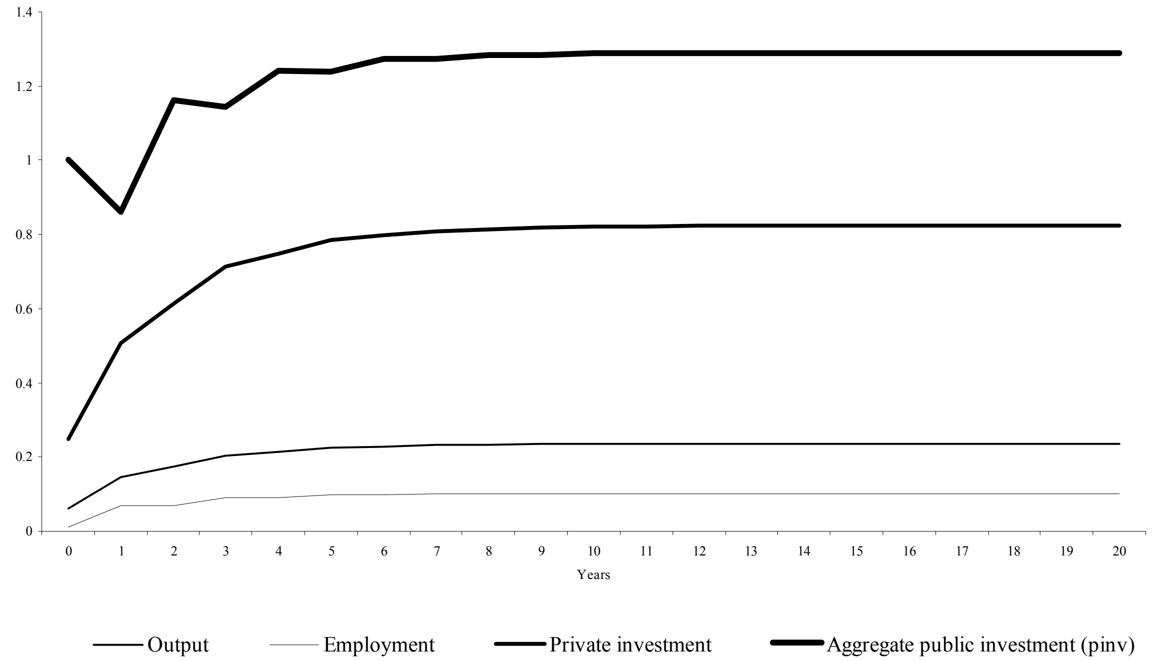


Figure 11: Accumulated impulse response functions for national roads (pinv1)

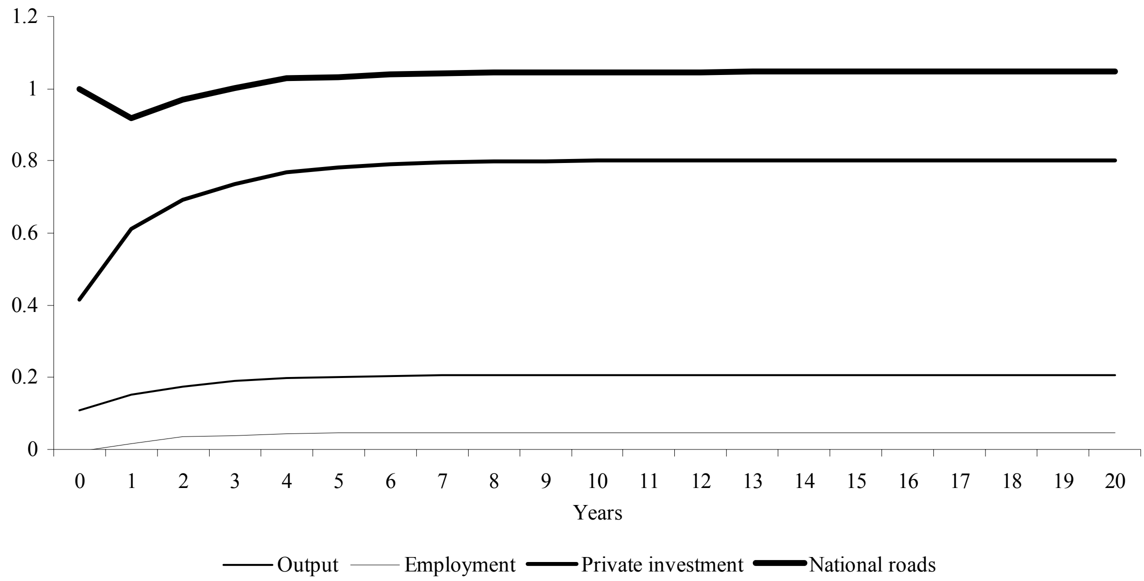


Figure 12: Accumulated impulse response functions for municipal roads (pinv2)

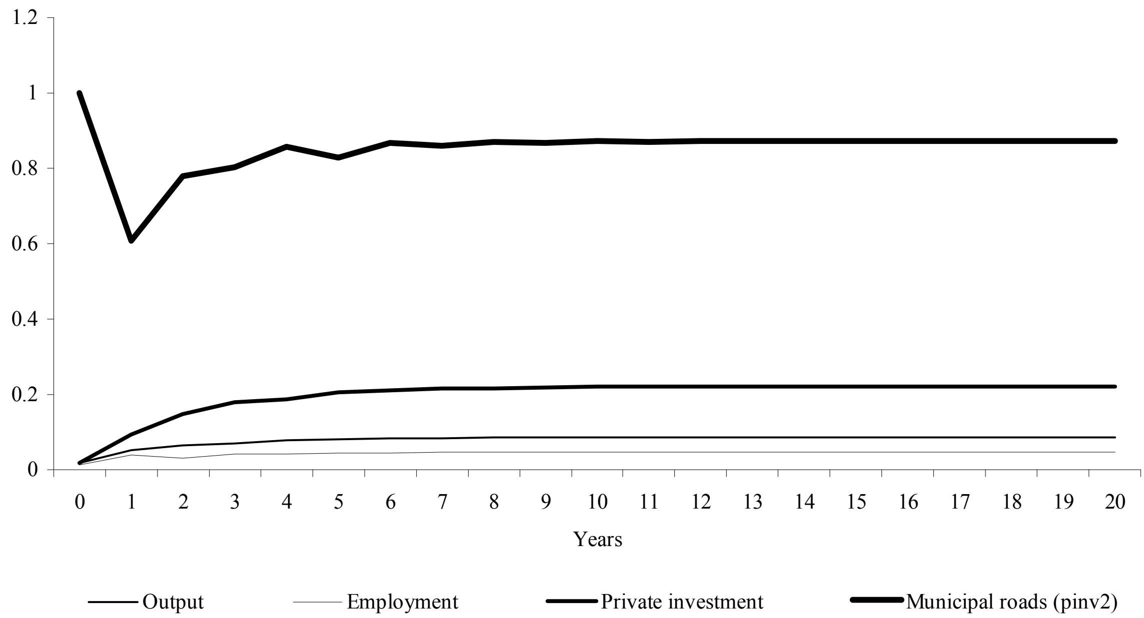


Figure 13: Accumulated impulse response functions for Highways (pinv3)

Figure 14: Accumulated impulse response functions for ports (pinv4)

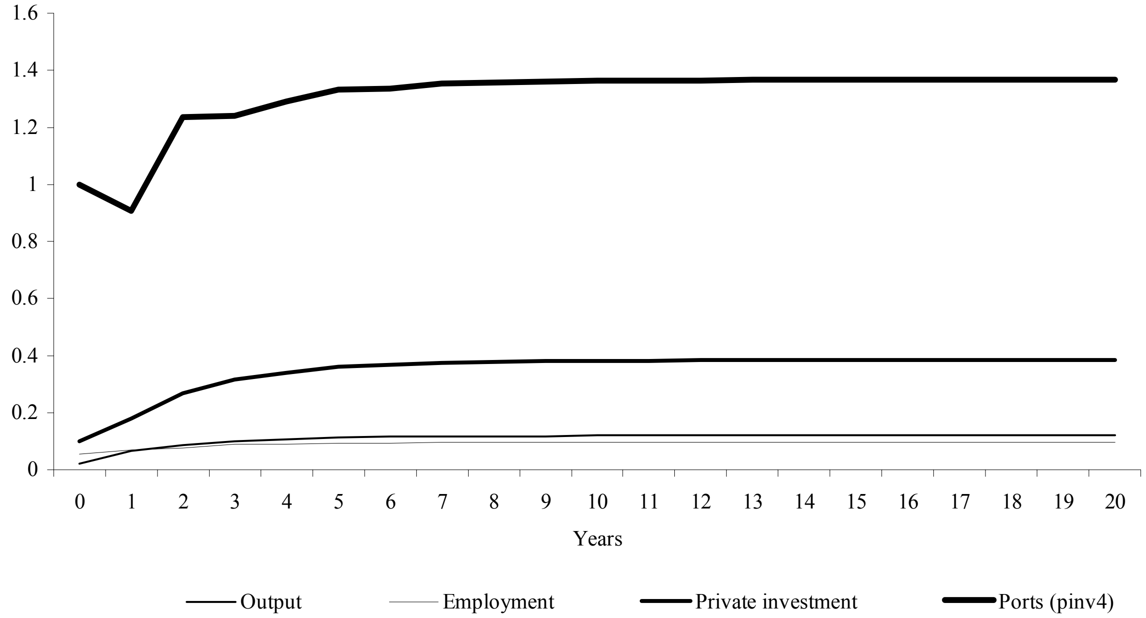


Figure 15: Accumulated impulse response functions for airports (pinv5)

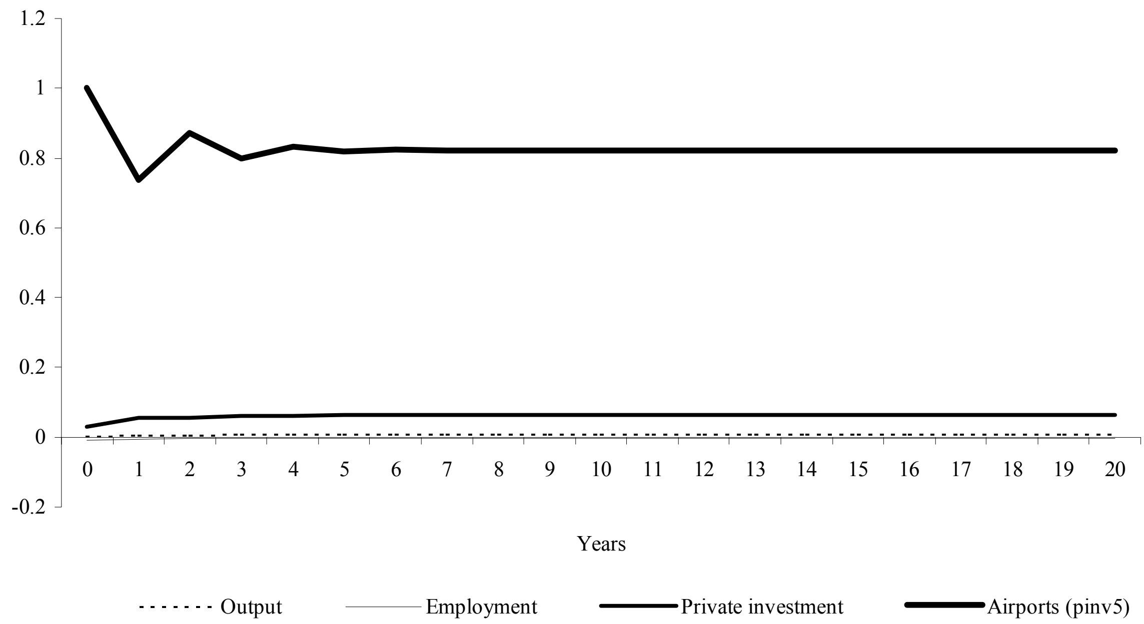


Figure 16: Accumulated impulse response functions for railways (pinv6)

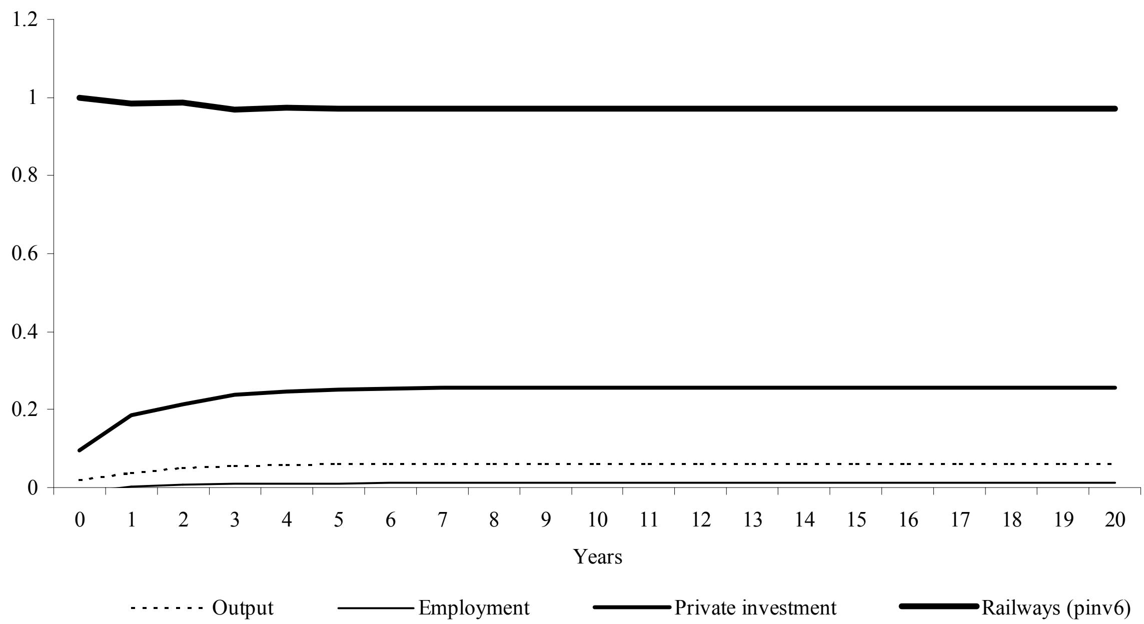


Table 13 – Effects of public investment on private investment

Public investment variable		Elasticities	Marginal productivity
pinv: Aggregate public investment			
	central case	0.63871	8.12
pinv1: National roads			
	central case	0.76549	29.58
pinv2: Municipal roads			
	central case	0.25396	14.05
pinv3: Highways			
	central case	0.11013	9.19
pinv4: Ports			
	central case	0.28102	84.40
pinv5: Airports			
	central case	0.07858	39.13
pinv6: Railways			
	central case	0.26418	18.83

Table 14 – Effects of public investment on employment

Public investment variable		Elasticities	Number of jobs (per million of Euros)
pinv: Aggregate public investment			
	central case	0.07860	230
pinv1: National roads			
	central case	0.04524	404
pinv2: Municipal roads			
	central case	0.05441	692
pinv3: Highways			
	central case	0.00865	164
pinv4: Ports			
	central case	0.07025	4800
pinv5: Airports			
	central case	-0.00438	-500
pinv6: Railways			
	central case	0.01221	204

Table 15 - Effects of public investment on output

Public investment variable		Elasticities	Marginal productivity	Rates of return
pinv: Aggregate public investment				
	central case	0.18264	9.54	15.9%
pinv1: National roads				
	central case	0.19807	31.41	23.0%
pinv2: Municipal roads				
	central case	0.09839	22.32	20.9%
pinv3: Highways				
	central case	0.02416	8.24	15.0%
pinv4: Ports				
	central case	0.08736	107.14	30.8%
pinv5: Airports				
	central case	0.00937	19.18	20.0%
pinv6: Railways				
	central case	0.06247	18.47	19.7%