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Identifying Priorities in Infrastructure Investmentin Portugal (*)

*Alfredo Marvão Pereira***
The College of William and Mary

Rui M. Pereira
The College of William and Mary

College of William and Mary
Department of Economics
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Abstract

In this paper we use a vector autoregressive approach to analyze the effects of infrastructure investment on economic performance using a newly developed data set for Portugal. We find that investments in other transportation infrastructures – railroads, ports and airports – and social infrastructures – health and education infrastructures, have the largest effects with long-term multipliers of 14.99 and 8.46, respectively. Investments in road transportation – roads and freeways - and on utilities – electricity, gas, water, refineries, and telecommunications – induce much smaller effects with multipliers of 2.75 and 3.52, respectively. We also show that for other transportation and social infrastructure investments, the short term effects are small relative to the accumulated effects and yet, in absolute terms, they exceed the long-term effects for road transportation and utilities. Finally, we show that investments in other infrastructures and in social infrastructures will pay for themselves in the form of long term enhanced tax revenues under rather reasonable effective tax rates. Overall, we have clearly identified other transportation infrastructures and social infrastructures as the key target areas for policy intervention in this context.

Keywords: Infrastructure Investment, Multipliers, Economic Performance, Budgetary Effects, VAR, Portugal.
JEL Classification: C32, E22, E62, H54, H60, O47, O52

Alfredo Marvão Pereira
Department of Economics,
The College of William and Mary, Williamsburg, USA
PO Box 8795, Williamsburg, VA 23187
ampere@wm.edu

Rui M. Pereira
Department of Economics,
The College of William and Mary, Williamsburg, USA
PO Box 8795, Williamsburg, VA 23187
rmpereira@wm.edu

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1. Introduction

Since 1986, with the accession of Portugal to the European Union, economic policies to promote growth have focused on investments in infrastructures, primarily on road infrastructure. Over the last decade, however, things have changed. With fewer EU funds available for infrastructure investment and the problematic and very unpopular utilization of public-private partnerships, financing for infrastructure investment must increasingly come from the public budget. This could not have come at a worse time. The recent sovereign debt crisis and quest for austerity and budgetary consolidation have resulted in an ongoing economic recession coupled with persistently high public debt levels. Infrastructure investments are often perceived of as the most politically expedient areas for budgetary cuts due to the distribution of potential benefits and costs through time and the diffusion of these benefits over the population. Indeed, as the current crisis reached its peak, infrastructure investment has been the expenditure category with the largest decline in the public budget. Not surprisingly, it reached in recent years their lowest levels in decades.

And yet, the dual needs for public policies to promote economic performance and for debt consolidation remain. As the country seems to start coming out of the dark in terms of the economic woes and with a persistent need to improve long term employment and productivity conditions, the question again arises on how to define priorities for achieving these goals.

From our perspective, the central issue is the role that infrastructure could or should play in achieving these goals. The criticisms of and suspicion about infrastructure investment is widespread. Long gone are the days when infrastructure investment was seen as a panacea. But critical questions remain. Is it still worth investing in infrastructures? And if so which types of assets? What are the effects of infrastructure investment on labor productivity, employment, private investment, and output? What is the relative importance of more short term demand effects versus the long term supply side effects of these investments? What are the ramifications of these investments for the long term prospects of fiscal consolidation?

In this paper we analyze the impact of public infrastructure investment on economic performance in Portugal and address the questions above, first at the aggregate level and then considering four main types of infrastructure investments – road transportation infrastructures, other transportation infrastructures, social infrastructures, and utilities. In doing so we intend to bring a level of clarity to the debate on defining strategic priorities as far as infrastructures investments are concerned. A clarity based on empirical evidence that will allow the debate to be based on facts not preconceived notions.

Conceptually, the ultimate objective of this paper is to estimate the long term multipliers of the different types of infrastructure investment in a way that incorporates information about their relative scarcity. The magnitude of the respective marginal products will be a good indicator of the relative economic relevance of the investments. Equally important, their magnitude will also determine if the investments will be self-financing or not over the long-term in the form of additional tax revenues. While a positive marginal product by itself suggests a meaningful investment from an economic perspective, a sufficiently large marginal product suggests also a meaningful investment from a budgetary perspective.

From a taxonomic perspective, we can expect infrastructure investments to conceivably fall into three categories. First, the case of negative or low positive marginal products. In this case, infrastructure investment are not important for the economy and have a detrimental effect on the budget and as such can be eliminated without significant economic or budgetary concerns. Second, the case of positive but not sufficiently large marginal products. These infrastructure investments are important for the economy but still have a detrimental effect on the public budget. Eliminating these investments although useful from a budgetary perspective is hurtful in economic terms. Third, the case of sufficiently large marginal products. In this case these infrastructure investments have positive economic and budgetary effects. Eliminating these investments hurts both the economy and the public budget.

We use a multivariate dynamic time series methodological approach, based on the use of vector autoregressive (VAR) models, developed in Pereira and Flores (1999) and Pereira (2000, 2001) and subsequently applied to the U.S. in Pereira and Andraz (2003, 2004), to Portugal in Pereira and Andraz (2005, 2006), and to Spain in Pereira and Roca-Sagales (2003), among others.

This econometric approach highlights the dynamic nature of the relationship between infrastructure investment and the economy. It does so at three distinct levels: i) it explicitly addresses the contemporaneous relationships in the innovations in each variable; ii) it incorporates the dynamic intertemporal feedbacks among the variables; and, iii), it accommodates the existence of long-run equilibrium co-integrating relationships among the variables. Built into the approach is the identification of a causal relationship among the variables rather than simple correlations.

In addition, it should be pointed out that although our approach is eminently empirical, it is not a-theoretical. Indeed, our analysis is grounded in a dynamic model of the economy. In this model, the economy uses a production technology based on the use of capital and labor, as well as public infrastructure, to generate output. Given market conditions and the availability of public infrastructure, private economic agents decide on the level of input demand and the supply of output. In turn, the public sector engages in infrastructure investment based on a policy rule that relates public infrastructure to the evolution of the remaining economic variables. The estimated VAR system can be seen as a dynamic reduced form system for a production function and three input demand functions – for employment and private investment as well as infrastructure investment [a policy function]. This framework captures the role of public infrastructure investment as a direct input to production and as an externality in production. Infrastructures further affect output indirectly through their effect on the demand for labor and private capital.

In this context, our work is also related to the literature on fiscal multipliers, i.e., on the macroeconomic effects of taxes and government purchases [see, for example, Baunsgaard et al. (2014) and Ramey (2011), for recent surveys of this literature]. It is in fact very much in the spirit of the approach pioneered by Blanchard and Perotti (2002), which is based on a VAR approach and uses the Choleski decomposition to identify government spending shocks. We focus, however, on a specific type of public spending – infrastructure investment and the channels through which it affects the economy, as opposed to aggregate spending as it is traditional in this literature.

Finally, and since this is clearly not the first paper dealing with infrastructure investment in Portugal using this methodology it is important to highlight the novelties in this paper. First, we use a new and recently completed comprehensive data set for infrastructure investment in Portugal covering the period between 1978 and 2012 [see Pereira and Pereira (2015)]. In doing so, this is the first paper to enlarge the scope of the analysis of the effects of infrastructure investments by considering non-transportation infrastructures. Specifically, we consider also social infrastructures – education and health facilities, and utilities – water, electricity and gas, refineries, telecommunications. At the same time this is also the first treatment of the transportation infrastructure using data after the late 1990s as previous work used data ending in 1998. From a more conceptual perspective, this is the first contribution that decomposes the marginal products between the sort-term demand effects on impact and the long term supply side effects and that maps the evolution of the marginal products over time to identify patterns of decreasing marginal returns. From a policy perspective, and in response to the economic conditions developing over the last decade, this is the first time the above taxonomy is introduced and applied and the policy implications of the results are framed in terms of the economic and budgetary dilemma.

This paper is organized as follows. Section 2 presents the economic and infrastructure data. Section 3 presents the preliminary econometric results including the VAR model specification and discusses the identification of exogenous shocks to infrastructure investment as well as the measurement of their effects. Section 4 presents the main evidence as to the economic impact of infrastructure investment as well as their policy implications. Section 5 provides some international comparisons for the results in this paper. Section 6 presents a summary and concluding remarks.

2. Data Sources and Description

We use annual data for Portugal from 1978 to 2011. The economic data are obtained from the Instituto Nacional de Estatística (National Institute for Statistics, Portugal). The data for infrastructure investment are from a new data set developed by Pereira and Pereira (2015). Gross domestic product (GDP), private investment, and infrastructure investment are measured in millions of constant 2005 Euros while employment is measured in thousands of employees.

We consider total infrastructure investment as well as four main types of infrastructure investments: road transportation infrastructure, other transportation infrastructure, social infrastructures, and utilities infrastructure. Table 1 presents some summary information for infrastructure investment effort, as a percent of GDP, as well as their respective growth rates.

Road transportation infrastructures include national roads, municipal roads and highways and account for 28.2% of total infrastructure for the sample period. Investment efforts and the extension of motorways in Portugal grew tremendously during the 1990s with the last ten years marked by a substantial increase in highway investment made possible due to public private partnerships. This corresponds in absolute terms to an increase from 0.75% of GDP in the 1980s to 1.56% in the last decade.

Other transportation infrastructures include railroads, airports and ports. Other transportation infrastructure investment accounted for 9.0% of total infrastructure investment between 1980 and 2011. Investment in social infrastructures reached its greatest levels, as a percent of total infrastructure investment, with the modernization of the railroad network and port expansion projects in the context of the second community support framework during the 1990s. The last ten years has also brought with it substantial growth in investment in airports with the renovation and expansions of the airports in Lisbon and Porto. These efforts are reflected in an increase in investment volumes from 0.22% of GDP in the 1980s to 0.48% in the last decade.

Social infrastructures include health facilities and educational buildings. Social infrastructures accounted for 23.8% of total infrastructure investment and have shown a slowly declining pattern over time in terms of their relative importance in total infrastructure investment. In absolute terms, however, these investments have remained stable over the last two decades representing an average of just over 1.0% of GDP.

Public utilities include water supply and treatment, electric power generation, transmission and distributions, petroleum refining and telecommunications infrastructures. Together these account for 39.1% of total infrastructure investment over the sample period. In terms of their relative importance, investment in utilities were of particularly high relevance, in terms of total infrastructure investment in the 1980s, driven by the expansion of the telephone network, substantial investment in the major coal powered generating units in Sines and investment in the two refineries in Portugal, in Matosinhos and Sines following the oil price shocks of the 1970s. More recently, the expansion of mobile communications networks as well as investments in renewable energies have contributed to sustained growth in investment in utilities. In absolute terms, we witnessed a constant increase in importance for these investments from 1.1% of the GDP in the 1980s to 2.1% in the last decade.

Overall, investment levels have grown substantially over the past thirty years, averaging 2.9% of GDP in the 1980s, 4.5% in the 1990s and 5.2% over the last decade. The increase in infrastructure investment levels is particularly pronounced after 1986, the year in which Portugal joined the EU, and in the 1990s when EU transfers within the context of the Structural and Cohesion Funds stimulated a substantial increase in investment levels (Community Support Framework 1, 1989-1993; Community Support Framework 2, 1994-1999). Investment efforts decelerated substantially during the last decade during the Third Community Support Framework, 2000-2006, and the QREN (National Strategic Framework), 2007-2011. These landmark dates for joining the EU as well as the start of the different community support frameworks are all considered as potential candidates for structural breaks in every step of the empirical analysis that follows.

3. Preliminary Data Analysis

3.1. Unit Roots, Cointegration, and VAR specification

We start by using the Augmented Dickey-Fuller as well as the Zivot-Andrews t-test to test the null hypothesis of a unit root in the different variables, without any structural breaks and with endogenously determined break points, respectively. We use the Bayesian Information Criterion (BIC) to determine the number of lagged differences to be included in the regressions, and we include deterministic components, a constant and/or a trend, as well as structural breaks in the regressions if they are statistically significant.

For both tests and for the variables in log-levels, the t-statistics are lower, in absolute levels, than the 5% critical values and, therefore, the tests cannot reject the null hypothesis of a unit root. In turn, for the tests applied to the first differences of the log-levels, i.e., the growth rates of the original variables, 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.

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

We now test for cointegration among output, employment, private investment, and infrastructure investment as well as each one of the four infrastructure investment variables. We use the standard Engle-Granger approach to test for cointegration and the corresponding Gregory-Hansen test with an unknown breakpoint. 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 smaller samples based on annual data, Johansen's tests are known to induce strong bias in favor of finding cointegration when it does not exist.

Following the standard 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 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 deterministic components and structural breaks are included if they are statistically significant. This amounts to forty tests, four for each of the five infrastructure investment variable for each of the two tests.

The value of the t-statistics is lower, in absolute value, than the 5% critical values in all but five of the forty cases considered and never in more than one of the four cases considered for each infrastructure type. Moreover, all the test statistics without exception are lower, in absolute value, than the 1% critical values. Thus, our tests cannot reject the null hypothesis of no cointegration.

The absence of cointegration is neither surprising nor problematic. On one hand, it is not surprising to find lack of evidence for long-term equilibrium relationships for an economy that is still clearly in the process of converging to the level of its peers in the European Union. On the other hand, it is not problematic as it only implies that a dynamic approach based exclusively on OLS univariate estimates of the variables in log-levels would lead to spurious results.

We have now determined that all of the variables are stationary of first order and that they 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 estimate the models using the growth rates of the original variables.

We estimate five VAR models. Each VAR model includes output, employment, and private investment. In addition, it includes a different infrastructure investment variable – one model for aggregate infrastructure investment and one for each of the four different types of infrastructure investment. This means that, consistent with our conceptual arguments, the infrastructure investment variables are endogenous variables throughout the estimation procedure. We use the BIC to determine whether exogenous structural breaks and deterministic components, the constant and trend, should be included in the VAR system.

Our test results suggest that a first order VAR specification with a constant and a trend as well as structural breaks in 1989, 1994, and 2000 is the preferred choice for the models with aggregate infrastructure investment, other transportation, social infrastructure, and utilities. The case of road infrastructure requires a second order VAR with the same deterministic components and structural breaks. The identification of the structural breaks is very meaningful as it shows the relevance of the inception of the first three community support frameworks but the lesser importance of the most recent one, the QREN.

Finally, it should be pointed out that the estimated matrices of variance and covariance of the residuals display in general a strong block-diagonal pattern in which the innovations in the private economic variables show low correlations with the more public infrastructure investment variables. The exception is utilities, in which case the block diagonal pattern does not exist. This is consistent with the significant privatization efforts of the late 1990s and early 2000s which implies that the bulk of investment in utilities is now private. The existence of this block diagonal pattern is relevant in that it suggests that our estimates of the effects of innovations in the infrastructure investment variables have a low contemporaneous correlation with innovations in the other variables, a matter to be further discussed below.

3.2. Identifying Exogenous Innovations in Infrastructure Investment

While the infrastructure investment variables are endogenous in the context of the VAR models, the central issue in determining the economic impact of infrastructure investment is the identification of exogenous shocks to the infrastructure investment variables. This means that we need to identify the shocks to infrastructure investment variables that are not contemporaneously correlated with – that are orthogonal to – shocks in the other variables. These exogenous shocks allow us to identify the effects of innovations in infrastructure investment that are not contaminated by other contemporaneous innovations as they avoid contemporaneous reverse causality issues.

In dealing with this issue we draw from the approach typically followed in the literature on the effects of monetary policy [see, for example, Christiano, Eichenbaum and Evans (1996, 1998), and Rudebusch (1998)] and adopted by Pereira (2000) in the context of the analysis of the effects of infrastructure investment.

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

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

We have two reasons for making this our central case. First, it seems reasonable to believe that the economy reacts within a year to innovations in infrastructure investment decisions. Second, it also seems reasonable to assume that the public sector is unable to adjust infrastructure investment decisions to innovations in the economic variables within a year. This is due to the time lags involved in information gathering and public decision making.

The central results we report in this paper are the ones obtained under our preferred orthogonalization strategy, assuming that investment in infrastructures affects all other variables contemporaneously. These are the results to focus upon. These tables also include ranges of variation over all possible statistical orthogonalization strategies under the Choleski decomposition approach. These ranges should not be understood as confidence intervals in that they just literally report the range of variation for all conceivable strategies including therefore all alternatives statistically possible even if not meaningful from an economic perspective. They just measure the level of ambiguity that could conceivably be introduced by the well-known problem of the dependency of impulse response function in a VAR framework to the contemporaneous correlations among the estimated residuals.

The policy functions for aggregate infrastructure investment as well as the different types of infrastructure investment relate the evolution of infrastructure investment to the evolution of the economic variables with a one-year lag. The specification of these policy functions was tested. In no case were variables lagged more than one period statistically significant. More importantly, in no case were the contemporaneous values of the economic variables statistically significant. This confirms our assertion that our central case scenario is the most plausible also from an econometric perspective.

The different policy functions are presented in Table 2. For aggregate infrastructure investment, as well as for each of the four individual infrastructure types, the policy functions suggest that there is no feedback from the other variables to the infrastructure investment variable. This also means that these variables do not Granger-cause infrastructure investment, and infrastructure investment is truly an exogenous variable. The exogeneity of infrastructure investment decisions in Portugal is easily explained by the fact that for most of the sample period infrastructure investment decisions have been closely related to EU structural and cohesion policies.

3.3. Measuring the Effects of Innovations in Infrastructure Investment

We consider the effects of one-percentage point, one-time random shocks in the rates of growth of the different types of infrastructure investment on output, employment, and private investment. We expect these temporary shocks in the growth rates of the different types of infrastructure investment to have temporary effects on the growth rates of the other variables. They will, however, have permanent effects on the levels of these variables. All of these effects are captured through the impulse response functions and accumulated impulse response functions associated with the estimated VAR models. In all cases standard deviation bands were calculated to ascertain the statistical significance of the results.

The accumulated impulse response functions are presented in Figure 1 and Figure 2. All of them show a smooth convergence pattern within a ten-year period. Furthermore, the estimated standard deviation bands always fall in the positive range of results suggesting that the effects we identify are significantly different from zero. The only exception although marginal is the case of the effects on employment and output from road infrastructure in which case the standard deviation bands although falling mostly on positive range also overlap with the negative range, though it is important to note that the actual coverage of these bands far exceeds their nominal coverage [see Killian (1998)].

To measure the effects of infrastructure investment we calculate the long-term elasticities and the long-term marginal products of the different economic variables with respect to each type of infrastructure investment. However, these concepts are used in a way that departs from conventional definitions because they are not based on *ceteris paribus* assumptions, but include all the dynamic feedback effects among the different variables. That is, they measure both the direct and dynamic effects of infrastructure investment on the economic variables and the indirect dynamic effects of infrastructure investment through changes in the evolution of these variables. This while considering the dynamic feedbacks from these variables to the evolution of infrastructure investment. Naturally, these are the relevant concepts from the standpoint of policy making.

Table 2 presents the elasticities of private investment, employment and output with respect to infrastructure investment, both at the aggregate level and disaggregated by type of infrastructure. These long-term accumulated elasticities are to be interpreted as the total accumulated percentage point long-term change in the other variables for a one-percentage point accumulated long-term change in infrastructure investment.

Table presents the marginal products for private investment, employment and output with respect to infrastructure investment, both at the aggregate level and disaggregated by type of infrastructure. The long-term accumulated marginal products of public infrastructure investment measure the dollar change in private investment and output, and the number of permanent jobs created, for each additional dollar of investment in public infrastructures. The marginal product figures are obtained by multiplying the average ratio of each variable to public investment by the corresponding elasticity. Accordingly, the marginal product figures are the most interesting from a policy perspective as they capture the effects of scarcity in addition to the effects of the coupling of infrastructure investment and the economy as reflected in the elasticities figures.

In computing the marginal products, we use the average ratio of the economic variable to the level of infrastructure investment over the last ten years of the sample. This allows the marginal product figures to reflect the relative scarcity of the different types of infrastructures at the margin of the sample period without letting these ratios be overly affected by business cycle factors. In addition, to measure the effects on the marginal products of evolution of the relative scarcity, we also calculate the marginal product figures using rolling ten year averages starting for the beginning of the sample period.

Finally, Table 5 presents the annual rate of return of the different infrastructure investments. The rate of return is calculated from the marginal product figures by assuming a useful life schedule for railroad capital assets consistent with its observed implicit depreciation rate. The rate of return is the annual rate at which an investment of one dollar would grow over the lifetime of the asset to yield its accumulated marginal product.

4. On the Effects of Infrastructure Investment by General Asset Type

4.1 On the Elastiticities with Respect to Infrastructure Investments

The results at the aggregate level suggest that investment in infrastructure crowds in both private investment and employment. Indeed, we estimate that the elasticity of private investment with respect to aggregate infrastructure investment is 0.6205, and the elasticity of employment with respect to aggregate infrastructure investment is 0.0881. Given the positive effects on private investment and on employment, it follows naturally a positive impact on output. Indeed, we find that aggregate infrastructure investment has a positive effect on output, with an elasticity of 0.1712.

At a more disaggregated level, considering the elasticities with respect to the four types of infrastructure, we observe that they are all positive and within relatively narrow ranges. The elasticities of private investment range from 0.2292 for ***road transportation*** to 0.3911 for ***social infrastructure***; the elasticities of employment range from 0.0169 for ***road transportation*** to 0.0547 for ***public utilities***; and, the elasticities of output from 0.0496 for ***road transportation*** to 0.0962 for ***public utilities***. It should be noted that in general the elasticities are lower for ***road transportation*** and ***other transportation*** on one hand than for ***social infrastructures*** and ***public utilities*** on the other, reflecting a stronger structural connection to the rest of the economy on the part of the latter.

It should be noted that with one exception, the results above are all statistically different from zero, and strongly so, as suggested by the standard deviation bands around the accumulated impulse response functions. The exception is road infrastructures in which case the results for employment and output are not statistically different from zero with our more stringent confidence bands but would significant be with more conventional levels and less stringent confidence intervals.

4.2 On the Effects of Infrastructure Investments on Labor Productivity

The effects of infrastructure investment on labor productivity can be determined from the relative magnitudes of the output and employment elasticities with respect to infrastructure investment. To the extent that changes in infrastructure investment have a larger effect on output than on employment, this implies that these investment activities increase output per worker and therefore the productivity of the workforce. The effects of infrastructure investments on labor productivity are depicted in Figure 3.

The elasticity of output with respect to aggregate infrastructure investment is significantly larger than the elasticity of labor which implies that investment in infrastructures has led to a significant increase in labor productivity in Portugal. At a more disaggregated level we see important albeit more tenuous effects and differences. Investments in ***social infrastructures*** and ***public utilities*** have the largest effects on labor productivity, 0.0435 and 0.0415, respectively. In turn, ***road transportation*** and ***other transportation*** have lower but still very significant effects, 0.0327 and 0.0393, respectively.

4.3 Marginal Products with Respect to Infrastructure Investment and Rates of Return

While the elasticity figures are interesting in and of themselves, the marginal product figures are a better measure of the relative effects of different types of infrastructure investments and the relevant measure from a policy perspective. This is because they reflect the relative scarcity of the different types of infrastructure investment at the margin of the sample period. They give therefore a direct measure of the long-term accumulated impact to be expected from new investments. The marginal products of the different infrastructure investments are depicted in Figure 4.

At the aggregate level, for total infrastructure, we find a marginal product of private investment of €2.52. This means that at the aggregate level, infrastructure investment crowds in private investment and that one euro of additional infrastructure investment will induce, in the long term, an accumulated total of €2.52 of private investment. In turn, our results suggest that at the aggregate level, 52.3 additional permanent jobs are created in the long term for each additional one million euros in infrastructure investment.

In terms of output we estimate an aggregated marginal product of €2.77. This implies that the increase of one euro in infrastructure investment leads to a total accumulated increase of €2.77 in output over the long term. This marginal product implies a rate of return of 5.2% assuming an average lifespan of the infrastructure assets of twenty years. In addition, it suggests that one euro in aggregate infrastructure investment would pay for itself in the long term in the form of increased tax revenues for an effective tax rate in the economy in excess of 36.1%.

At this aggregate level, we would conclude that while there are positive economic effects from additional infrastructure investments they are relatively small and with a rate of return below what would likely be required by the private sector. More importantly the positive economic effects are certainly not strong enough to unambiguously guarantee that these investments would pay for themselves in the form of future additional tax revenues.

Naturally the more aggregate results are just indicative. Let's consider now the magnitude of the effects at a more disaggregated level to identify more nuanced patterns. Here we see that the largest positive effects of infrastructure investment on private investment come from ***other transportation*** and ***social infrastructure***, €12.62 and €8.66, while the largest effects on employment come from ***other transportation***, with 271 long-term jobs per million euros, and from **social infrastructure** with 169 permanent jobs per million euros.

The same pattern can be observed in terms of the impact of the different types of infrastructure on output. The largest effects come from investment in ***other transportation*** infrastructures, with a marginal product of €14.99 and ***social infrastructure*** with a marginal product of €8.46. These values imply rates of return over thirty years of 14.5% and 11.3%, for ***other transportation*** and ***social infrastructures***, respectively, rates which are very competitive by market standards. The multipliers and rates of return for ***road transportation*** and of ***public utilities*** are significantly smaller.

From a policy perspective these more disaggregate effects are very informative. All marginal products are positive so that in our taxonomy all infrastructure investment types fall clearly in either case two or three, i.e., they induce relevant economic effects. The only question is what to expect in terms of budgetary effects. Here there is a significant difference. While investments in ***other transportation*** and in ***social infrastructures*** would be self-financing even for very low effective tax rates, investments in ***road transportation*** and in ***public utilities*** would only come close to paying for themselves under effective tax rates in excess of 36.3% and 28.5% respective. These two cases are too marginal to be confident about their positive budgetary effects in the long term.

The policy implication is critical, while reducing investment in ***road infrastructures*** and in ***public utilities*** may help the public budget, cuts in ***other transportation*** investments and in ***social infrastructure*** investments will not; they will, in fact, have a detrimental effect on the public budget.

4.4 Long-term Marginal Products versus Effects on Impact

From a methodological perspective, it is possible to decompose the long-term effects of infrastructure investments into two effects: the effect on impact and the long-term accumulated effect. This is a very important distinction from a policy perspective. In fact, infrastructure investment can be expected to have two types of effects, short-term demand side effects that are induced by implementation of the investment efforts, mainly the construction of the infrastructure and how it reverberates in the economy. In addition, there are the long-term effects that in addition to this short-term demand effects include the impact that the availability of the infrastructure has on the economic performance of the country, that is, the longer-term supply side effects.

In Table we report the decomposition of the marginal products of infrastructure investment in a way that in addition to the total accumulated long-term effect, it shows how much of this effect is due to a demand side impact effect, the difference being naturally the longer-term supply-side effect.

For total infrastructure investment, we estimate significant effects on impact of around 40% of the total effect for private investment, employment, and output. This means that a very sizable part of the economic as well as budgetary effects would occur almost immediately.

When we consider the four main types of infrastructure investment we get a better picture. In terms of ***road transportation***, the bulk of the effects on private investment and output, 59% specifically, are on impact, that is, in the year of construction. This suggests that the declining pattern of small and decreasing marginal products have pretty much eroded the long-term supply side benefits of these infrastructures and most of what is left is short-term demand side effects related to construction. An exception to this pattern is the employment effects. The short term employment effects are a very small part of what is anyway a very small long term effect.

For ***other transportation***, the short term effects are about one-third of the total effects. This means that aside from the short-term demand side effects related to construction there are also quite sizable long-term supply side effects to the economy. It could be noted that in terms of their magnitude, the short term effects on impact of other infrastructure are larger than the overall long terms effects of either road transportation or utilities.

In the case of ***social infrastructures***, the other area of significant economic and budgetary potential, the short term effects are also moderate, about 45% for private investment, 26% for employment and 35% for output. This means that the long term supply-side effects also dominate but to a lesser extent than in the case of other transportation. Equally interesting is that all of the short-term effects of social infrastructure investments are larger than the total effects of both road infrastructure and utilities, in this case with the exception of the total output effects of utilities.

Finally, for ***public utilities***, we find that the short-term demand side effects tend to be stronger than for other transportation and social infrastructure but less than road transportation.

From a policy perspective these results suggest that the types of infrastructure investment with the largest accumulated effects – other transportation and social infrastructures – are also the ones where the short-term effects are in relative terms the least important. In absolute terms, however, we see that they dominate also in terms of the magnitude of the short-term effects. This means that even if the objective of infrastructure investment were simply to be employed as a demand side tool to promote employment and growth, investments in other transportation and social infrastructures would still be the best bets for the public sector. Furthermore, and from a budgetary perspective, these investments would pay for themselves on impact for effective tax rates as low as 25% and 33%, respectively.

4.5 Long-Term Marginal Products and the Relative Scarcity of Infrastructure Capital

Economic theory suggests that a pattern of diminishing marginal return to infrastructure capital should be expected, meaning that with a more developed stock of infrastructure incremental additions through investment will have progressively smaller economic effects. In this context, it is important to recall that the marginal products with respect to infrastructure investment presented in this work are computed using infrastructure investment and the other relevant economic data for the last ten years. This recent period is chosen to reflect the most recently available data and accurately reflect the effect of infrastructure scarcity on the economic impact of infrastructure investment at the margin. A ten year period is chosen to ensure that the results are not overly affected by business cycle fluctuations.

To assess the evolution of the effects of scarcity on the measurement of the marginal products with respect to infrastructure investment throughout the sample period, we present now the marginal products using alternative time periods. Specifically, we consider 10-year moving averages beginning in 1978 thereby tracing the evolution of the marginal products as reflecting the evolution of the relative scarcity of the infrastructure asset. This information is particularly useful in depicting the specific patterns of diminishing marginal productivity of infrastructure investment in the different cases and specifically how fast it is decreasing. This is fundamental in evaluating the potential for policies to encourage the development of additional infrastructures.

The evolution of the marginal products for total infrastructure investment and the four main types of infrastructure assets are presented in Figure 5 and Figure 6. As a point of reference, the values for the marginal products we have presented and discussed above are the very last points in the different figures, that is, are the points where each curve ends using averages for the last ten years of the sample.

The diminishing pattern is clear in all cases when we consider the evolution of the marginal products at the level of total infrastructure investment. The diminishing pattern is clear in all cases. In terms of the effects on private investment, with current values for the marginal products of investment, employment and output now at about 60%, 37%, and 55% respectively of the values implied by the scarcity in the earlier years of the sample.

Considering the four main types of infrastructure assets provides a very rich differentiation amongst the evolution of the marginal products of the different infrastructure investment. Indeed, for ***road transportation***, we see a pattern of steady decline of marginal products, one that is more pronounced earlier in the sample period than over the last ten years. Indeed, the marginal products at the end of the sample are just 50%, 34%, and 47%, for investment, employment, and output, of the values observed earlier in the sample. This is consistent naturally with a pronounced effort throughout the sample in the development of road transportation infrastructures and the concomitant reduction of the relative scarcity of these infrastructures. The case of ***public utilities*** is similar both qualitatively and quantitatively to the case of road transportation we just described.

For **other transportation** infrastructures as well as for ***social infrastructures*** we also see an overall pattern of decreasing marginal returns although less pronounced and indeed with a small inflection point after the early 2000s. The levels of marginal productivity measured at the end of the sample period are actually remarkably close to the levels as measure at the end of the 1990s. This is consistent with the idea that these infrastructures were the focus of attention mostly in the latter part of the sample but even then they did not play center stage.

These patterns are relevant from a policy perspective. The marginal products for ***road infrastructure*** and ***public utilities*** tend to be small currently and show throughout the sample a strong declining pattern. The expectation therefore should be that future infrastructure investments in these areas would generate small and progressively declining effects. Their economic effect is becoming smaller and their budgetary effects moving more and more into the potentially detrimental region. Therefore, we reinforce the idea presented above that these do not seem to be key areas for public policy efforts. In turn, the opposite is true for investments in ***other transportation*** and ***social infrastructure***. These show large and relatively stable marginal products over the last decade adding to their desirability both in economic and budgetary terms.

5. International Comparisons

There is a wide body of literature dealing empirically with the economic effects of infrastructure investment [see, for example, Munnell (1992), Gramlich (1994), Romp and de Haan (2007) and Pereira and Andraz (2013), for literature surveys as well as the literature review in Kamps (2005)]. Accordingly, making general and merely qualitative comparisons is easy although not particularly interesting. More relevant quantitative comparisons are, however, surprisingly difficult. This is because of wide differences in the temporal and typological scope and definition of the data sets used, the great different in econometric approaches and their implications in terms of the interpretation of such basic terms as elasticities and marginal products.

Although difficult, meaningful international comparisons are not impossible. We focus here on comparisons with the evidence on the output multipliers of infrastructure investment in Portugal [see, Pereira and Andraz (2005, 20011)] and Spain [Pereira and Roca (2003, 2007)] on one hand and Ontario, Canada [see Pereira and Pereira (2014)] and the U.S. [see Pereira (2000)] on the other hand. In all cases the results are based on the same methodological approach and therefore more directly comparable to the ones developed in this paper. Canada and the U.S. provide for a comparison with an economy at a greater level of development and with arguably a lower level of infrastructure scarcity. In contrast, Spain provides for a comparison at a similar level of development and scarcity in the infrastructure stock. Naturally, the most interesting comparisons will be with previous evidence for Portugal itself.

In most cases the data sets end in the middle to late 1990s. The exception is for the case of Ontario, Canada where data covers 1976 to 2011 and is therefore close to the time frame used in this paper. The studies for the US use data from 1956 to 1997 while the Portuguese case uses info from 1978 to 1998 and the Spanish case from to 1970-1995. Finally, comparisons with the results for Portugal and Spain are more limited in that the Portuguese and Spanish cases only consider transportation infrastructure – roads, highways, ports, airports, rail - and in the Spanish case communications. The studies for Ontario, Canada and the U.S. are more generally comparable in terms of scope of the data base used, which is more comprehensive, considering infrastructure types beyond transportation. For Ontario, Canada, the study considers government, administrative and other infrastructures, health infrastructures, education infrastructures, road infrastructures, and water and waste water infrastructures. For the U.S., the study considers road infrastructure, electric and gas facilities, water and sewage, education, hospital and other buildings, and a residual category.

The estimates for the output multipliers of ***road transportation*** investments for the US is 1.97, the smallest multiplier among the infrastructure types considered, while for Ontario, Canada the multiplier for road infrastructures is actually negative. Our estimate of 2.75 although larger than these two cases is similarly, the smallest among the infrastructure types considered. In terms of the multipliers for ***other transportation*** infrastructure investments, the closest category for the U.S. study is core infrastructure which includes transit and airfields – but also electricity and gas. The estimated multiplier for core infrastructures in the U.S. is 19.79 and is the largest among the infrastructure types considered. For Ontario, Canada, the largest multiplier is also for transit with a marginal product of 29.19. Our estimate for Portugal including airports, ports and railroad infrastructure is similarly the largest at 14.99.

The evidence for Spain considering total transportation infrastructure – road and otherwise – suggests a multiplier of 5.50. This figure can be compared directly to the evidence for Portugal for a comparable time horizon, a multiplier of 9.54. The natural conclusion is that the marginal benefits of further investments in transportation infrastructure were greater at the time for Portugal than Spain, reflecting a pattern of greater scarcity in Portugal. In turn, the figure for just road transportation for Portugal for the same period is 18.06, suggesting therefore an even greater marginal product and an even greater scarcity when only road infrastructure is considered.

In turn, for the U.S. the multiplier for the infrastructure type that most resembles ***social infrastructure*** – but also includes administrative buildings – is 5.53, and is in the middle of the range of results, while for Ontario, Canada the estimate of the multiplier for education infrastructure is 14.17 and health infrastructure is 23.46 and are among the largest. Our estimate for social infrastructure is 8.46 and is only second to other transportation infrastructure. Finally, for ***utilities***, the estimates for the U.S. for water and water systems are 6.35 while for Ontario, Canada the same multiplier is 8.29. Our multiplier for utilities is 3.52 but comparing it to these figures has to be very tentative as we also include in this category, electricity and gas, refineries, and telecommunications.

All of the above suggests that our estimates are within the range of, and in line with, roughly comparable estimates for Ontario, Canada using recent data and the U.S. using data until the late 1990s. We now turn our attention to the case of the evidence for transportation infrastructure in both Spain and Portugal also using data until the late 1990s.

Let us now consider more closely the comparisons with precious estimates of the multipliers for Portugal. Again, our results now for ***road transportation*** and for ***other transportation*** are 2.75 and 14.99, respectively, while for the combination of both that is ***total transportation*** – a result not previously introduced in the paper – it is 3.18. These figures are to be contrasted with multipliers for the period ending in the late 1990s of 18.06 for road infrastructures, around 19.0 for other transportation, and 9.54 for total transportation.

The multiplier for road transportation is now 6.5 times smaller than by the late 1990s. This not only reflects a rapid decline in the marginal productivity of these investments as it could be seem from the discussion in the precious section, but even more so from a decoupling of road infrastructure investments and economic performance as reflected by the decline in the elasticity itself from 0.29 to 0.05. In turn, for other transportation the values are somewhat smaller but certainly not to the same degree. Overall the multiplier for total transportation infrastructure investment is now about one third of what was estimated for the late 1990s. Clearly, in terms of the output effects there is a degree of diminishing returns and even more so of increasing decoupling which is particularly large for road infrastructures investments. The same patterns of decreasing marginal products and increasing decoupling, although in a more evenly manner between these two effects, can also be observed in terms of the effects on private investment and employment.

6. Summary and Concluding Remarks

This study analyzes the effects of infrastructure investment on economic performance in Portugal. We employ a vector autoregressive approach to estimating the elasticity and marginal product of public infrastructure investment on private investment, employment and output. This approach is consistent with the argument that the analysis of the effects of infrastructure investment on economic variables requires the consideration of dynamic feedback effects among the different variables.

We start by establishing that overall infrastructure investments have a moderate positive impact on private investment, employment and output. More importantly, we proceed to show that these aggregate effects hide a wide variety of asset-specific results. We find that investments in other transportation – railroads, ports and airports – and social infrastructures – health facilities and educational structures, have the largest effects with long-term multipliers of 14.99 and 8.46, respectively. Investments in road transportation – roads and freeways – and in utilities – electricity, gas, water, refineries, and telecommunications – induce much smaller effects with multipliers of 2.75 and 3.52, respectively. We also show that for other transportation and social infrastructure investments, the short term effects are small relative to the accumulated effects and yet in absolute terms they exceed the long-term effects for road transportation and utilities. Finally, we show that under rather reasonable effective tax rates investments in other infrastructures and in social infrastructures will pay for themselves in the form of greater tax receipts over the long term.

Overall, we have identified other transportation infrastructure and social infrastructure as the key target areas for policy intervention in this area of infrastructure development. They have the advantage of generating not only positive economic effects but also favorable budgetary impact. Moreover these positive effects on the economy and the budget are felt in the very short term although they continue in the longer term – the point is that the authorities do not have to wait long for the positive effects to be evident. The focus on these two areas of infrastructure investment therefore, fits perfectly into the policy and political economy conundrum of trying to promote long term growth in a context of rather delicate budgetary situation and even more fragile political balance.

Our recommendation for a strategic focus on ***other transportation*** is consistent with the concern that investments in railroads and ports have been neglected and the investments in railroads have been rather insufficient. Our results give substance to the recommendations of a government appointed group to identify heuristically priorities in transportation infrastructure investment [see Ministério da Economia (2014)]. Their recommendation focused mostly on railroad and port investments.

In turn, our recommendation for a strategic focus on ***social infrastructures*** needs some elaboration. First, it needs to be clear that we are not talking about investing in education and health in general but rather on health and education infrastructures. There is a growing body of the international evidence suggesting that these infrastructures embody technological advances and lead to high quality job creation. This is also consistent with a growing interest of the private sector in investments in health infrastructures through the mechanisms of public-private partnerships.

In turn, our recommendation to move away from road infrastructure investment fits into and substantiates – by giving ample empirical support – the common wisdom that this is an exhausted strategy. It is also consistent with view of the European Commission in their refusal to allocate any further community financing in the context of the structural policy and cohesion programs to these types of projects. Our recommendation to move away from investments in utilities is also consistent with the fact that a lot of the sector has been privatized and therefore these investments are progressively out of the jurisdiction of the public sector and will be undertaken only to the extent that private profitability is guaranteed.

Our results open the door to several important avenues of future research directly relevant for policy purposes. The first, would be a finer analysis at a more disaggregated infrastructure level of the effects of investments – the more disaggregated the more relevant the policy recommendations. Second, one should consider the effects of infrastructure investment at the industry level. This is particularly relevant to identify the relative effects of these investments in traded and non-traded industries and thereby allow us to understand the interaction between infrastructure investment and general policies to promote international competitiveness in Portugal. Third, one should consider the effects of infrastructure investment at the regional level. This would be particularly important as it would shed light on the issue of inter-regional infrastructure investment spillovers and the effects of infrastructure investment in the regional concentration of economic activity.

To conclude, it should be mentioned that although this paper is an application to the Portuguese case and is intended to be directly relevant from the perspective of policy making in Portugal, its interest is far from parochial. The quest for policies that promote long-term growth in a framework of fragile public budgets is widespread. As EU structural transfers have shifted towards new members, countries such as Ireland, Greece, and Portugal have been forced to rely on domestic public policies to promote real convergence. This poses a challenge since growing public spending, pro-cyclical policies, and more recently, falling tax revenues have contributed to rapidly increasing levels of public debt and a sharp need for budgetary consolidation. How to direct the infrastructure investment efforts in a way that is friendly to both the economy and the public budget is, therefore, a question in search of an answer in many other countries facing similar difficulties.

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Table 1 Investment Effort and Growth in Portugal by Infrastructure Type

	Total Infrastructure Investment	Road Transportation	Other Transportation	Social Infrastructures	Utilities
			Percent of GDP		
1978-2011	4.19	1.19	0.38	0.96	1.66
1980-89	2.92	0.75	0.22	0.82	1.13
1990-99	4.45	1.34	0.47	1.09	1.55
2000-09	5.17	1.56	0.48	1.04	2.09
			Growth Rate		
1978-2011	3.54	3.77	1.77	2.29	4.12
1980-89	4.74	3.41	2.04	3.18	7.17
1990-99	7.79	6.22	11.16	9.39	7.04
2000-09	1.22	3.47	-2.82	-3.49	3.04
			Percent of Total		
1978-2011	100.00	28.20	8.98	23.76	39.06
1980-89	100.00	25.99	7.57	28.41	38.04
1990-99	100.00	30.35	10.52	24.52	34.61
2000-09	100.00	30.23	9.21	20.13	40.43

Table 2 Policy Functions for Infrastructure Investment

	gdp_{-1}	emp_{-1}	$gfcf_{-1}$	$pinv_{-1}$	1989	1994	2000	$Constant$	$Trend$
Aggregate Infrastructure	1.4805	1.2678	0.0045	-0.2164	-0.1041	-0.1706	-0.3468	-0.0872	0.0150
	(2.4991)	(2.1692)	(0.7254)	(0.2708)	(0.1073)	(0.1537)	(0.2286)	(0.1117)	(0.0106)
Road Transportation	0.3147	-0.1106	0.7340	-0.1295	0.2292	0.2555	0.5058	0.1906	-0.0233
	(3.4884)	(3.0071)	(0.9454)	(0.2036)	(0.1505)	(0.2)	(0.3001)	(0.154)	(0.0138)
Other Transportation	0.0419	-2.6824	0.7860	0.0279	0.0417	0.0351	-0.1265	0.0333	0.0024
	(4.1778)	(3.6803)	(1.1259)	(0.2433)	(0.1804)	(0.2463)	(0.3918)	(0.1891)	(0.0178)
Social Infrastructures	1.9727	0.1490	0.5998	-0.1587	-0.0468	-0.0816	-0.1904	-0.0443	0.0062
	(2.6142)	(2.2437)	(0.7707)	(0.2248)	(0.1107)	(0.1493)	(0.2235)	(0.1153)	(0.0102)
Utilities	2.5442	5.4785	-1.6959	-0.1765	-0.4196	-0.5598	-1.1046	-0.2923	0.0491
	(5.0049)	(4.3211)	(1.3517)	(0.1922)	(0.2175)	(0.301)	(0.4471)	(0.224)	(0.0207)

Standard errors in parentheses
* p<0.05, ** p<0.01, *** p<0.001

Table 2 Elasticities with respect to Infrastructure Investment - Main Types of Assets

	Private Investment	Employment	Output
Total Infrastructure	0.6205	0.0881	0.1712
	[0.0249,0.6205]	[0.0035,0.0881]	[-0.0150,0.1712]
Road Transportation Infrastructure	0.2292	0.0169	0.0496
	[-0.0803,0.2292]	[-0.0238,0.0169]	[-0.0381,0.0496]
Other Transportation Infrastructure	0.2596	0.0379	0.0772
	[0.0881,0.2596]	[0.0130,0.0379]	[0.0275,0.0772]
Social Infrastructures	0.3911	0.0521	0.0956
	[0.0117,0.3911]	[0.0127,0.0521]	[-0.0189,0.0956]
Utilities	0.3156	0.0547	0.0962
	[0.020,0.3156]	[0.0024,0.0547]	[0.0006,0.0962]

Table 4 Marginal Product of Infrastructure Investment - Main Types of Assets

	Private Investment	Employment	Output
Total Infrastructure	2.5115	0.0523	2.7692
	[0.1007,2.5115]	[0.0021,0.0523]	[-0.2419,2.7692]
Road Transportation Infrastructure	3.1801	0.0343	2.7492
	[-1.1145,3.1801]	[-0.0484,0.0343]	[-2.1138,2.7492]
Other Transportation Infrastructure	12.6197	0.2706	14.9993
	[4.2817,12.6197]	[0.0925,0.2706]	[5.3426,14.9993]
Social Infrastructures	8.6569	0.1692	8.4546
	[0.2594,8.6569]	[0.0413,0.1692]	[-1.6690,8.4546]
Utilities	2.8891	0.0735	3.5198
	[0.1828,2.8891]	[0.0033,0.0735]	[0.0212,3.5198]

Table 5 Rate of Return on Infrastructure Investment - Main Types of Assets

	Lifespan of			
	20 years	30 years	40 years	50 years
Infrastructure Investment	5.22	3.45	2.58	2.06
Road Transportation	5.19	3.43	2.56	2.04
Other Transportation	14.50	9.45	7.00	5.57
Social Infrastructures	11.26	7.37	5.48	4.36
Utilities	6.49	4.28	3.20	2.55

Table 6 Long-term Marginal Products versus Effects on Impact - Main Types of Assets

		GFCF	EMP	GDP
Aggregate Infrastructure	Long Term	2.51	0.05	2.77
	Short Term	1.05	0.02	1.12
	Percent	0.42	0.44	0.40
Road Transportation Infrastructure	Long Term	3.18	0.03	2.75
	Short Term	1.88	0.01	1.63
	Percent	0.59	0.19	0.59
Other Transportation Infrastructure	Long Term	12.62	0.27	15.00
	Short Term	3.75	0.09	4.07
	Percent	0.30	0.33	0.27
Social Infrastructures	Long Term	8.66	0.17	8.45
	Short Term	3.87	0.04	3.00
	Percent	0.45	0.26	0.35
Utilities	Long Term	2.89	0.07	3.52
	Short Term	1.03	0.04	1.35
	Percent	0.36	0.55	0.38

Figure 1 Accumulated Impulse Response Functions with respect to Infrastructure Investment

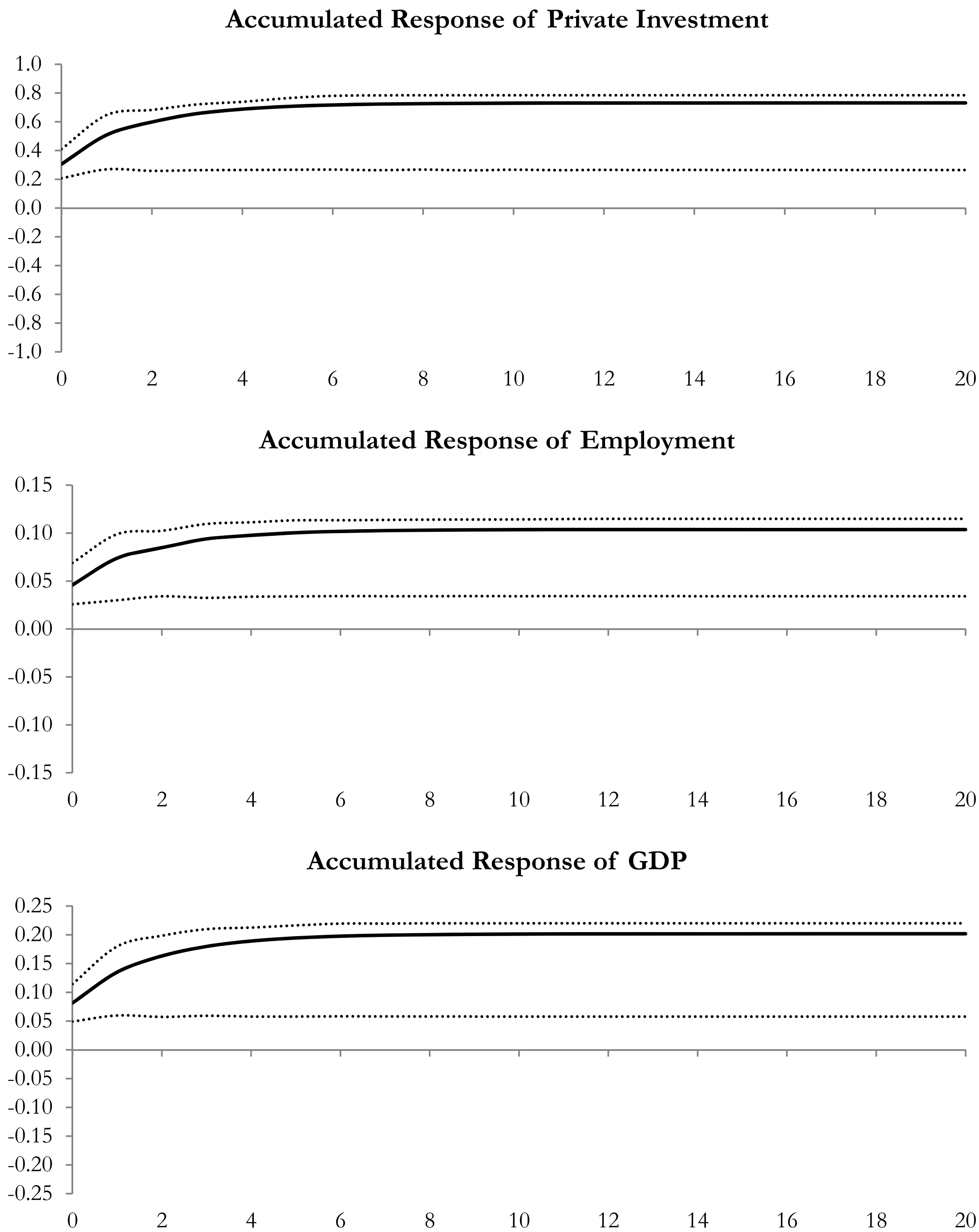

Figure 2 Accumulated Impulse Response Functions with respect to Infrastructure Investment

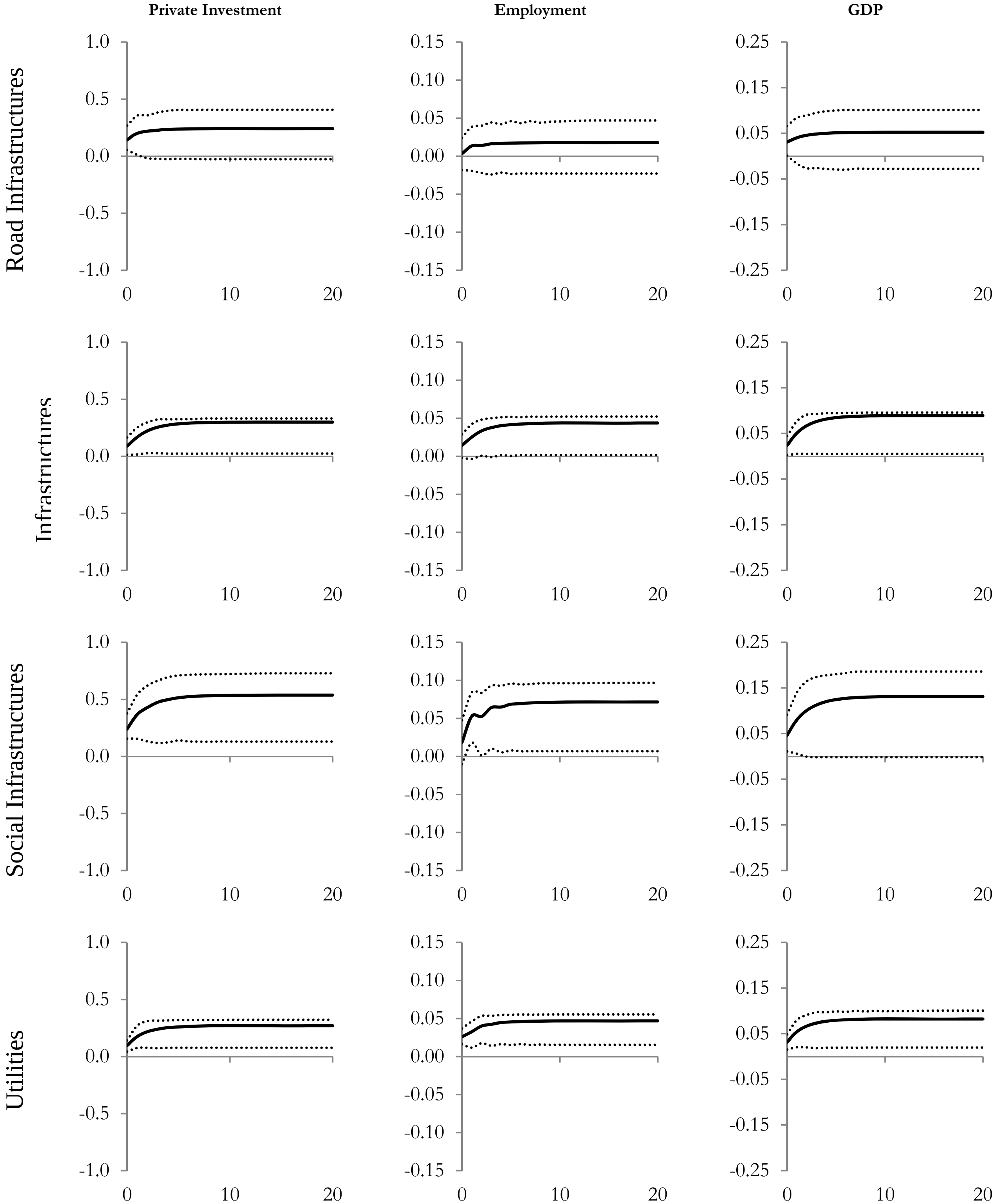

Figure 3 Effects of Infrastructure Investment on Labor Productivity

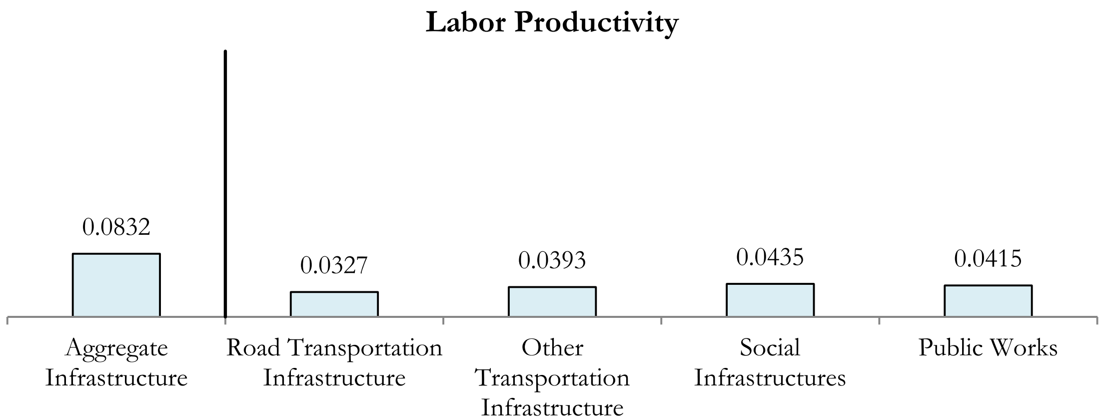

Figure 4 Effects of Infrastructure Investment - Main Types of Assets

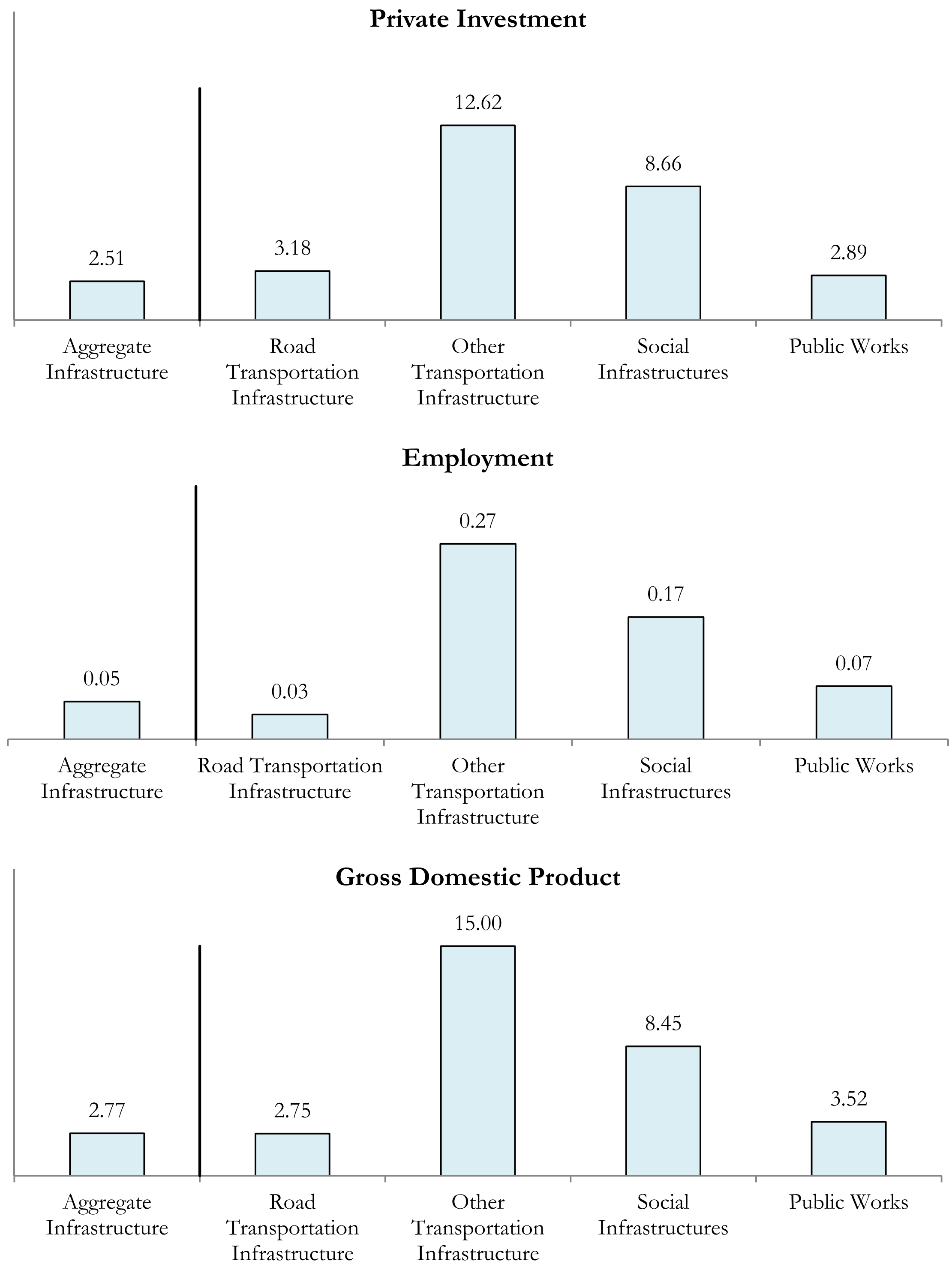

Figure 5 Marginal Productivity using Alternative Sample Periods

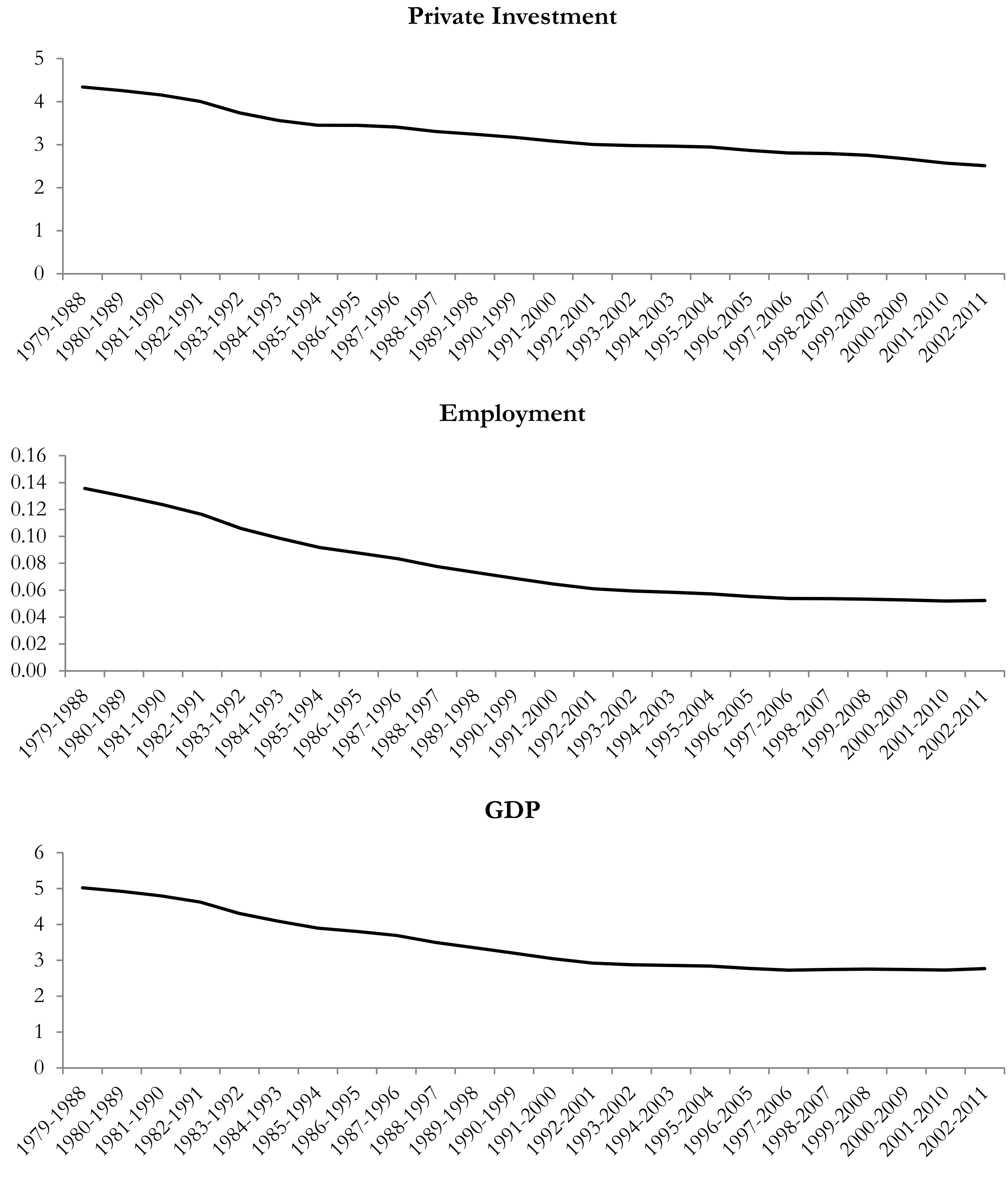

Figure 6 Marginal Productivity using Alternative Sample Periods – by Asset Type