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Are all infrastructure investments created equal? The case of Portugal

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ABSTRACT

Using a newly developed data set, we analyze the effects of infrastructure investment on economic performance in Portugal. A vector-autoregressive approach estimates the elasticity and marginal products of twelve types of infrastructure investment on private investment, employment, and output. We find that the largest long-term accumulated effects come from investments in railroads, ports, airports, health, education, and telecommunications. For these infrastructures, the output multipliers suggest that these investments pay for themselves through additional tax revenues. For investments in ports, airports and education infrastructures, the bulk of the effects are short-term demand-side effects, while for railroads, health, and telecommunications, the impact is mostly of a long-term and supply-side nature. Finally, investments in health and airports exhibit decreasing marginal returns, with railroads, ports, and telecommunications being relatively stable. In terms of the other infrastructure assets, the economic effects of investments in municipal roads, electricity and gas, and refineries are insignificant, while investments in national roads, highways, and waste and waste water have positive economic effects but too small to improve the public budget. Clearly, from a policy perspective, not all infrastructure investments in Portugal are created equal.

Keywords: *infrastructure investment; multipliers; budgetary effects; VAR; Portugal*

1. Introduction

The recent sovereign debt crisis in Portugal and the fiscal austerity that followed in the quest for budgetary consolidation resulted in a prolonged economic recession, coupled with persistently high level of public debt relative to GDP. As the current crisis reached its peak, infrastructure investment led the pack as the category with the largest decline in the public budget [see, for example, CFP (2016)]. Unsurprisingly, in recent years, infrastructure investment reached its lowest levels in decades, after having played a major role in the development strategy of the country in the 1990s and early 2000s. And yet, the dual needs for public policies to promote economic performance and consolidate public finances still remain. Once again, there is the question as how to achieve these goals and what role infrastructure investment can or should play in achieving them. In the case of the Portuguese economy, are infrastructures still worth investing in? And, if so, which types ought to be top priority? What are the effects of infrastructure investment on labor productivity, employment, private investment, and output? What is the relative importance of

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their short-term demand-side effects and the long-term supply-side effects? What are the implications of these investments for long-term fiscal consolidation?

This article focuses on the impact of infrastructure investment on economic performance in Portugal and addresses these questions. Conceptually, our ultimate objective is to estimate the long-term multipliers for the different types of infrastructure investments. The magnitudes for the estimated marginal products are a good indicator of the relative economic relevance of these investments. Equally important, their magnitude will also determine if the investments will pay for themselves or not over the long term in the form of additional tax revenues.

From a taxonomic perspective, we can expect infrastructure investments to fall into one of three categories. First, consider the case of negative or low positive marginal products. In this case, infrastructure investments 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, consider 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, there is 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. In this context, our quest for identifying priorities in infrastructure investments represents searching for areas of investment that fall into this third category, *i.e.*, infrastructures investments with virtuous economic and budgetary effects.

The analysis of the economic effects of infrastructure investments was brought to the limelight by the seminal work of Aschauer (1989a, 1989b). The initial work was based on a univariate and static production function approach applied at an aggregated level to the U.S. case. The body of empirical literature that developed in its aftermath is extensive [see, for example, Munnell (1992), Gramlich (1994), Kamps (2005), Romp and de Haan (2007, Pereira and Andraz (2013), and Bom and Ligthart (2014), for literature surveys]. The empirical literature focuses on a large variety of issues, for the U.S. and for other countries, both at the aggregate level and at the industry and regional levels. A variety of econometric approaches to deal with issues of simultaneity, causality, and dynamics have been proposed in the literature.

In this paper, we use a multivariate dynamic time series approach developed in Pereira (2000, 2001).[1] We employ a vector-autoregressive (VAR) model, relating output, employment, private investment, and infrastructure investment to estimate the long-term elasticities and marginal products of output, employment, and private investment with respect to infrastructure investment through an analysis of the resulting impulse-response functions.

This econometric approach highlights the dynamic nature of the relationship between infrastructure investment and the economy. It does so at three distinct levels: first, it explicitly addresses the contemporaneous relationships in the innovations in each variable; second, it incorporates the dynamic

1. This work is also related to the voluminous 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, and Leduc and Wilson (2012) for a related analysis]. In fact, it is 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 on the different channels through which it affects the economy, as opposed to aggregate spending, as is traditional in this literature. In this sense, the focus of this article is closer to Leduc and Wilson (2012).

intertemporal feedbacks among the variables; and, third, it accommodates the possibility of long-run equilibrium cointegrating relationships among the variables. Built into this approach are the simultaneous endogeneity of all variables and the identification of a causal relationship among the variables and infrastructure investment, rather than simple correlations.

Finally, and since this is not the first article that deals with infrastructure investment in Portugal—indeed we could regard this paper as an update and extension of Pereira and Andraz (2005)—it is important to highlight its contributions to the literature. First, we use a new and recently completed comprehensive data set for infrastructure investment in Portugal from 1978 to 2012 [see Pereira and Pereira (2016)]. In doing so, this is the first research to enlarge the scope of the analysis of the effects of infrastructure investments by c onsidering six types of non-transportation infrastructures (health and education infrastructure investments, water, electricity and gas, refinery facilities, and telecommunications). At the same time this is also the first treatment of six transportation infrastructure types (national roads, municipal roads, highways, railroads, ports, and airports) using data after the late 1990s. From a more conceptual perspective, we feature the decomposition of the marginal products between the short-term demand-side effects on impact and the long-term supply-side effects, and we map the evolution of the marginal products over time to identify patterns of decreasing marginal returns. From a policy perspective, framed in terms of the economic and budgetary dilemma, and in response to the economic conditions developing over the last decade, we introduce and apply the aforementioned taxonomy, drawing policy implications from the results.

2. Data sources and description

We use an annual data for Portugal from 1978 t o 2012. The economic data are obtained from the *Instituto Nacional de Estatística* (National Institute for Statistics) and is available online at www.ine.pt. The data for infrastructure investment are from a new data set developed by Pereira and Pereira (2016). Gross domestic product (GDP), private investment, and infrastructure investment are measured in millions of 2005 Euros, while employment is measured in thousands of employees.

We consider total infrastructure investment as well as twelve different types of infrastructures, grouped in four categories of infrastructure investments: road transportation infrastructure, other transportation infrastructure, social infrastructures, and utilities infrastructure. Table 1 presents summary statistics for infrastructure investment effort, as a percent of GDP and as a percent of total infrastructure investment.

Road transportation infrastructures include national roads, municipal roads, and highways, and account for 28.49% of total infrastructure investment. Road investment grew tremendously during the 1990s under European Union support programs, with the last ten years marked by a boost in highway investment related to the expansion of public-private partnerships. Road investment increased from 0.74% of the GDP in the 1980s to 1.52% in the 2000s.

The largest component of road transportation investments for the sample period was national road investment, amounting to 0.52% of GDP and 12.46% of total infrastructure investment. What is most striking, however, is the substantial increase in investment in highways since 2000. In fact, the network of freeways in Portugal increased by more than a third since 2000. In the last decade, highway infrastructure investment amounted to 0.59% of GDP, and surpassed national road infrastructure investment in importance, with highway investment amounting now to 11.70% of total infrastructure investment. In contrast, the past thirty years have seen a steady decline in municipal road infrastructure investment volumes.

Table 1. Infrastructure investments

	1980–2011	1980–89	1990–99	2000–09
Percent of GDP (%)				
Infrastructure Investment	**4.18**	**2.88**	**4.40**	**5.04**
Road Transportation	**1.19**	**0.74**	**1.32**	**1.52**
National roads	0.52	0.33	0.61	0.57
Municipal roads	0.36	0.34	0.41	0.36
Highways	0.32	0.07	0.30	0.59
Other Transportation	**0.38**	**0.22**	**0.47**	**0.46**
Railroads	0.29	0.15	0.37	0.35
Ports	0.05	0.03	0.06	0.06
Airports	0.04	0.03	0.03	0.06
Social Infrastructures	**0.96**	**0.81**	**1.08**	**1.02**
Health	0.46	0.28	0.47	0.60
Educational	0.50	0.53	0.60	0.41
Utilities	**1.65**	**1.11**	**1.53**	**2.04**
Water	0.31	0.14	0.27	0.42
Petroleum	0.16	0.09	0.18	0.15
Electricity and Gas	0.61	0.46	0.38	0.87
Telecommunications	0.57	0.41	0.70	0.61
Percentage of Infrastructure Investment (%)				
Infrastructure Investment	**100.00**	**100.00**	**100.00**	**100.00**
Road Transportation	**28.49**	**25.99**	**30.35**	**30.23**
National roads	12.46	11.52	14.09	11.43
Municipal roads	9.16	11.90	9.47	7.10
Highways	6.86	2.56	6.79	11.70
Other Transportation	**8.91**	**7.57**	**10.52**	**9.21**
Railroads	6.64	5.17	8.31	6.92
Ports	1.21	1.23	1.40	1.08
Airports	1.06	1.17	0.81	1.21
Social Infrastructures	**23.76**	**28.41**	**24.52**	**20.13**
Health	10.82	9.89	10.73	11.97
Educational	12.94	18.52	13.79	8.16
Utilities	**38.85**	**38.04**	**34.61**	**40.43**
Water	6.99	4.90	5.98	8.17
Petroleum	3.64	3.22	4.06	2.83
Electricity and Gas	14.44	15.97	8.45	17.53
Telecommunications	13.77	13.94	16.12	11.89

Other transportation infrastructures include railroads, airports, and ports, and account for 8.91% of total infrastructure investment between 1978 and 2011. These investments reached their highest levels, as a percent of total infrastructure investment, in the 1990s with the modernization of the railroad network and port expansion projects while the last ten years brought substantial growth in investment in airports, compared to the previous decade. This reflects an increase from 0.22% of the GDP in the 1980s to 0.46% in the last decade.

Railroads represent the bulk of investment in other transportation infrastructures, nearly 75% of total investment in other types of transportation infrastructures. Investment in railroad infrastructures amounted to 0.29% of GDP over the sample period, reaching 0.37% of GDP during the 1990s in the context of the community support frameworks. Investment in ports and airports over the past thirty years has represented relatively smaller investment volumes due to the rather limited number of major airports (3) and ports (12) in the country. Nonetheless, very substantial investments in the airports of Lisbon and Oporto were undertaken in the last decade with investment volumes reaching 0.06% of GDP, nearly double that seen in the 1980s—a period in which major investments were directed towards the Lisbon airport—and 1990s. During the last decade, investments in airports accounted for 1.21% of total infrastructure investment.

Social infrastructures include health facilities and educational buildings. Social infrastructures account for 23.76% of infrastructure investment and show a slowly declining pattern in terms of their relative importance in total infrastructure investment. As a percentage of GDP, these investments remained stable over the last two decades representing on average of 1.05%.

Investment in health facilities and educational buildings both figure heavily in investment in social infrastructures with health facilities accounting for 10.82% and educational buildings accounting for 12.94% of total infrastructure investment. Investment in health facilities amounted to 0.46% of GDP and investment in educational facilities amounted to 0.50% of GDP over the sample period. While both are relatively important, their evolution over time is markedly distinct. In particular, investment in health facilities has been increasing steadily, both as a percent of GDP and also a percent of total infrastructure investment. In contrast, investment in educational buildings has been declining steadily in relation to the remaining infrastructure types. In addition, investment in educational facilities as a p ercent of GDP reached their highest levels in the 1990s, amounting to 0.60% of GDP. In turn, investment in health facilities reached its greatest volumes in the last decade and amounted to 0.60% of GDP.

Finally, public utilities include electric power generation, transmission and distribution, water supply and treatment, petroleum refining, and telecommunications infrastructures. Together these account for 38.85% of total infrastructure investment in the sample period. In terms of their relative importance in terms of total infrastructure investment, investments in utilities reached a peak in the 1980s, driven by the expansion of the telephone network and substantial investment in major coal-powered electricity production units and in two refineries. More recently, the expansion of mobile-communications networks, as well as investments in renewable energies, have contributed to sustained growth in investment in utilities since 2000. Overall, we witnessed a constant increase in importance from 1.11% of the GDP in the 1980s to 2.04% in the last decade.

Investment in electricity and gas infrastructures, followed closely by investments in telecommunications, represent the largest components of investment in utilities. The evolution of these investments, however, is quite distinct and reflective of both the state and development of technologies, as well as international economic dynamics. Specifically, investment in electricity and gas infrastructures accounted for a relatively large share of total infrastructure investment, 15.97%, in the 1980s due to the construction of the Sines thermoelectric-power plant, a coal-fired plant with four large generating units that supply nearly 20% of the electricity consumed in Portugal. The decision to invest in expanding electricity-generating capabilities at the time was a direct product of the oil price shocks of the 1970s. Similarly, the last decade has seen very pronounced efforts to increase the production of electricity from renewable sources, primarily through investment in wind turbines, and from natural gas and expanding the natural gas distribution network. As such, investment volumes reached 0.87% of GDP and accounted for 17.53% of total infrastructure investment. Investment in telecommunications amounted to 0.57% of GDP over the sample period. The largest investment volumes were associated with the development of the telephone network in the late 1980s and the developments in digital and information technologies in the late 1990s. Indeed, in the 1990s investment in telecommunications amounted to 16.12% of total infrastructure investment.

Overall, investment levels grew substantially over the past thirty years, averaging 2.88% of GDP in the 1980s, 4.40% in the 1990s and 5.04% 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 First Community Support Framework (1989–1993) and the Second Community Support Framework (1994–1999) stimulated a substantial increase in investment levels. 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

3.2 Unit roots and cointegration tests[2]

We start by using the Augmented Dickey-Fuller (ADF) *t*-tests to test the null hypothesis of a unit root in the different variables. Following Ivanov and Kilian (2005), we use the Bayesian Information Criterion (BIC) to determine the number of lagged differences, the deterministic components, as well as the dummies for the potential structural breaks to be included.

For the variables in log-levels, the *t*-statistics are lower, in absolute levels, than the 5% critical values. 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 hypotheses of unit roots in the growth rates. We take this as evidence of stationarity in first differences for all the time series under consideration.

We test for cointegration among output, employment, private investment, and infrastructure investment, and each one of the twelve infrastructure investment variables. We use the standard Engle-

2. Detailed test results are available from the authors upon request.

Granger approach.[3] In each case, we perform four tests, with each case having a different endogenous variable. In all of the tests, again following Ivanov and Kilian (2005), the optimal lag structure, deterministic components, and structural breaks are chosen using the BIC.

The value of the *t*-statistics is lower, in absolute value, than the 5% critical values in all but five of the forty-eight cases considered, and never in more than one of the four cases considered for each infrastructure type. Moreover, all the test statistics are lower, in absolute value, than the 1% critical values. Thus, our tests cannot reject the null hypothesis of no cointegration.

3.2 The VAR specification[4]

We estimate twelve VAR models, each including the growth rates of output, employment, private investment, and the growth rates of one of the twelve infrastructure investment variables. 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 in almost all cases. 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.

3.3 Identifying exogenous innovations in infrastructure investment

The central issue in determining the effects of infrastructure investment is the identification of exogenous shocks to infrastructure investment, shocks that are not contemporaneously correlated with shocks in the other variables. 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, 1999), and Rudebusch (1998)] and adopted by Pereira (2000) in the context of the analysis of the effects of infrastructure investment. The idea is to imagine a policy function which relates the rate of growth of infrastructure investment to the relevant information set. The residuals from this policy functions are uncorrelated with innovations in other variables.

We assume that the relevant information set for the policy function includes one-year lags of the economic variables, but not current values. This is equivalent in the context of the standard Choleski decomposition to assuming that innovations in infrastructure investment lead innovations in economic variables. We have two reasons for this assumption. 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, due to the time lags in gathering information and in public decision-making, to adjust infrastructure investment decisions to innovations in the economic variables within a year.

For each infrastructure type, the estimated policy functions suggest that there is no feedback from the

3. We have chosen this procedure over the often-used Johansen alternative, since we do not have any priors that suggest the possible existence of more than one cointegrating relationship; as such, the Johansen approach is not necessary. More importantly, for smaller samples based on annual data, Johansen's tests are known to induce a strong bias in favor of finding cointegration when one does not exist (although, arguably, the Engle-Granger approach can be criticized for suffering from the exact opposite).
4. See footnote 2.

economic variables to the investment variable.[5] 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, such decisions have been closely related to EU structural and cohesion policies.

3.4 The impulse response functions

We consider the effects of one-percentage point, one-time shocks in the rates of growth of the different types of infrastructure 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 accumulated impulse response functions associated with the estimated VAR models.[6]

Standard deviation bands were calculated to ascertain the statistical significance of the results. The error bands surrounding the point estimates convey the uncertainty around estimation, and are computed via bootstrapping methods. We consider 90% confidence intervals, although bands that correspond to a 68% posterior probability are the standard in the literature [see, for example, Sims and Zha (1999)]. Employing one-standard deviation bands narrows the range of values that characterize the likelihood shape and only serves to reinforce and strengthen our results. Further evidence exists that nominal coverage distances may underrepresent the true coverage in a variety of situations [see Kilian (1998)]. Thus, the bands presented are wider than the true coverage would suggest. From a practical standpoint, when the 90% error bands for the accumulated impulse response functions include zero in a way that is not marginal, we consider that the effects are not significantly different from zero.

4. On the impact of infrastructure investment by asset type

4.1 Long-term elasticities of infrastructure investments

The elasticities of output, employment, and private investment with respect to infrastructure investment are reported in Table 2, and are obtained from the accumulated impulse response functions. These elasticities measure the total accumulated percentage-point long-term change in the economic variables induced by a one-percentage-point accumulated long-term change in infrastructure investment.

Each type of infrastructure investment has a positive effect on private investment except for investment in ports. The positive elasticities are within a relatively narrow range, from 0.432 for health infrastructures and 0.300 for national roads to 0.018 for refineries. The same is true in terms of the effects on employment, in which case the only negative effect comes from investment in national roads. The positive employment elasticities range again from 0.059 for health infrastructures, 0.027 for education and 0.030 for telecommunications to 0.003 to refineries and electricity and gas infrastructures. Accordingly, our estimates suggest that, in the overwhelming majority of the cases, infrastructure investments crowd in both private investment and employment.

5. Once again, detailed results are available from the authors upon request.
6. Detailed plots of the accumulated impulse response functions and respective standard deviation bands are available from the authors upon request.

Naturally, the output effects of all the different types of infrastructure investments are positive. The largest effects come from investments in health and telecommunications, with elasticities of 0.117 and 0.071, respectively. The lowest elasticities are for municipal roads, ports, refineries, and electricity and gas, all with elasticities around 0.005.

The overwhelming majority of the accumulated long-term elasticities are statistically different from zero as implied by the standard deviation bands around the accumulated impulse response function estimates. There are, however, important exceptions. These exceptions are all of the elasticities with respect to investments in municipal roads, refineries, and electricity and gas. For these infrastructure investments we find no evidence of positive economic effects. In addition, the effects of investments in national roads on employment and of ports on private investment are not statistically significant either.

Table 2. Elasticities with respect to infrastructure investment

	Private Investment	Employment	Output	Labor Productivity
Road Transportation Infrastructure				
National roads	0.300	-0.004*	0.044	0.048
Municipal roads	0.062*	0.016*	0.004*	-0.012*
Highways	0.084	0.009	0.023	0.014
Other Transportation Infrastructure				
Railroads	0.173	0.016	0.043	0.027
Ports	-0.001*	0.008	0.006	-0.002
Airports	0.053	0.008	0.019	0.011
Social Infrastructures				
Health	0.432	0.059	0.117	0.058
Educational	0.239	0.027	0.043	0.016
Utilities				
Water	0.110	0.018	0.030	0.012
Petroleum	0.018*	0.003*	0.007*	0.004*
Electricity and Gas	0.025*	0.003*	0.005*	0.002*
Telecommunications	0.227	0.030	0.071	0.041

** Not statistically different from zero*

4.2 Long-term effects 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 presented in the last row of Table 2.

The effects of road infrastructure investments on labor productivity include a very large effect from investments in national roads, and a medium size effect from highways. The effect of investment in municipal roads is not statistically different from zero. In turn, the largest effects of other transportation investments are due to railroad investments, the effects of infrastructure investment in airports being medium size, and the effects from port investments being negligible. In turn, for social infrastructure investments, we have a strong effect from health infrastructure investment and a moderate effect from education infrastructure investment. Finally, the impact of investment in public utilities on labor productivity comes primarily from investments in telecommunications, as the effects from water and wastewater are moderate and the effects from refineries and electricity and gas are not statistically significant.

4.3 Long-term marginal products and rates of return

We now turn our attention to the marginal products of private investment, employment and output with respect to each type of public infrastructure category. The marginal product figures are a better measure of the relative effects of different types of public infrastructure investments and the relevant measure from a policy perspective. This is because they reflect the relative scarcity of the different types of public investment at the margin of the sample period.

The marginal products of infrastructure investment measure the long-term accumulated Euro change in private investment and output, and the number of permanent jobs created, for each additional Euro of investment in infrastructures. These figures are obtained by multiplying the average ratio of each variable to infrastructure investment by the corresponding elasticity. We use average ratios for the last ten years of the sample. This allows the marginal product to reflect the relative scarcity at the margin of the sample period without being overly affected by business-cycle factors. The marginal products are presented in Table 3.

Table 3. Marginal product of infrastructure investment

	Private Investment (million per million euros)	**Employment** (thousand jobs per million euros)	**Output** (million per million euros)
Road Transportation Infrastructure			
National roads	9.69	-20*	5.70
Municipal roads	3.93*	148*	1.02*
Highways	3.30	51	3.55
Other Transportation Infrastructure			
Railroads	11.32	156	11.36
Ports	-0.39*	482	9.75
Airports	17.92	400	26.52
Social Infrastructures			
Health	15.34	306	16.54
Educational	14.02	231	10.04
Utilities			
Water	4.48	108	4.79
Petroleum	2.04*	54*	3.05*
Electricity and Gas	0.51*	9*	0.40*
Telecommunications	8.60	164	10.70

** Not statistically different from zero*

In turn, Table 4 presents the annual rate of return of each type of infrastructure investment, calculated from the marginal product figures by assuming different life expectancies for the infrastructure assets. The rate of return is the annual rate at which an investment of one Euro would grow over the expected lifetime of the asset to yield its accumulated marginal product.

The marginal products of different road infrastructure investments are, in general, low. The only sizable effects are the impact of national roads on private investment, €9.69m, and on output, €5.70m. The remaining effects, namely all the effects of highway infrastructure investment, are very small while the effects of investments in municipal roads are not statistically different from zero. The corresponding thirty-year rates of return are all very low. The largest is 5.97% for investments in national roads.

The impacts of other transportation investments are much more significant. Large effects are almost universally observed. The main exception is that investment in ports has no statistically significant effect on private investment in the long term. On the flip side, investments in ports have a very large effect on labor in the long term, with 482,000 permanent jobs created, actually the largest effect among the twelve infrastructure types. In turn, airports have large private investment and employment effects, with marginal products of €17.92m and 400,000 jobs. The output multipliers are very large, €11.36m, €9.75m, and €26.52m for railroads, ports, and airports, respectively. The thirty-year rates of return are very competitive, the lowest being 7.89% for ports and the largest 11.54% for airports.

Table 4. Rate of return on infrastructure investment (%)

	Assuming a lifespan of			
	20 years	30 years	40 years	50 years
Road Transportation Infrastructure				
National roads	9.09	5.97	4.45	3.54
Municipal roads*	0.09	0.06	0.04	0.04
Highways	6.54	4.31	3.22	2.57
Other Transportation Infrastructure				
Railroads	12.92	8.44	6.26	4.98
Ports	12.06	7.89	5.86	4.66
Airports	17.81	11.54	8.54	6.78
Social Infrastructures				
Health	15.06	9.80	7.27	5.77
Educational	12.22	7.99	5.94	4.72
Utilities				
Water	8.16	5.37	4.00	3.19
Petroleum*	5.73	3.78	2.82	2.25
Electricity and Gas*	-	-	-	-
Telecommunications	12.58	8.22	6.10	4.85

** Not statistically different from zero*

The economic impact of social infrastructure investments is also very significant. Large effects can be identified for both health and education although the results tend to be larger for health. The effects on investment and employment are €15.34m and €14.02m, and 306,000 and 231,000 jobs, for health infrastructure and education infrastructure investments, respectively. The output multipliers are €16.54m for health infrastructure investments and €10.04m for education infrastructure investment, which imply thirty-year rates of return of 9.80% and 7.99%, respectively.

Finally, the effects of different public utilities investments are very diverse. While the effects of investments in water are very small, the effects of investments in petroleum, and electricity and gas are not statistically different from zero. In turn, the effects of investments in telecommunications are very sizable. The marginal products of these investments on private investment and employment are €8.60m and 164,000 jobs. The output multiplier is €10.70m, which translates into a thirty-year annual rate of return of 8.22%.

4.4 On the potential long-term budgetary effects

To identify the potential budgetary effects of investments in a given infrastructure we consider the output multiplier with respect to that variable. The potential budgetary effect of an investment depends on the amount of additional tax revenue generated by enhanced output conditions. Table 5 presents the long-term budgetary effects of the different types of infrastructure investments.

Table 5. Long-term budgetary effects of infrastructure investments

	Equilibrium Tax Tate	Fiscal Revenues with a Tax Rate of 25% (€)	Payoff Period (years) with a Tax Rate of 25%
Road Transportation Infrastructure			
National roads	17.5%	1.43	21
Municipal roads*	99.8%	0.25	120
Highways	28.2%	0.89	34
Other Transportation Infrastructure			
Railroads	8.8%	2.84	11
Ports	10.3%	2.44	13
Airports	3.8%	6.63	5
Social Infrastructures			
Health	6.0%	4.14	8
Educational	9.9%	2.51	12
Utilities			
Water	20.8%	1.20	25
Petroleum*	>100%	0.10	300
Electricity and Gas*	32.8%	0.76	40
Telecommunications	9.4%	2.68	12

** Not statistically different from zero*

In terms of road infrastructure, investments in national roads are the only ones that could pay for themselves, albeit by a small margin, in the form of future tax revenues. Both investments in municipal roads, which do not lead to significant effects, and in highways, which lead to small effects, would not pay for themselves. In turn, given the magnitude of the output multipliers, investments in all of the three types of other transportation infrastructures could be reasonably expected to pay for themselves in terms of increased future tax revenues they induce. With respect to social infrastructure investments, the magnitude of the output multiplier suggests that, from a budgetary perspective, both investments in health and education facilities would pay for themselves over the long term. Finally, of all of the investments in public utilities, only investments in telecommunication infrastructure would pay for themselves.

4.5 Long-term marginal products versus effects on impact

Infrastructure investments can be expected to have two types of effects. First, there are short-term demand-side effects that are induced by the very implementation of the investment efforts, mainly the construction of the infrastructure and how this activity reverberates throughout the economy. Second, there are longer-term supply-side effects that reflect the impact of the availability of the infrastructure on economic performance. Table 6 reports the decomposition of the marginal products of infrastructure investment in a way that, in addition to the total accumulated long-term effect, shows how much of this total effect is due to a demand-side effect on impact. The difference between the two is, naturally, the longer-term supply-side effect.

Let's consider first road infrastructure assets. For national roads, we observe that most of the effects on private investment, and all of the effects on output, are short-term effects. Actually, the short-term effects on output exceed the long-term accumulated effects, which suggest a small negative long-term effect. As mentioned before, the effects for investments in municipal roads are not statistically significant while for highways they are rather small, and we observe that most of the effects, actually all of the employment effects, are long-term effects.

As to other transportation, for investments in railroad infrastructures, only less than one-third of the effects are short-term effects. The opposite is true for port and airport investments. For port infrastructure investment, the positive employment effects are short-term and about half of the total investment and output multiplier effects occur in the short term, while for airport infrastructure investment, consistently about two-thirds of the long-term effects are on impact.

In the case of social infrastructures, for health infrastructures the short-term effects are well below one-third of the total long-term accumulated effects. For education, on the other hand, around two-thirds of the effects on private investment and output are observed in the short term.

Finally, for utilities, investments in refineries and electricity and gas infrastructures are not statistically significant. The effects of investments in water and wastewater are more evenly distributed between shorter- and longer-term effects, while the effects of telecommunications are mainly long-term, in particular for the effects on employment.

Table 6. Long-term marginal products versus effects on impact

		Private Investment	**Employment**	**GDP**	
Road Transportation					
National roads	Total Effect	9.69	-0.02*	5.70	
	Short-Term	6.52	-0.05	6.72	
	(% of total)	(67%)	(250%)	(118%)	(Average: >100%)
Municipal roads	Total Effect	3.93*	0.15*	1.02*	
	Short-Term	1.93	0.07	-1.81	
	(% of total)	(49%)	(48%)	(-178%)	(Average: <0%)
Highways	Total Effect	3.30	0.05	3.55	
	Short-Term	1.16	-0.00	1.00	
	(% of total)	(35%)	(-2%)	(28%)	(Average: 20%)
Other Transportation					
Railroads	Total Effect	11.32	0.16	11.36	
	Short-Term	3.61	0.03	2.62	
	(% of total)	(32%)	(16%)	(23%)	(Average: 24%)
Ports	Total Effect	-0.38*	0.48	9.75	
	Short-Term	-0.22	0.48	4.66	
	(% of total)	(57%)	(100%)	(48%)	(Average: 68%)
Airports	Total Effect	17.92	0.40	26.52	
	Short-Term	11.45	0.27	18.43	
	(% of total)	(64%)	(68%)	(69%)	(Average: 67%)
Social Infrastructures					
Health	Total Effect	15.34	0.31	16.54	
	Short-Term	4.75	0.07	3.91	
	(% of total)	(31%)	(23%)	(24%)	(Average: 26%)
Educational	Total Effect	14.02	0.23	10.04	
	Short-Term	9.49	0.09	6.01	
	(% of total)	(68%)	(39%)	(60%)	(Average: 56%)
Utilities					
Water	Total Effect	4.48	0.11	4.80	
	Short-Term	1.52	0.07	2.11	
	(% of total)	(34%)	(68%)	(44%)	(Average: 49%)
Petroleum	Total Effect	2.04*	0.05*	3.05*	
	Short-Term	0.03	0.01	0.39	
	(% of total)	(2%)	(15%)	(13%)	(Average: 10%)
Electricity and Gas	Total Effect	0.51*	0.01*	0.40*	
	Short-Term	0.40	0.01	0.35	
	(% of total)	(78%)	(143%)	(88%)	(Average: >100%)
Telecommunications	Long Term	8.60	0.16	10.70	
	Short-Term	3.46	0.02	4.44	
	(% of total)	(40%)	(12%)	(41%)	(Average: 31%)

** Not statistically different from zero*

4.6 On the relative scarcity of infrastructure capital

A pattern of diminishing marginal returns to infrastructure capital is to be expected, *i.e.*, with a more developed stock of infrastructure, incremental investments should have progressively smaller economic effects. In this context, it is important to recall that the marginal products are computed using infrastructure investment and the other relevant economic data for the last ten years. This recent period is chosen to include the most recently available data and to accurately reflect the effect, at the margin, of the scarcity of infrastructure on the economic impact of infrastructure investment.

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, next we present 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.[7]

For road transportation, we can clearly see a pattern of steady decline of marginal products for national roads, particularly for highways where the decline is extremely steep. To illustrate, the long-term output multiplier for highway investments, which is now €3.55, would be at about €25 if measured by the scarcity standards of the late 1980s. This is consistent with an enormous effort in highway infrastructure in the last few decades.

For other transportation infrastructures, we also see an overall pattern of decreasing marginal returns, although less pronounced and indeed in some cases (railroads and ports) with a small inflection point after the early 2000s. In these cases, the levels of marginal productivity measured at the end of the sample period are actually remarkably close to the levels measured at the end of the 1990s and between one-third and one-half of the values by late 1980s. This is consistent with the idea that these infrastructures were the focus in the latter part of the sample, but even then they did not play center stage. In the case of airports, however, the pattern of decreasing returns is more pronounced, as these infrastructure investments have witnessed a surge in more recent years.

In the case of social infrastructures, we observe opposite patterns for health and educations investments. For health infrastructures, the marginal products have been consistently high, declining somewhat in the first years of the sample, but remarkably stable after the early 2000s. The case of education, however, is sharply distinct, in that the marginal products have actually increased in the last decade, reflecting an increasing relative scarcity of these infrastructures.

Finally, for the case of public utilities, we see a rather stable evolution of marginal products around the high values for telecommunications. In turn, for water and wastewater infrastructure, we see an extremely sharp decline in marginal products with very low effects at the end of the sample.

5. Some international comparisons

Making meaningful international comparisons is surprisingly difficult. This is because of wide differences in the temporal and typological scope and definition of the data sets, due to differences in econometric approaches and naturally in the interpretation of their estimates. As such, we focus here on

7. Detailed plots of the evolution of the marginal products for the different types of assets are available from the authors upon request.

comparisons with the evidence on the output effects of infrastructure investment in strictly comparable cases: Ontario, Canada [see Pereira and Pereira (2014)], the U.S. [see Pereira (2000)], and, more importantly, Portugal [see Pereira and Andraz (2005)]. These comparisons are presented in Table 7.

Table 7. International comparisons for the estimated output multipliers

	Present Study		**Portugal***		**United States****		**Ontario, Canada*****	
	1978–2012		1978–1998		1956–1997		1976–2011	
Road Transportation					0.006	1.97	negative	negative
National roads	0.044	5.70	0.198	31.41				
Municipal roads	0.004	1.02	0.098	22.32				
Highways	0.023	3.55	0.024	8.24				
Other Transportation Infrastructures					0.021	19.79	0.068	29.19
Railroads	0.043	11.36	0.062	18.47				
Ports	0.006	9.75	0.087	107.14				
Airports	0.019	26.52	0.009	19.18				
Social Infrastructures					0.017	5.53		
Education	0.043	10.04					0.068	14.17
Health	0.117	16.54					0.113	23.46
Utilities								
Water	0.030	4.80			0.009	6.35	0.019	8.29

** Pereira and Andraz (2005)*
*** Pereira (2000)*
**** Pereira and Pereira (2014)*

The estimates of the output multipliers for road infrastructure investments in the U.S. is 1.97, the smallest of all multipliers for the U.S., while for Ontario, Canada, the multiplier is actually negative. Our estimates for each of the individual assets are 1.02 for municipal roads, 3.55 for highways, and 5.70 for national roads. These estimates are in the same ballpark, but more importantly are also among the smallest effects we estimate. In terms of the multipliers, for other transportation infrastructure investments, where the closest category for the U.S. is core infrastructure which includes transit and airfields (but also electricity and gas), the multiplier is 19.79 and is the largest multiplier. For Ontario, Canada, the largest multiplier is also for transit with 29.19. Our estimates for Portugal are equally important effects, albeit to different degrees: 11.36 for railroads, 9.75 for ports, and 26.52 for airports.

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 our results, while for Ontario, Canada the estimate of the multiplier for education infrastructure is 14.17 and health infrastructure is 23.46—amongst the largest for that region. Our estimates for social infrastructure of 16.54 for health and 10.04 for education are of the same order of magnitude and also among our largest estimates. Finally, for public 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 corresponding multiplier is 4.80, which although smaller is of the same order of magnitude.

We now turn our attention to the comparisons with previous estimates of the output multipliers for Portugal, using data until the late 1990s. The decoupling of the infrastructure investment from the economy, as suggested by lower estimates of the elasticities, is particularly profound in the case of municipal roads and ports and less so for national roads and railroads. In turn, the elasticities for highway investment did not change significantly, while the elasticity for airports is now substantially larger.

When we consider the multipliers, we observe that only in the case of airport investment has the estimate increased—from 19.18 in the late 1990s to 26.52 now. This is completely due to a greater responsiveness of the economy to these investments, as the reduction in scarcity in itself would imply a decrease in the long-term multiplier. On the flip side, we see a very sharp decline in the multiplier for municipal roads (from 22.32 to 1.02) and for ports (from 107.14 to 9.75), which are in both cases totally due to the decoupling effects, that is, due to a lower elasticity. In turn, for national roads and railroads, we find more of a mixed role of decoupling and decreased scarcity in explaining the decline in the output multipliers from 31.41 to 5.70, and from 18.47 to 11.36, respectively. Finally, for highway investment, the decline in the multiplier from 8.24 to 3.55 is completely due to diminished scarcity.

6. Summary and concluding remarks

The wealth and variety of results presented in this paper suggests that a targeted approach to the design of infrastructure investment policy is desirable. Different types of infrastructure may be better suited to address different policy objectives, such as increasing labor productivity, encouraging private investment, creating jobs, or generating output. In addition, different investments—regardless of their long-term accumulated effects—may have rather different short-term effects on impact. Finally, in some cases, we observe sharply decreasing marginal returns in the last decade of the sample, that is, the 2000s, while in other cases the evolution of the marginal products seems to be much more stable.

The main public policy implication from our results is the recommendation that the government should promote investments in railroads, ports, airports, health and education infrastructures, and in telecommunications, as these investments have the largest output multipliers. These are not only the infrastructure assets with the highest effects on output, they are also the ones with high enough returns to imply that they would very likely pay for themselves in the form of future tax revenues generated by improved economic conditions. These investments may be good vehicles to promote not only economic growth and faster real convergence to the EU, but also budgetary consolidation. Cutting them back would, therefore, have detrimental effects on economic performance as well as on the public budget.

On the flip side, and as we consider the remaining infrastructure assets, in terms of their output effects, investments in municipal roads, highways, and electricity and gas infrastructures do not have meaningful or significant effects. Accordingly, cutting back on these investments would not particularly hurt the economy and would certainly have favorable effects on the public budget. In the middle of our taxonomic distribution are investments in national roads and water and wastewater infrastructures. In this case, although the long-term output multipliers are big enough to suggest some relevant effects on GDP, they are not large enough to be advantageous from a budgetary perspective. Cutting these investments would help the budget but hurt the economy.

Among the recommended investment categories, we have showed that the effects of investments in railroads, health, and telecommunications are mostly long-term supply-side effects while those of investments in ports, airports, and education are more short-term demand-side impact effects. From a public policy perspective, and *ceteris paribus*, this makes the investments in the former relatively more desirable than in the latter, as the main motivation for infrastructure investments should generally be to create the conditions for accelerated long-term economic growth. This also means that the latter are actually likely to be more desirable if the policy objective is to generate immediate short-term economic stimulus.

We also found that the long-term output multipliers of railroads, ports, airports, and health clearly show decreasing marginal returns. Accordingly, a strategy of promoting investments in these assets can only go so far, as additional investment reduces the relative scarcity and effectively lowers marginal products. In turn, there are no clear patterns of decreasing marginal returns for investments in telecommunications, which may be due to the relatively recent nature of the technologies involved. For investments in education infrastructures, there is a pattern of increasing marginal effects, likely due to a clear disinvestment and decommissioning of educational facilities over the last decade.

Because of their immediate relevance for policy-making, it is appropriate to include here two cautionary notes. First, these results deal with general macroeconomic impacts and provide proper but necessarily yet only general guidance. The fact that an infrastructure asset is identified as yielding important positive effects does not imply that all investment projects pertaining to the same assets are equally desirable or even desirable at all. The same reasoning applies to the assets that we have identified as less important: it does not mean that all projects in these areas would also be undesirable. To make these determinations, there is no substitute for a comprehensive benefit-cost analysis. Second, the macroeconomic impacts we have identified are relevant from a policy perspective and are indicative of the benefits for the country as a whole as determined by its economic fabric. These numbers are not indicative of the desirability that these projects could have for the private sector.

To conclude, although this study is an application to policy-making, 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 tight public budgets is widespread, and the role of infrastructure investments in this quest is increasingly recognized. Indeed, among international organizations, there has been in recent years a remarkable renewal of interest on issues relating to public investment and, in particular, to infrastructure investments [see, for example, Council of Economic Advisers (2016), European Central Bank (2016), European Commission (2014a, 2014b, 2016), IMF (2014, 2015), and World Bank (2016, 2017)].

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