JOURNAL OF ECONOMIC DEVELOPMENT 79
Volume 37, Number 2, June 2012

ON THE ECONOMIC EFFECTS OF INVESTMENT IN RAILROAD INFRASTRUCTURES IN PORTUGAL

ALFREDO M. PEREIRA[a] AND JORGE M. ANDRAZ[b*]

[a]*The College of William and Mary, U.S.A.*
[b]*Universidade do Algarve and CEFAGE(EU)- Center for Advanced Studies in Management and Economics, Universidade de Évora, Portugal*

The objective of this paper is to identify the effects of railroad infrastructure investment on aggregate and regional economic performance in Portugal. At the aggregate level, we show that railroad investment crowds in private investment and employment and have strong effects on output. At the regional level, we show that railroad investment affects private investment positively in all regions, employment in only Lisbon and the North, and output in all regions with the exception of Alentejo. The effects are regionally distributed in a rather uneven manner with Lisbon and the North capturing the bulk of the effects. Our results also highlight the relevance of regional spillovers. In terms of the relative effects of comparable railroad investment in the region and elsewhere in the country, we find that the North and the Center benefit more from investment elsewhere while the remaining regions benefit more from local investment. Finally, from a country-wide perspective, railroad investment located in Lisbon generates the largest marginal benefits, which reflect, mostly, the large effects in the Lisbon region itself. By contrast, railroad investment in the remaining regions has a much lower marginal benefit to the country, but these benefits reflect mostly spillovers. This highlights the difficulty in implementing policies that simultaneously maximize aggregate growth and reduce regional disparities.

Keywords: Railroad Infrastructure, Public Investment, Regional Spillovers
JEL classification: C32, H54, R53

[*] This paper is part of a research project on the “The Economic and Fiscal Impact of Investments in Railway Infrastructures” sponsored by Refer, EP. The opinions expressed in this article, however, are of the sole responsibility of its authors and in no way should be perceived as reflecting the views of Refer, EP or the institutions the authors are affiliated with. We would like to thank Rui M. Pereira for very skillful research assistance and an anonymous referee for very useful comments and suggestions.

1. INTRODUCTION

There is broad agreement in both academic and policy circles on the critical role of public infrastructure investment as a driving force for the economy. Therefore, it is no surprise that such investments are consistently at the center of the policy debate in many countries.[1] The Portuguese case is no exception. The policy debate over public investment in transportation infrastructure in Portugal has traditionally focused on road investments. This is true in the context of the development, after 1998, of the highway network system under public-private partnerships and financed by shadow tolls, as well as the more recent Plan for Investment in Priority Infrastructure of 2005. In the last few years, however, the debate has shifted towards a focus on railroad infrastructure investments.

This noticeable shift in focus is in good part explained by the fact that, with the sustained investment effort in the past decades on road infrastructures, the country may have reached a stage of rapidly diminishing marginal returns to road investment. While there are still deficits in coverage for national and municipal roads, the extension of highways in Portugal has increased six-fold since 1990 and Portugal now has one of the largest shares of highways in the road network in the EU and one of the largest extensions per capita and relative to its GDP of the OECD. In addition, the current concerns about climate change and the environmental impacts of transportation activities also lead to a greater focus on railroad transportation which is widely perceived as more environmentally friendly. Indeed, the National Program for Climate Change as presented in Instituto do Ambiente (2006) has mandated policies to promote a modal shift towards railroads as a means to reduce energy consumption and associated greenhouse gas emissions. These policies focus primarily on the modernization of the existing network of railways and subways as well as the development of a high speed railway network.

The current debate in Portugal about railroad infrastructures has focused on traffic demand, financial rates of return and political considerations, but has been conditioned by the absence of any empirical evidence on the macroeconomic effects of such investments. Indeed, the literature on the macroeconomic effects of public investment in Portugal is scant[2] and, in particular, on the macroeconomic effects of railroad investments is non-existent.

The purpose of this paper is to fill this gap by analyzing the effects of public investment in railroad infrastructures on private investment, employment, and output both at the aggregate and regional levels. We do so from three different perspectives.

[1] See, for example, Bose and Haque (2005), Mamatzakis (2002), Pereira and Pinho (2011), Rioja (2001), and Wolde-Rufael (2009) for a sample of the wide scope of this literature and Pereira and Andraz (2010) for a comprehensive survey.

[2] See, for example, Ligthart (2000), Pina and St. Aubyn (2005), Pereira and Andraz (2005, 2006, 2007), and Afonso and St. Aubyn (2010).

First, we estimate the aggregate effects of public investment in railroad infrastructures and their regional decomposition, distinguishing for each region between direct effects from investments in the region itself and spillover effects from investments elsewhere in the country. Second, we estimate, for each region, the relative importance of investments of the same magnitude in the region and elsewhere. Accordingly, we identify whether each region benefits more from investment in the region or elsewhere and determine if it is in the best interest of a given region to lobby for railroad investments in the region itself or in the country in general. Third, we analyze the impact of railroad investment in each region on aggregate economic performance. As such, we identify the regions in which railroad investments generate the largest benefits for the whole country and determine from a country-wide perspective where railroad investments should be located.

This is a very timely effort for a variety of reasons. First, there is the increasingly difficult issue of financing public investment. Portugal has faced an adverse budgetary situation for a while, a situation which has been further aggravated by the current economic recession. Furthermore, in the last two decades the country has relied heavily on EU structural funds to finance infrastructure investments. These funds are now becoming increasingly scarce due to a new focus by the EU on the new member states. Second, regardless of the progress already made in terms of convergence to EU standards, it is clear that there is still a long way to go, and that public investments will have a role to play in the process. At the same time, it is also clear that regional asymmetries have not been reduced in the recent past. Accordingly, the issue is not just growing the economy but to grow the economy in a regionally harmonious manner.

There is a large body of literature dealing with the analysis of the effects of public investment stemming mostly from the seminal work of Aschauer (1989a, 1989b, 1989c). The earlier literature adopted a univariate production function approach with all the ensuing problems.[3] More recent contributions have evolved to a more comprehensive and robust methodological approach, mostly in a vector autoregressive [VAR] framework greatly inspired by the macroeconomic literature, in particular after the seminal contribution of Blanchard and Perroti (2002).[4]

In this paper, we follow the approach developed in Pereira (2000, 2001), and Pereira and Andraz (2003) to evaluate the effects of investment in public infrastructures in the United States and adopt a VAR methodology. As is typical in this literature, our multivariate dynamic analysis relates private-sector variables -output, employment and investment- and public infrastructure investment. This approach highlights the relevance

[3] See Munnell (1992), Hulten and Schwab (1993), Gramlich (1994), Sturm *et al.* (1998) and Pereira and Andraz (2010) for comprehensive surveys of this early literature as well as the whole array of its econometric criticisms.

[4] See Kamps (2005) and Perotti (2004) for a detailed discussion of the literature on the effects of public investment in a VAR context.

of dynamic feedbacks among the variables, as well as the possible endogeneity of railroad investment. Indeed, while the evolution of railroad investment is allowed to affect private sector variables through time, the evolution of these variables is also allowed to affect railroad investment. Accordingly, this approach fully accommodates, by design, the possibility of reverse causality in the standard sense of Granger-causality. Furthermore, following Pereira and Andraz (2004, 2006), we estimate separate VAR models for the aggregate Portuguese economy and for each of the five administrative regions in the country, relating private output, employment and investment, and railroad investment, both in the region and elsewhere in the country. This allows us to identify the regional effects of railroad investment in a framework that makes it possible to identify the importance of regional spillovers and that is methodologically consistent with the evaluation of the aggregate effects.

Finally, it should be noted that, although our approach is exclusively empirical in nature it is not a-theoretical. Indeed, we have in the background of our analysis a dynamic model of the economy. In this model, the economy uses a production technology based on the use of private inputs, capital and labor, as well as railroad infrastructure, to generate private output. For each region, output is affected by railroad infrastructure located in the region itself, as well as railroad infrastructures located elsewhere in the country. Given the market conditions and the availability of railroad infrastructures, the private sector decides on the appropriate levels of input demands. In turn, the public sector decides on the evolution of railroad investments, using a policy rule that relates investment in railroad infrastructure to the evolution of the private sector variables. The estimated VAR models can be thought of as a reduced form for the production function, input demands and policy function as discussed in detail in Pereira and Flores (1999).

This paper is organized as follows. In section 2, we present the data as well as the preliminary statistical results. In section 3, we discuss the issue of identification of exogenous changes in railroad investment. In section 4, we present the aggregate effects of railroad investment. In section 5, we address the regional effects of railroad investment, including the regional decomposition of the effects as well as the importance of spillover effects. In section 6, we address the issue of where to invest, i.e., which regions benefit the most from comparable railroad investments in the region and elsewhere and which regions generate the largest benefits in terms of aggregate economic performance. Finally, section 7 provides summary and concluding remarks.

2. DATA AND PRELIMINARY RESULTS

In this section we present a description of the data set and the relevant preliminary empirical results-unit root, cointegration, and VAR specification tests. For the sake of brevity no details are provided. Details on both the data set and the empirical results are available from the authors upon request.

Table 1. Railway Infrastructure Investment

Regions	1980-88	1989-93	1994-98	1999-03	1989-03	1980-03
North	19.6	19.1	15.9	27.8	20.9	20.4
Center	26.5	28.2	26.6	26.0	26.9	26.7
Lisbon	29.0	29.0	36.1	19.4	28.2	28.5
Alentejo	19.3	19.2	19.2	22.5	20.3	19.9
Algarve	5.7	4.5	2.3	4.4	3.7	4.5
Total	100.0	100.0	100.0	100.0	100.0	100.0
(% of GDP)	(0.17)	(0.30)	(0.51)	(0.58)	(0.46)	(0.35)

2.1. Data: Sources and Description

We consider annual data for output, employment, and private investment, as well as investment in railroad infrastructures for the period 1980-2003. We consider both aggregate and regional data for the five administrative regions [Nuts II] in the country -North, Center, Lisbon, Alentejo, and Algarve. If we think about the country as a rectangle, the long sides being the western Atlantic Ocean front and the eastern Spanish border, these regions are the five contiguous segments from the north to the south of the country.

Output and employment data come from annual issues of the Regional Accounts published by the National Institute of Statistics. Lisbon and North are by far the most important regions. They account for 46.4% and 31.1% of output and 36.9% and 37.4% of employment, respectively. Center represents 14.5% of output and 17.6% of employment while Alentejo and Algarve combined account for just 8.0% of output and 8.1% of employment. Regional private investment data, which is not available from official sources, was constructed as aggregate investment weighted by the region's output share.

Data for investment in railroad infrastructures was obtained from two sources. Data from 1980 to 1998 comes from Pereira and Andraz (2001). Data after 1998 comes from Refer, S.A., which is responsible for investments in the railway network. Summary statistics are provided in Table1. Lisbon has the greatest share of railroad investment with 28.5% of the total, followed by Center with 26.7%, North with 20.4%, Alentejo with 19.9%, and Algarve with 4.5%.

The evolution of railroad infrastructure investment in Portugal has been closely related to the EU structural transfer programs, the Community Support Frameworks (CSFs), which have been very important tools to support public investments in transportation infrastructures in general. Our sample period, consisting of twenty-four years, includes fifteen years covered by the CSFs: the first CSF program (1989-93), the second CSF program (1994-97) and the third CSF program (1997-2003).

The importance of the CSFs in the dynamics of railroad infrastructure investment is visible in the increasing share of railroad investment. Investment in railroads averages

0.35% of GDP for the sample period. It represents, however, an increasing trend from 0.17% in the period 1980-88 to 0.46% in the period 1989-98. Furthermore, it is possible to detect changes from the first to the second and the third CSFs in that the share of railway investment increased from 0.30% during the first CSF to 0.51% and 0.58% during the second and the third CSFs, respectively. In turn, the shares of public investment in railroads located in Lisbon and Algarve decreased slightly with the CSFs, i.e., from the first to the second half of the sample period, while the shares of the other three regions increased accordingly. This suggests the possibility of structural breaks due to these programs, whose occurrence is fully incorporated into the econometric analysis that follows.

2.2. Unit-Root and Cointegration Analysis

In order to determine the order of integration of the variables, we use the Augmented Dickey-Fuller (ADF) test. We use the Bayesian Information Criterion (BIC) to determine the optimal number of lagged differences, and we include deterministic components and dummies for periods of the three CSF programs when they are statistically significant. We start by applying the ADF *t*-tests to aggregate and disaggregated output, employment, private investment and railroad infrastructure investment, in log-levels. The test results suggest overwhelmingly that these variables are non-stationary. We then test for stationarity of the different variables in growth rates. The results of the corresponding ADF *t*-tests show that at the aggregate level the null hypothesis of a unit root in the growth rate can be rejected for all variables at a level of significance below 5%. Also, for virtually all of the regional level variables, the values of the t-statistics are smaller than the 5% critical values. We take this as a strong indication that stationarity in growth rates is a good approximation for all variables. This evidence is consistent with the conventional wisdom in the macroeconomics literature that aggregate output, employment, and private investment are I(1). Since most of our series are more disaggregated, the same pattern of stationarity is not surprising.

We next test for cointegration at both the aggregate and regional levels, among output, employment, private investment and railroad infrastructure investment. Following the standard Engle-Granger approach, we performed four tests in each case. This is because it is possible that one of the variables enters the cointegrating relationship with a statistically insignificant coefficient and a test that uses such a variable as the endogenous variable will not pick up the cointegration. Therefore, a different variable is endogenous in each of the four tests. We apply the ADF *t*-test to the residuals from the regressions of each variable on the remaining variables. The optimal lag structure is chosen using the BIC, and a deterministic component and dummies for periods of the two CSF programs are included when they are statistically significant. At the aggregate level as well as for all tests at the regional level, the values of the *t*-statistics are all larger than the 5% critical values. Thus, we cannot reject the null hypothesis that the variables are not cointegrated.

Table 2. Specification of VAR Models

Regions	Order	Deterministic Componentes	No dummy	One dummy (1989)	Two Dummies (1989,1994)	Three Dummies (1989, 1994, 2000)
North	1	C	-23.17316	-23.28873	-24.46781	-24.67829
	1	CT	-23.00019	-23.52392	-24.32558	**-24.90642**
Center	1	C	-20.66292	-20.84158	-21.23201	-22.05932
	1	CT	-20.71561	-21.06377	-21.60604	**-22.68148**
Lisbon	1	C	-23.98999	-24.35090	-25.13047	-25.56316
	1	CT	-23.94208	-24.32274	-25.39070	**-26.12016**
Alentejo	1	C	-19.23815	-19.59477	-20.33165	-20.62473
	1	CT	-19.27100	-19.64506	-20.38581	**-21.14285**
Algarve	1	C	-13.45959	-13.78722	-14.32196	-14.61586
	1	CT	-13.33625	-13.66185	-14.25979	**-15.51912**
Portugal	1	C	-22.26249	-22.45126	-22.95309	-23.41114
	1	CT	-22.16749	-22.35739	-22.99903	**-23.54139**

Note: selected specification in bold.

The absence of cointegration is not conceptually problematic and is consistent with results in the literature such as Pereira (2000) and Pereira and Andraz (2003) for the US case, and Pereira and Andraz (2003) for the Portuguese case. In fact, for economies in a transition stage, as it is the case of the Portuguese economy, not finding cointegration, i.e., not finding in the data evidence of convergence to the so-called great ratios among the aggregate variables, is hardly surprising.

2.3. VAR Specification and Estimates

We have now determined that all the variables are stationary in first differences and that they are not cointegrated. Accordingly, we follow the standard procedure in the literature and estimate VAR models in growth rates. We first estimate a model for the whole country that includes aggregate investment in railroad infrastructures in addition to aggregate private sector variables - output, employment, and investment. Second, we estimate region-specific VAR models with region-specific private-sector variables and railroad investment, including an additional variable that reflects investment in railroad infrastructures elsewhere in the country. These regional models yield the central results in the paper.

We confine the search for the best model to first order specifications due to the relatively small sample size available. This strategy, however, is not likely to be problematic. Indeed, at the aggregate level, for which a much larger data sample is available, the first order specification is consistently selected over specifications up to the fourth order.

The VAR specification has two jointly determined dimensions - the specification of the deterministic components and the possibility of structural breaks. In order to consider possible structural changes due to the three CSFs, we distinguish four periods - the period before 1989, the period of first CSF program, 1989-93, the period of the second CSF program, 1994-98, and the period of the third CSF program, 1999-03. Therefore, we consider four alternatives in terms of the VAR specification - no structural break/no dummies, one structural break/one dummy distinguishing the periods before and after 1989, and two structural breaks/two dummies, or three structural breaks/three dummies reflecting the possibility of the four different periods mentioned above. The results are presented in Table 2. We find that the BIC criterion leads to the selection of VARs with three structural breaks for both the aggregate and the five regional models. In addition, test results suggest that both at the aggregate level and for the five regional models the best specification includes a deterministic constant and a trend.

3. IDENTIFICATION AND MEASUREMENT OF THE EFFECTS OF INNOVATIONS IN RAILROAD INVESTMENT

3.1. On The Identification of Exogenous Innovations in Railroad Infrastructure Investment

We use the impulse-response functions associated with the estimated VAR models to obtain the effects of innovations in railroad investment. While railroad investment is endogenous in the context of the VAR model, the central issue for the determination of the effects of railroad investment is the identification of shocks to these investment that are not contemporaneously correlated with shocks in the private sector variables. In dealing with this issue we draw from the approach in the literature on the effects of monetary policy as in Christiano *et al*. (1996, 1998), and Rudebusch (1998). This approach was adapted to the analysis of the effects of public capital formation in Pereira (2000, 2001) and the details about its application at the regional level may be found in Pereira and Andraz (2004, 2006).

Ideally, the identification of exogenous shocks to railroad investment would result from knowing what fraction of the government appropriations in each period is due to purely non-economic reasons. The econometric counterpart to this idea is to estimate policy functions which relate the rate of growth of public investment to the information relevant for policy makers. The residuals from these policy functions reflect the unexpected component of the evolution of railroad investment and, by definition, are not correlated with innovations in the private sector variables.

At the aggregate level we assume that the relevant information set includes past but not current values of the aggregate private sector variables. This is equivalent to assuming, in the context of the Choleski decomposition, that innovations in railroad investment affect private sector variables contemporaneously, while the reverse is not true.[5] Indeed, it is perfectly reasonable to assume that the private sector reacts within a year to innovations in railroad investment. It is also reasonable to assume that, due to the time lags involved in information gathering and public decision-making, the public sector is unable to adjust railroad investment to innovations in the private-sector variables within a year. This is even more so since most of the railroad infrastructure investment for the sample period was undertaken under the auspices of the CSF programs.

At the regional level, we also assume that innovations in regional railroad investment affect regional private sector variables contemporaneously, but the reverse is not true. This assumption is even more plausible at the regional level since most railroad investment is financed at the central government level. We would expect innovations in central government funding to be less correlated with innovations in regional private sector variables than innovations in aggregate railroad investment with innovations in aggregate private sector variables. Finally, in the regional models we assume that innovations in railroad investment outside the region contemporaneously affect innovations of railroad investment in the region but the reverse is not true. This assumption is justified by the fact that railroad investment undertaken in any given region is relatively small compared to the railroad investment undertaken elsewhere.

Table 3. Aggregate and Regional Effects of Railroad Infrastructure Investments

Regions	Elasticities with Respect to		Marginal Product with Respect to(*)		
	Railroad Investment in the Region	Railroad Investment Elsewhere	Railroad Investment in the Region (1)	Railroad Investment Elsewhere (2)	Total (3)=(1+2)
	Effects on Private Investment				
Portugal	0.37176 [0.070; 0.397]		18.21		
North	0.03901 [-0.026; 0.078]	0.33331 [0.065; 0.333]	0.95	4.46	5.41
Center	-0.00233 [-0.048; 0.024]	0.13933 [0.042; 0.159]	-0.01	1.18	1.17
Lisbon	0.29644 [0.046; 0.296]	0.33214 [0.068; 0.455]	12.97	5.75	18.72
Alentejo	0.00989 [-0.323; 0.010]	0.04689 [-0.067; 0.047]	0.01	0.12	0.13
Algarve	0.00553 [-0.017; 0.006]	0.29963 [0.034; 0.308]	0.02	0.55	0.57
Total All Regions			13.94	12.06	26.00
% of Aggregate			76.6%	66.2%	142.8%

[5] See Blanchard and Perotti (2002) for a similar assumption.

(Table 3 continues)

Regions	Elasticities with Respect to		Marginal Product with Respect to(*)		
	Railroad Investment in the Region	Railroad Investment Elsewhere	Railroad Investment in the Region (1)	Railroad Investment Elsewhere (2)	Total (3)=(1+2)
	Effects on Employment				
Portugal	0.02805 [-0.009; 0.035]		8.71		
North	0.00071 [-0.023; 0.017]	0.05427 [0.004; 0.054]	0.16	4.96	5.12
Center	-0.02209 [-0.025; -0.002]	-0.02761 [-0.033; 0.008]	-0.86	-1.75	-2.61
Lisbon	0.02976 [-0.010; 0.030]	0.09131 [0.034; 0.107]	5.09	9.54	14.63
Alentejo	0.13246 [0.042; 0.157]	-0.02668 [-0.027; 0.015]	0.52	-0.48	0.04
Algarve	0.01435 [0.002; 0.016]	-0.04812 [-0.121; -0.023]	0.34	-0.56	-0.22
Total All Regions			5.25	11.71	16.96
% of Aggregate			60.3%	134.4%	194.7%
	Effects on Output				
Portugal	0.12195 [0.026; 0.130]		23.64		
North	0.05909 [0.009; 0.085]	0.09391 [0.013; 0.155]	5.81	4.96	10.77
Center	-0.01911 [-0.025; -0.009]	0.03661 [0.005; 0.058]	-0.31	1.23	0.92
Lisbon	0.10264 [0.015; 0.103]	-0.02047 [-0.045; -0.003]	17.67	-1.41	16.26
Alentejo	0.09392 [-0.142; 0.094]	-0.08338 [-0.196; -0.024]	0.19	-0.87	-0.68
Algarve	0.00860 [-0.003; 0.009]	0.14771 [0.095; 0.251]	0.13	1.08	1.21
Total All Regions			23.49	4.99	28.48
% of Aggregate			99.4%	21.1%	120.5%

Notes: The numbers presented in this table correspond to the central Choleski orthogonalization assumption. The numbers in square bracket are the ranges of variation in each case over all possible alternatives under the Choleski decomposition approach. These ranges should not be understood or interpreted as confidence intervals.

These arguments establish a very plausible central case for the identification of innovations in railroad investment that are not correlated with innovation in other variables. These are the values reported in Table 3. Nevertheless, to determine the robustness of our central case results we consider also all the possible alternatives in terms of the definition of which observations are included in the information set. This is equivalent to considering all the possible orderings of the variables within the Choleski decomposition framework. The range of results for all the possible orderings are reported in square brackets in Table 3.

3.2. The Policy Functions for Railroad Infrastructure Investment

The policy functions at the aggregate and regional levels are reported in Table 4. At the aggregate level, there is no feedback from the other variables to public investment, which implies that railroad investment is truly an exogenous variable. It is interesting to contrast this with the evidence of endogeneity for the US. In fact, Pereira (2000) shows that changes in public investment in the US are positively correlated with lagged changes in output and negatively correlated with lagged changes in employment. Therefore, in the US, changes in private-sector variables affect the evolution of public investment, which is not an exogenous variable. The exogeneity of railroad investment in Portugal, however, is a natural consequence of the fact that railroad investment decisions, and public investment in transportation infrastructures in general, have long been closely linked with the Portuguese participation in the EU. Particularly after 1989, the bulk of the railroad investment has been conducted under the three CSFs programs which are typically negotiated between the recipient economies and the EU, and which focus on long-term goals and deliberately avoid short-term considerations.

Table 4. Policy Functions

Regions	Constant	Trend	D1989	D1994	D2000	GGDP(-1)	GEMP(-1)	GINV(-1)	GRINV(-1)	GRELSE(-1)
North	0.1473	0.0320	-0.3347	-0.2969	-0.4748	0.3046	-11.1888*	1.2500	-0.4492*	0.0967
	(0.76)	(1.10)	(-1.51)	(-0.84)	(-0.97)	(0.15)	(-3.58)	(1.42)	(-3.25)	(0.53)
Center	1.2628*	-0.1348*	0.4295	1.0721*	1.8949*	-2.9534	2.0978	2.7019*	0.3862*	0.6219*
	(4.16)	(-3.13)	(1.33)	(2.06)	(2.59)	(-1.48)	(0.69)	(2.31)	(-2.37)	(2.39)
Lisbon	0.1180	0.0120	0.0699	0.0075	-0.4114	0.8915	2.7420	-1.3307	0.2949	-1.1906*
	(0.40)	(0.05)	(0.20)	(0.01)	(-0.52)	(0.33)	(0.62)	(-1.12)	(1.36)	(-3.22)
Alentejo	-1.1164*	0.1799*	-0.8866*	-1.8049*	-2.6474*	4.9272*	-1.6596	-3.053*	-0.5109*	1.1360*
	(-3.04)	(-3.07)	(-2.05)	(-2.52)	(-2.66)	(3.71)	(-0.80)	(-2.60)	(-2.25)	(3.17)
Algarve	-2.5005	0.4786*	-4.2234*	-4.4336	-7.8153	-13.9446	-8.5717	8.7267	-0.2175	3.3868*
	(-1.43)	(1.73)	(-1.71)	(-1.30)	(-1.61)	(-1.59)	(1.01)	(1.17)	(-1.24)	(1.79)
Portugal	0.0249	0.0201	-0.0110	-0.2067	-0.2722	0.3236	-4.3435	-0.0588	-0.0925	-
	(0.12)	(0.63)	(-0.05)	(-0.54)	(-0.53)	(0.14)	(-1.31)	(-0.07)	(-0.41)	-

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

The exogeneity of railroad investment, suggested by the aggregate policy function, hides a much richer regional picture. Indeed, it seems that although the aggregate evolution of railroad investment is exogenous, its regional allocation is not always completely exogenous. The region-specific policy functions suggest that railroad investment is responsive to lagged changes in certain region-specific private sector variables in all regions except for Lisbon. However, each of those regions does not carry sufficient weight to impose the regional patterns on those observed at the national level. The only exception may be the case of the negative responsiveness of railroad investment in the North to lagged changes in employment which almost carries over to the aggregate level.

3.3. Measuring the Effects of Innovations in Railroad Infrastructure Investment

To measure the effects for each region of exogenous innovations in railroad investment in the region itself, as well as elsewhere in the country, we use the accumulated impulse-response functions associated with the estimated VAR models and the corresponding policy functions (see Figures 1-10). For each region, we consider a one percentage-point, one-time innovation in the rate of growth of railroad investment either in the region itself or elsewhere in the country. As all accumulated impulse response functions converge, these innovations have temporary effects on the growth rates of the private-sector variables. Naturally, they have permanent effects on the levels of these variables. Furthermore, since the temporary effects on the growth rates of the different variables vary, the level effects will also be different, which implies changes in the long-term observed ratios between variables, a result consistent with the absence of cointegration.

We report the long-term cumulative elasticities with respect to railroad investment. Long term is defined as the time horizon over which the growth effects of innovations disappear. These elasticities represent the total accumulated percentage point changes in output for one long-term accumulated percentage-point change in railroad investment. It should be pointed out that unlike the standard definition of elasticity, the concept we use captures all feedback effects over time, it measures total effects and not ceteris paribus type of effects and it measures accumulated long-term effects - in practice over a thirty-year period - and not annual effects.

We also report the long-term accumulated marginal products of railroad investment. These numbers measure the long-term accumulated change in private-sector variable per one Euro long-term accumulated change in railroad investment. We obtain each figure by multiplying the long-term elasticity by the corresponding variable to railroad investment ratio for the last ten years of the sample. This allows us to interpret the marginal products as the long-term accumulated effects of policies implemented at the end of the sample measured under the conditions observed by the end of the sample period, while avoiding business cycle effects.

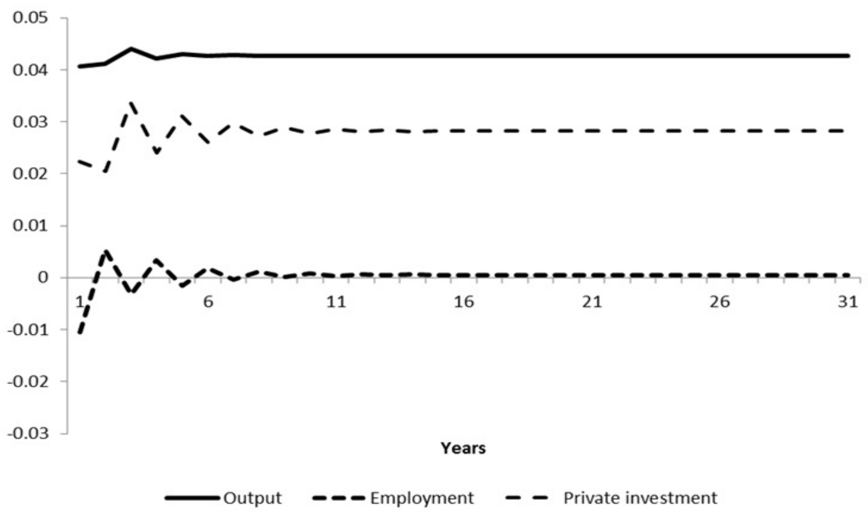

Figure 1. North: Accumulated Impulse-Response Functions with respect to a Shock in Railroad Investment in the Region Itself

Figure 2. North: Accumulated Impulse-Response Functions with respect to a Shock in Railroad Investment Elsewhere in the Country

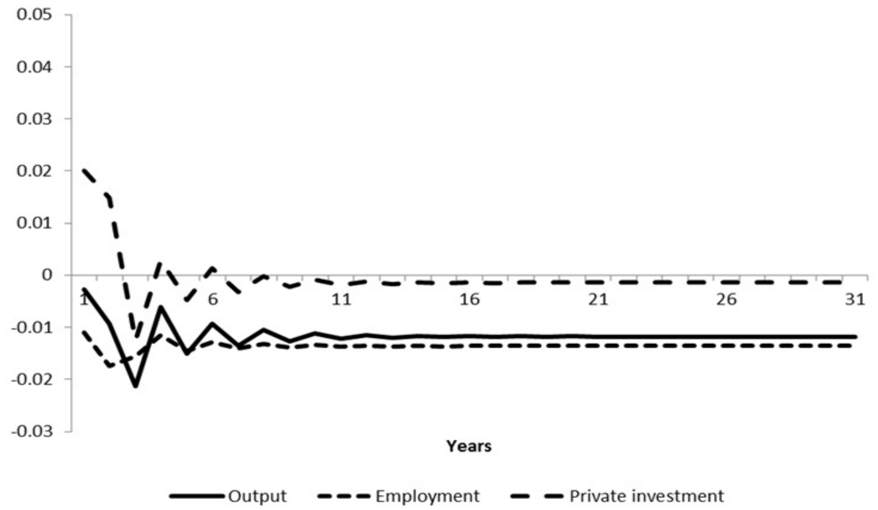

Figure 3. Center: Accumulated Impulse-Response Functions with respect to a Shock in Railroad Investment in the Region Itself

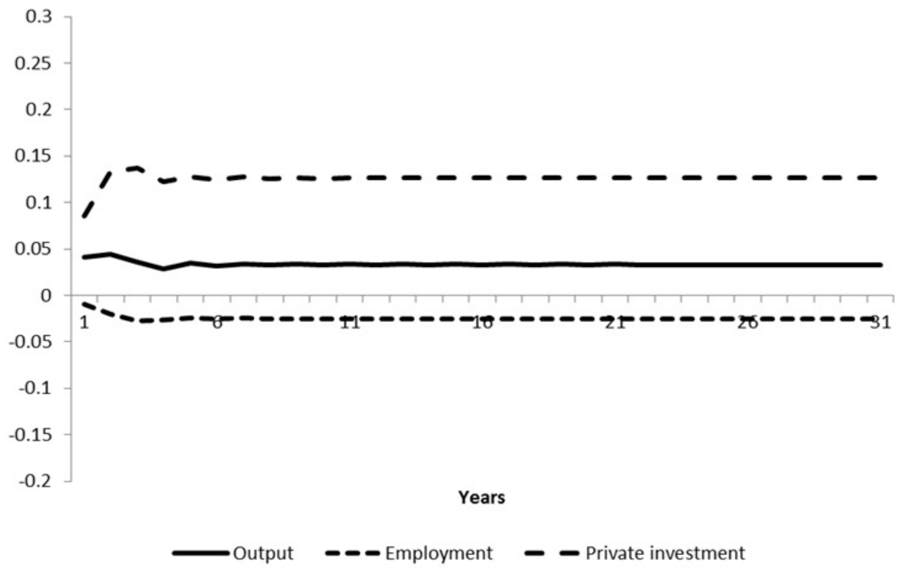

Figure 4. Center: Accumulated Impulse-Response Functions with respect to a Shock in Railroad Investment Elsewhere in the Country

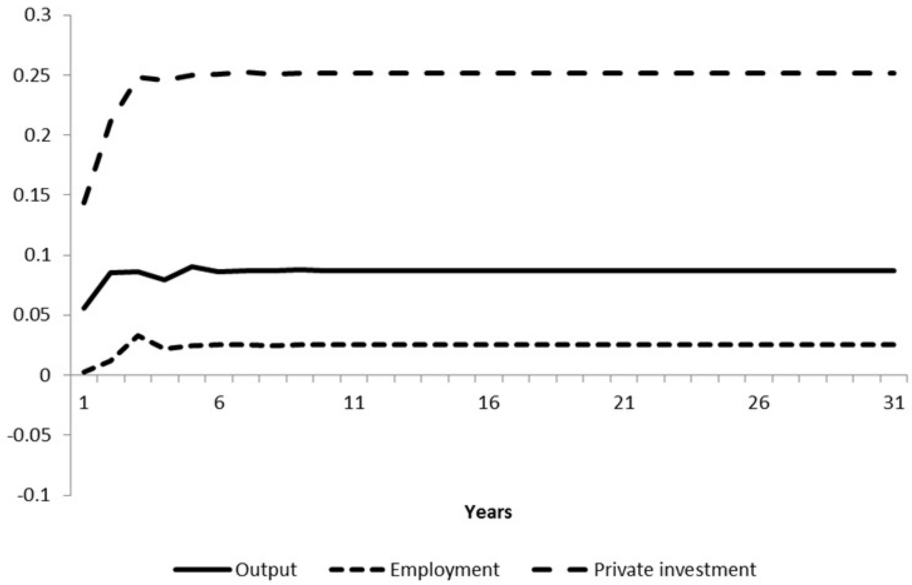

Figure 5. Lisbon: Accumulated Impulse-Response Functions with respect to a Shock in Railroad Investment in the Region Itself

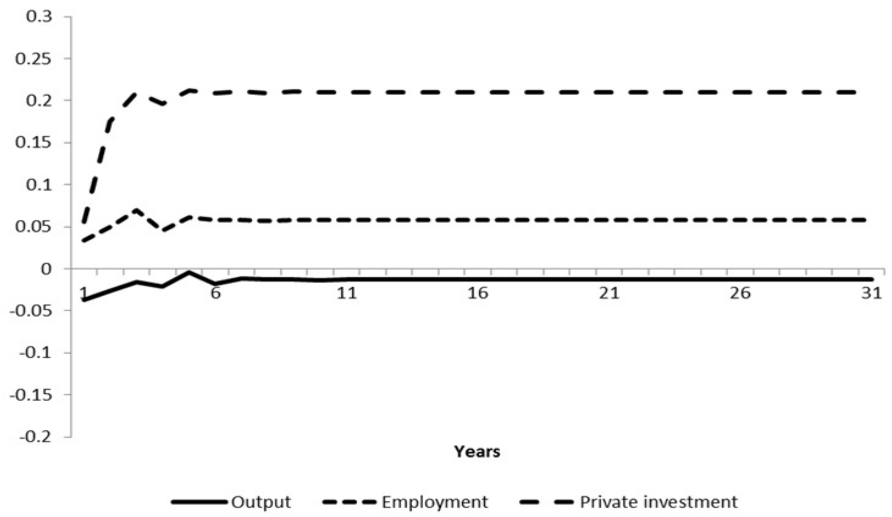

Figure 6. Lisbon: Accumulated Impulse-Response Functions with respect to a Shock in Railroad Investment Elsewhere in the Country

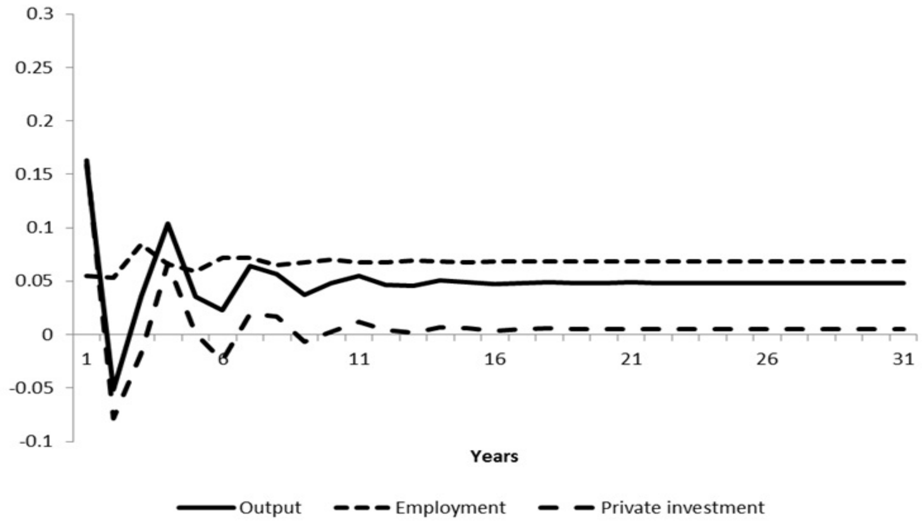

Figure 7. Alentejo: Accumulated Impulse-Response Functions with respect to a Shock in Railroad Investment in the Region Itself

Figure 8. Alentejo: Accumulated Impulse-Response Functions with respect to a Shock in Railroad Investment Elsewhere in the Country

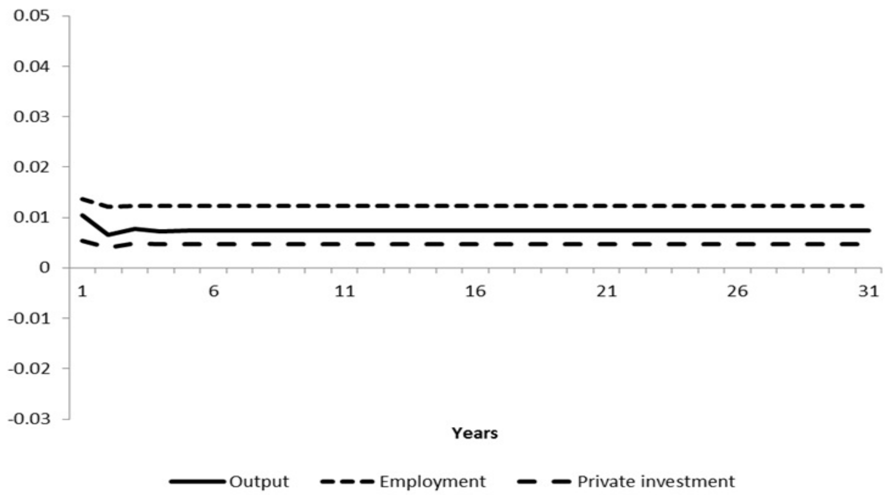

Figure 9. Algarve: Accumulated Impulse-Response Functions
with respect to a Shock in Railroad Investment in the Region Itself

Figure 10. Algarve: Accumulated Impulse-Response Functions
with respect to a Shock in Railroad Investment Elsewhere in the Country

4. THE AGGREGATE EFFECTS OF RAILROAD INFRASTRUCTURE INVESTMENT

4.1. On the Aggregate Effects

The aggregate results are obtained from the impulse response functions associated with the VAR model, relating output, employment, private investment and railroad investment at the national level. These results are reported in the top panels of each variable in Table 4. The elasticity of private investment with respect to railroad investment is 0.372. This implies that one million Euros in railroad investment induces, in the long term, an accumulated increase of 18.21 million Euros in private investment and suggests that, at the national level, investments in railroad investment and private investment are complements. In turn, the elasticity of private employment with respect to railroad investment is 0.028. This implies that one million Euros in railroad investment creates, in the long-term, about 8.7 new private sector jobs. Therefore, at the national level, investment in railroads and employment are also complements. Finally, the elasticity of output with respect to railroad investment is 0.122. This means that one million Euros invested in railroads leads to an accumulated long-term increase in private output of 23.64 million Euros. This result implies an annual rate of return over a thirty-year period of 11.1%.

Comparing these results with those of Pereira and Andraz (2012) relative to the effects of road infrastructure investments provides further insight on the relative importance of railroad infrastructure investments. The authors estimate marginal products of private investment, employment and output with respect to road infrastructure investment of 8.43, 24.50, and 18.06, respectively. This means that the marginal products of private investment and output with respect to road investment are lower than the effects of railroad investment, which reflects the relative scarcity of this type of investment. Nevertheless, the effect of road investment on employment is higher.

4.2. On the Aggregate Effects versus the Aggregation of Regional Effects

The relationship between the aggregate results and the sum of the results obtained from the regional models requires some reflection. It is perfectly plausible that the sum of the estimated regional marginal products would not coincide with the effects at the aggregate level. This is due to the possible existence of general equilibrium effects that are not captured at the regional level. Consider, for example, the effects of railroad investment on decisions regarding private factor demands. When more railroad infrastructure is accessible, greater factor quantities are demanded, simultaneously, in all regions. This simultaneous increase in factor demand is limited by restrictions in the economy. As a result, a part of the increase in demand translates into increases in factor prices which lower demand in various regions. However, each region by itself does not have enough weight to drive price changes and it is to be expected that the sum of the regional marginal products exceeds the aggregate effects. Our estimation results show that the sum across regions of the effects of railway investment represents 142.8%, 194.7%, and 120.5% of the estimated aggregate results for private investment, employment and output, respectively. In light of the previous discussion, these values suggest that general equilibrium effects are relevant for all of the private sector variables, particularly investment and employment.

5. THE REGIONAL EFFECTS OF RAILROAD INFRASTRUCTURE INVESTMENT

We consider now the effects of investment in railroad infrastructures at the regional level by considering the impulse response functions associated with the VAR estimates from the region-specific VAR models, which include private sector variables and railroad investment in the region as well as railroad investment elsewhere in the country. This additional variable allows us to estimate the effects for each region of railroad investment in the region itself, as well as the effects of railroad investments in other regions, i.e., the spillover effects. The total effect for each region of railroad investment in the country is the sum for each region of the direct effect and the spillover effect.

5.1. On the Regional Decomposition of the Effects of Railroad Investment

We start by considering the regional decomposition of the aggregate effects of railroad investment, that is, the regional decomposition of the effects of aggregate changes in railroad investment following the historical pattern of regional decomposition of such investments. Accordingly, in what follows, the raw marginal products are multiplied by the average ratio between regional railroad investment and aggregate railway investment over the past ten years. In this way, all regional marginal products reflect the effects for each region of one million Euros of investment in the country. The results are reported in Table 4.

In terms of ***private investment***, railroad investment in the region has positive effects in all regions but one, the Center, whose effects are only marginally different from zero. In terms of the marginal products, our estimates suggest that one million Euros in railroad investment generates, in the long term, a net increase in private investment of 13.94 million Euros, Lisbon being the region that captures the bulk of this effect. In turn, public investment elsewhere affects regional private investment positively in all regions. Our estimates suggest that one million Euros in railroad investment generates, in the long term, spillover effects of about 12.06 million Euros, the largest marginal products being for North and Lisbon. Finally, the total effect, i.e., the sum for each region of the direct and spillover effects, is positive in all regions. The largest effect occurs in Lisbon, with a marginal product of 18.72 million Euros. The effects for North and Center are less significantly, with marginal products of 5.41 million Euros and 1.17 million Euros, respectively. The marginal products for the Alentejo and Algarve regions are negligible.

In terms of ***employment***, railroad investment in the region has positive effects in four regions, the exception being again Center. The results suggest that one million Euros in regional public investment creates, in the long term, 6.1 new private jobs. Of these, 5.3 are new jobs, while the remaining 0.8 correspond to jobs shifted across regions. Lisbon is the region that benefits the most. As to the effect of railroad investment elsewhere, we get positive effects in only two regions. One million Euros in railway investment elsewhere generates, in the long term, spillover effects of about 11.7 new private jobs. The largest effects occur in Lisbon with 9.5 new jobs and North with 5.0 new jobs. The total effect is positive only in the Lisbon with 14.6 new jobs and North with 5.1.

Finally, ***output*** is positively affected by railroad investment in the region in four regions, the exception being Center. In terms of marginal products, the overall long-term accumulated gain is 23.49 million and output shifts across regions are negligible; Lisbon and North are the regions which capture the greatest effects. In addition, regional output is positively affected by railroad investment elsewhere in three of the five regions, the exceptions being Lisbon and Alentejo. One million Euros in railroad investment generates spillover effects that amount to 4.99 million Euros in the long term, North being the region that exhibits the largest marginal product. Finally, the total effects are positive for all regions, except for Alentejo. Once again, the regions with the highest total marginal products are Lisbon and North with 16.26 and 10.77 Euros, respectively.

Comparing these results with those of Pereira and Andraz (2012) relative to the effects of road infrastructure investments is again very informative. The regions of Lisbon and North, the two largest economic regions in the country, show consistently larger effects from railroad investment (marginal products of 16.3 and 10.8 million Euros for output, respectively) than from investment in road infrastructures (10.7 and 1.1 million Euros, respectively). In turn, the other regions show, in general, much lower effects which, however, are larger in the case of investment in road infrastructures.

5.2. On the Importance and the Regional Incidence of the Spillover Effects

To determine the importance of the regional spillover effects we calculate how much of the total effect of railroad investment in the country and in each region is due to the direct effects and how much is due to the spillover effects. The results are reported in Table 5.

In terms of the effects on ***regional private investment***, of the total marginal product of 26.00 Euros, the direct effects correspond to 13.94 and the spillover effects to 12.06 or 46.4% of the total. This means that direct effects and spillover effects are of the same order of magnitude. Furthermore, the spillover effects are more important than the direct effects for four of the five regions, the exception being Lisbon. As to the effects on ***regional employment***, of the total effects of 16.96 new jobs, the direct effects correspond to 5.25 and the spillover effects to 11.71 or 69.0%. These spillovers are concentrated only in Lisbon and North. Finally, in terms of the effects on ***regional***

output, the direct effects account for 23.49 of a total of 28.48 Euros, while the spillovers correspond to the remaining 4.99 Euros or 17.5%. Spillovers are important only in Center and Algarve.

Table 5. On the Importance for Each Region of Spillover Effects of Railroad Investment(*)

Regions	Private Investment	Employment	Output
North	82%	97%	46%
Center	100%	0%	100%
Lisbon	31%	65%	0%
Alentejo	92%	0%	0%
Algarve	96%	0%	89%
Portugal	46.4%	69.0%	17.5%

Notes: (*) Measured as spillovers as a fraction of total effects of public investment both in the region and elsewhere. The value is presented as 100% if denominator is negative and is 0% if numerator is negative.

If we compare these results on the relevance of spillovers with those of Pereira and Andraz (2012), relative to the effects of road infrastructure investments, we find two important patterns. First, the spillover effects are much more significant in the case of road infrastructure investment and account for almost 100% of the effects on private investment, for 78% of the effects of employment and for 78.9% of total effects on output. Second, the regional patterns are also different. In the case of road infrastructure, investment spillovers are particularly important for North, Lisbon, and Alentejo in the cases of output and employment, and for Center, Lisbon and Alentejo in the case of private investment.

6. RAILROAD INFRASTRUCTURES: WHERE TO INVEST?

The results in the previous section are now complemented with two other sets of results with an eye on direct policy implications for future railroad investment decision. First, we consider the comparative effects for each region of one million Euros of railroad investment in the region and one million Euros of railroad investment elsewhere in the country. Second, we consider the effects for the whole country of investment in any given region, both the effects in the region and the effects induced in the other regions.

6.1. On the Relative Effects for Each Region of Railroad Investment in the Region and Elsewhere

We consider the effects for each region of one million Euros in railroad investment in the region and of one million Euros in railroad investment elsewhere. The relevant results are reported in Table 6.

Table 6. Effects of One Million Euros of Railroad Investment in the Region and Elsewhere in the Country [(*)]

	Private Investment		Employment[(**)]		Output	
	Railway Investment in the Region	Railway Investment Elsewhere	Railway Investment in the Region	Railway Investment Elsewhere	Railway Investment in the Region	Railway Investment Elsewhere
North	3.10	6.44	0.43	7.78	18.88	7.17
Center	-0.06	1.38	-4.76	-2.14	-2.10	1.44
Lisbon	27.99	10.72	13.81	15.10	38.12	-2.62
Alentejo	0.11	0.13	10.47	-0.51	4.30	-0.91
Algarve	0.53	0.57	8.97	-0.58	3.34	1.12

Notes: [(*)] The values are marginal products. They are not weighted values. They measure the effect, in the long term, of one million Euros of investment in each region and out of the region. [(**)] The marginal products represent the number of job posts created by a one million Euro investment at 1995 prices.

Let us consider first, the impact of railroad investment on ***regional private investment***. The regions that benefit the most from railroad investment in the region itself are Lisbon and North, with marginal products of 27.99 Euros and 3.10 Euros, respectively. These are also the regions that benefit the most from railroad investment located elsewhere, with marginal products of 10.72 Euros and 6.44 Euros, respectively. The benefits for the other regions are substantially lower. Considering the effects of railroad investment on ***regional employment,*** the region that benefits the most is again Lisbon, closely followed by Alentejo and Algarve. For these regions each million Euros in public investment in the region itself, creates, in the long term, about 13.8, 10.5 and 8.9 new jobs, respectively. At the same time, Lisbon and North are the only regions with positive effects from railroad investment elsewhere. One million Euros in railroad investment outside these regions creates, in the long term, 15.1 and 7.8 new regional jobs, respectively. Finally, regarding the effects of railroad investment on ***regional output***, Lisbon benefits strongly from railroad investment in the region itself, followed by North with marginal products of 38.12 Euros and 18.88 Euros, respectively. Alentejo and Algarve show much lower effects. In turn, in terms of the effects of railroad investment elsewhere, only North shows a substantial effect on output.

Overall we show that, in terms of output effects, all regions, except for Center, benefit more from investment in the region itself. From this standpoint, all regions except for Center, would want to lobby for railroad investments in the region itself than in the country in general. If the objective is to promote local private investment, then North and Center are better off lobbying for general railroad investment in the country and if the objective is employment opportunities, the North is clearly better off lobbying for general railroad investments as well.

It is interesting from a policy perspective to compare these results with those of Pereira and Andraz (2012) relative to the effects of road infrastructure investments. First, all marginal effects tend to be substantially larger in the case of investment in railroad infrastructures, once again reflecting a greater relative scarcity of these infrastructures. Second, in terms of private investment, North and Algarve benefit more from road investment in the region, while Lisbon benefits more from railroad investment in the region. In turn, in terms of employment, Center and Algarve benefit more from road investment in the region, while Alentejo and Algarve benefit more from railroad investment in the region. Finally, Center, Lisbon and Algarve benefit more from road infrastructure investment in the region itself, while all regions except for Center benefit more from railroad investment in the region itself.

6.2. On the Effects in the Country from Railroad Investment in Any Given Region

Since investment in railroad infrastructures in any given region affects economic performance in other regions and since each region benefits from railroad investment in the region and elsewhere, one would want to know which locations have the greatest aggregate effects. This is a critical question whether the overriding objective is to promote catching up to EU standards of living or reducing regional asymmetries. The relevant results are reported in Table 7.

In terms of the effects on ***national private investment***, railroad investments in Lisbon are the ones generating the largest benefits at the national level with a marginal product of 36.5 million Euros, reflecting mostly strong direct regional effects. For all the other regions marginal products are of comparable magnitudes, in the range of 15-20 million Euros, and reflect mostly important spillover effects. As to ***national employment***, railroad investments in Alentejo and Algarve generate the larger results with 30.6 and 29.2 new long-term jobs for each million Euros in railroad investment, due to a large extent to significant spillover effects. The other regions show again results of comparable magnitude of 12-18 new jobs per million Euros. Finally, in terms of ***national output***, the disparities are substantial. Investments in in Lisbon generate the largest effects with a marginal product of 46.9 million Euros, mostly due to direct regional effects. North is a distant second with 17.91, also due again to direct regional effects. The remaining three regions show much lower effects, but a much larger contribution of the spillover effects.

Table 7. Nationwide Effects of One Million Euros in Railroad Investment in Each Region

	Effects in the Region (1)	Effects in Other Regions (2)	Total Effects in the Country (3) = (1)+(2)
A. Private Investment			
North	3.10	12.80	15.90
Center	-0.06	17.86	17.80
Lisbon	27.99	8.52	36.51
Alentejo	0.11	19.11	19.22
Algarve	0.53	18.67	19.20
B. Employment			
North	0.43	11.87	12.30
Center	-4,76	21.79	17.03
Lisbon	13.81	4.55	18.36
Alentejo	10.47	20.16	30.63
Algarve	8.97	20.23	29.2
C. Output			
North	18.88	-0.97	17.91
Center	-2.1	4.76	2.66
Lisbon	38.12	8.82	46.94
Alentejo	4.30	7.11	11.41
Algarve	3.34	5.08	8.42

Overall we can say that railroad investments in Lisbon are the ones that show the largest marginal benefits in terms of the economic performance of the country as a whole. Most of the benefits, however, tend to be located in Lisbon itself. For the other regions, while their overall contribution is lower, they generate important spillovers. Again this pattern highlights the difficulty of implementing policies that simultaneously maximize aggregate growth and reduce regional disparities.

In absolute terms we notice that compared to the effects of road infrastructure investments reported in Pereira and Andraz (2012), the effects of investments in railroad infrastructures are, across the board, larger for private investment and smaller for employment. Accordingly, the results for output are mixed. Lisbon shows much larger effects from railroad investment, while the other four regions show clearly larger effects from road investment. For road investment, the two most desirable locations from a national output perspective are Center and Algarve, with very substantial spillover effects, while for railroad investment it is Lisbon, with very substantial direct effects.

7. SUMMARY AND CONCLUDING REMARKS

In this paper we analyze the effects of railroad infrastructure investment in Portugal with the general objective of identifying the contribution of such investments to the economic performance of the country, as well as the regional pattern of such effects.

At the aggregate level, we find that railroad investments have very important positive effects on private investment, employment, and output. At the regional level, we find that railroad investment affects private investment positively in all regions, employment in only Lisbon and North and private output in all regions with the exception of Alentejo. Our results suggest that the aggregate effects of railroad investment are distributed rather unevenly regionally, as Lisbon and North, the largest regions, economically speaking, capture the bulk of the effects on private investment, employment and output, respectively. Our regional results also show that spillover effects are very important for employment, and less so for private investment and, in particular, output.

In addition, we find that in terms of output effects all regions, except for Center, benefit more from investment in the region itself than from comparable investments elsewhere. From this standpoint, all regions, except for Center, would want to lobby for railroad investments in the region itself rather than in the country in general. However, if the objective is to promote local private investment, then North and Center are better off lobbying for general railroad investment in the country, while if the objective is employment opportunities, the North is clearly better off lobbying for general railroad investments as well. In a different vein, we find that railroad investments in Lisbon are the ones that show the largest marginal benefits for the country as a whole. Most of the benefits, however, tend to be located in Lisbon itself. For the other regions, while their overall contribution is lower, they generate important spillovers. Again this pattern highlights the difficulty of implementing policies that simultaneously maximize aggregate growth and reduce regional disparities.

From a policy perspective, it is instructive to compare the economic effects of railroad infrastructure investments, as presented in this paper, and the economic effects of road infrastructure investments as presented in Pereira and Andraz (2012). This is important since, as argued earlier, there is a widespread notion that road infrastructures are becoming relatively less scarce, and that railroads have been somewhat neglected in the last few decades and are more environment friendly.

First, the marginal products of private investment and output with respect to road investment are lower than the effects of railroad investment, which reflects the relative scarcity of this type of investment. Nevertheless, the effect of road investment on employment is higher. Second, the regions of Lisbon and North, the two largest economic regions in the country, show consistently larger effects from railroad investment than from investment in roads. In turn, the other regions show, in general, larger effects from investment in road infrastructures although all effects are much smaller than the ones observed for Lisbon and North. Third, spillover effects are much more significant in the case of road infrastructure investment than for railroad infrastructure investment and the regional patterns are also very different, as spillovers are particularly important for Lisbon and Alentejo for road infrastructures and much more evenly distributed for railroad infrastructures. Fourth, considering for a given region the effects of comparable investments in the region itself and elsewhere in the country, all marginal effects tend to be substantially larger in the case of investment in railroad infrastructures, once again reflecting a greater relative scarcity of these infrastructures. In terms of output effects, Center, Lisbon and Algarve would benefit most from road infrastructure investment in the region itself while all regions except for Center benefit more from railroad investment in the region itself. Finally, in terms of the output effects for the country of investments in a given region for road investment the two most desirable locations from a national output perspective are Center and Algarve, with very substantial spillover effects, while for railroad investment it is Lisbon with very substantial direct effects. Overall, the comparison of the effects of road and railroad infrastructure investment suggests that railroad investments have a higher marginal product but that their spillover effects are more moderate and that a strategy of aggregate growth would lead to railroad investments in Lisbon with low spillovers and, therefore, a greater potential for adversely affecting regional asymmetries.

Despite the importance of our results and maybe even because of their importance, it is appropriate to include here several cautionary notes. First, our results provide useful information for the evaluation of future railroad investment projects by providing estimates about the order of magnitude of the economic effects of past investments. The use of these results to evaluate specific railroad investment projects, however, should be done carefully and always in conjunction with the appropriate idiosyncratic information. Second, our estimates of the marginal products of railroad investments are based on historical patterns at a time of greater scarcity of railroad infrastructures. While our estimates of the marginal products are comfortably large, one should expect a pattern over time of declining marginal products. Third, our objective is to measure the effects of investments in railroad infrastructure and not to establish their relative merits. This means that, while our results may suggest that railroad infrastructure investment is important and it may even be better from certain perspectives than investments in road infrastructures, they do not suggest that railroad infrastructure investment is the best development strategy for the future. Fourth, our analysis covers a period in which the bulk of the railroad infrastructure investment was undertaken under the auspices of the EU Structural Funds Programs. This means that not considering in the analysis the cost of financing such investments is not a matter of concern. It implies, however, that our results should be regarded as the upper bound of the effects that would be obtained if financing were to be an issue. This is important since with the dwindling of EU funding, the Portuguese government will have progressively to rely on taxation or borrowing to finance future investment projects and, therefore, the costs of such financing cannot be ignored.

Another cautionary note is necessary given that a lot of the current debate on railroad infrastructure investment in Portugal is centred on the issue of high speed train routes. Once again, our results provide some guidance as to the order of magnitude of the expected effects of such investments. It is important to notice, however, that there are substantial differences between the effects of conventional and high speed railroad networks. The conventional network affects economic activity through the mobility of passengers and their accessibility to their workplace and freight services. In general terms, the same is true for high speed rail. However, high speed rail networks are typically intended for direct long-distance passenger and freight services and have very limited economic interface with the regions in between the nodes. Accordingly, one would expect the regional spillovers of a high speed system to be clearly lower than for the conventional network. Given how important these spillovers seem to be, this would also imply clearly lower overall economic effects for the high speed rail network compared to the conventional rail network. Overall, we would expect the benefits of a high speed network to be more local at the nodes and globally lower compared to conventional railroads.

Finally, it should be pointed out that although our results are important from the perspective of policy making in Portugal, their interest is far from parochial. In fact, there are a number of EU countries which have levels of development and infrastructure scarcities that are not unlike the Portuguese case in the early 1980s. Furthermore, these countries are expected to benefit from large EU structural funds upon accession, much like Greece, Ireland, Portugal, and Spain did. From this paper, we learn that the general strategy of investing in public infrastructure, in particular railroad infrastructures, may be very effective in promoting real convergence of these economies to EU standards. We also learn, however, that care must be taken in designing programs that do not achieve national converge to the EU standards at the cost of increased domestic asymmetries.

REFERENCES

Afonso, A., and M.St. Aubyn (2010), "Public and Private Investment Rates of Return: Evidence for Industrialised Countries," *Applied Economics Letters*, 17(9), 839-843.

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

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

_____ (1989c), "Public Investment and Productivity Growth in the Group of Seven," *Journal of Economic Perspectives*, 13(5), 17-25.

Blanchard, O., and R. Perroti (2002), "An Empirical Characterization of the Dynamic Effects of Changes in Government Spending and Taxes on Output," *Quarterly Journal of Economics*, 117(4), 1329-1368.

Bose, N., and M.E. Haque (2005), "Causality between Public Investment in Transport and Communications and Economic Growth," *Journal of Economic Development*, 30(1), 95-106.

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

_____ (1998), "Monetary Policy Shocks: What Have We Learned and to What End?" National Bureau of Economic Research Working Paper, 6400.

Gramlich, E. (1994), "Infrastructure Investment: A Review Essay," *Journal of Economic Literature*, 32, 1176-1196.

Hulten, C., and R.M. Schwab (1993), "Infrastructure Spending: Where Do We Go From Here?" *National Tax Journal* , 46(3), 261-273.

Instituto do Ambiente (2006), *National Program for Climate Change,* Ministério do Ambiente e Ordenamento do Território, Lisboa, Portugal.

Kamps, C. (2005), "The Dynamic Effects of Public Capital: VAR Evidence for 22 OECD Countries," *International Tax and Public Finance*, 12, 533-558.

Ligthart, J. (2000), "Public Capital and Output Growth in Portugal: An Empirical Analysis," International Monetary Fund Working Paper, 11.

Mamatzakis, E.C. (2002), "Public Infrastructures and Private Output: An Application to Greece," *Journal of Economic Development*, 27(2), 143-160.

Munnell, A. (1992), "Policy Watch, Infrastructure Investment and Economic Growth," *Journal of Economic Perspectives*, 6(4), 189-198.

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

_____ (2001), "Public Capital Formation and Private Investment: What Crowds in What?" *Public Finance Review*, 29(1), 3-25.

Pereira, A.M., and J.M. Andraz (2001), *Investimento Público em Infra-estruturas de Transporte em Portugal Continental,* Secretaria de Estado do Planeamento/ Ministério do Planeamento, Lisboa, Portugal.

_____ (2003), "Public Capital and Growth in the US: A Sector-Specific Analysis," *Public Finance Review*, 31(1), 66-90.

_____ (2004), "Public Highway Spending and State Spillovers in the US," *Applied Economics Letters*, 11, 785-788.

_____ (2005), "Public Investment in Transportation Infrastructures and Economic Performance in Portugal," *Review of Development Economic*s, 9, 177-196.

_____ (2006), "Public Investment and Regional Asymmetries in Portugal," *Annals of Regional Science*, 40(4), 803-817.

_____ (2007), "Public Investment in Transportation Infrastructure and Industry Performance in Portugal," *Journal of Economic Development*, 32(1), 1-20.

_____ (2010), "A Survey of the International Evidence on the Effects of Infrastructure Investment," College of William and Mary Economics Working Paper, 108.

_____ (2012), "On the Economic and Fiscal Effects of Investments in Road Infrastructures in Portugal," *International Economic Journal*, forthcoming.

Pereira, A.M., and R.F. Flores (1999), "Public Capital and Private Sector Performance in the US," *Journal of Urban Economics*, 46, 300-322.

Pereira, A.M., and M.F. Pinho (2011), "Public Investment, Economic Performance and Budgetary Consolidation: VAR Evidence from the First 12 Euro Countries," *Journal of Economic Development*, 36(1), 1-20.

Perotti, R. (2004), "Public Investment: Another (Different) Look," Universita Bocconi Working Paper, 277.

Pina, A., and M.St. Aubyn (2005), "Comparing Macroeconomic Returns of Human and Public Capital: An Empirical Analysis of the Portuguese Case," *Journal of Policy Modelling*, 27, 585-598.

Rioja, F.K. (2001), "Growth, Welfare and Public Infrastructure: A General Equilibrium Analysis of Latin American Economies," *Journal of Economic Development*, 26(2), 119-130.

Rudebusch, G.D. (1998), "Do Measures of Monetary Policy in a VAR Make Sense?" *International Economic Review*, 39(4), 907-931.

Sturm, J.-E., G.H. Kuper, and J. de Haan (1998), "Modelling Government, Investment and Economic Growth on a Macro Level: A Review Chapter 14," in ed., S. Brakman, H. van Ees, and S.K. Kuipers, *Market Behaviour and Macroeconomic Modelling.*

Wolde-Rufael, Y. (2009), "Does Public R&D Crowd-out Private R&D? A Note from Taiwan, ROC," *Journal of Economic Development*, 34(1), 59-70.

Mailing Address: Alfredo M. Pereira, Department of Economics, The College of William and Mary, Williamsburg, VA 23187, USA. E-mail:ampere@wm.edu.

Received June 30, 2011, Revised February 22, 2012, Accepted April 19, 2012.