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Article

On the effects of infrastructure investments in Portugal: Revisited

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Abstract: This study updates Pereira and Pereira by revisiting the macroeconomic and budgetary effects of infrastructure investment in Portugal using a dataset from the Portuguese Ministry of the Economy covering 1980–2019, thereby capturing a period of austerity and decreased investment in the 2010s. A vector-autoregressive approach re-estimates the elasticity and marginal product of twelve infrastructure types on private investment, employment, and output. The most significant long-term accumulated effects on output accrue from investments in airports, ports, health, highways, water, and railroads. In contrast, those in municipal roads, electricity and gas, and refineries are statistically insignificant. All statistically significant infrastructure investments pay for themselves over time through additional tax revenues. Compared to the previous study, highways, water, and ports have more than doubled their estimated marginal products due to a significant increase in relative scarcity over the last decade. In addition, our analysis reveals an important shift in the impacts of infrastructure investment, now producing more substantial immediate effects but weaker long-term impacts. This change offers policymakers a powerful tool for short-term economic stimulus and is particularly useful in addressing immediate economic challenges.

Keywords: infrastructure investment; multipliers; budgetary effects; vector-autoregressive; Portugal
JEL Classification: C32; E22; H54; L90; L98; O52

1. Introduction

This study re-examines the macroeconomic and budgetary effects of infrastructure investment in Portugal. We consider a new dataset published by the Portuguese Ministry of the Economy (Ministério da Economia, 2023), updated to cover four decades (1980–2019). Using a vector autoregressive approach, we estimate the short- and long-term elasticities and marginal products of twelve types of infrastructure investments on private investment, employment, and output. Therefore, this study updates the analysis and results of Pereira and Pereira (2018a) from 1978 to 2011.

This study's update is conceptually important, as it significantly advances our understanding of the role of infrastructure investment in the Portuguese economy. By extending our analysis to 2019, we capture a decade marked by a stark shift in investment patterns. The 2010s, characterized by austerity measures and the lingering effects of the European sovereign debt crisis, saw a sharp decrease in infrastructure investment. Simultaneously, economic performance largely maintained its long-term trajectory. This unique combination enriches our dataset by offering various connections between investment and economic outcomes, thus sharpening our estimates.

There is a broad consensus across the political spectrum in Portugal and international organizations regarding the crucial role infrastructure investment can play in supporting economic recovery and promoting long-term prosperity. The European Commission's 2021 Country Report for Portugal underscores the pivotal role of infrastructure investment in the country's recovery and resilience plan (European Commission, 2021). The report notes that transport, energy, and digital infrastructure investments are expected to contribute to recovery and increase the growth potential of the Portuguese economy.

The Recovery and Resilience Plan (PRR) for Portugal is a comprehensive national program designed to stimulate economic recovery, sustainable growth, and convergence with Europe until 2026. Initially presented in April 2021 (República Portuguesa, 2021) and subsequently updated (República Portuguesa, 2023), the plan now allocates a staggering 22.2 billion euros for 44 reforms and 117 investments. Infrastructure investment is a cornerstone of the PRR, with significant allocation across various sectors, emphasizing the modernization and expansion of critical infrastructure to support sustainable development and economic growth.

The contrast between these ambitious plans and Portugal's recent underinvestment highlights an urgent need. Policymakers must use solid evidence to make decisions regarding infrastructure. The choice between major investments requires rigorous analysis based on the most comprehensive datasets and advanced methodologies. This necessity makes it timely to revisit and expand upon the 1978–2011 study, applying cutting-edge techniques to data spanning 1980–2019. By doing so, we can better assess the macroeconomic impacts and budgetary implications of various infrastructure investments, providing policymakers with robust insights into their choices.

Infrastructure investments can potentially play a pivotal role in accelerating economic growth, reducing inequality, and fostering sustainable development globally (Calderón and Servén, 2014; Thacker et al., 2019). However, realizing their full potential requires addressing critical challenges, such as financing gaps, inefficient investment selection, and inadequate maintenance (Bhattacharya et al., 2015; Flyvbjerg, 2009). Our study sheds light, in particular, on the investment selection issue by quantifying the dynamic impacts of different infrastructure types and identifying patterns that can guide more effective policymaking. The finding that certain investments, such as in airports, ports, and health facilities, generate substantial economic benefits while easing budgetary pressures highlights promising areas for strategic prioritization (Kamps, 2005; Leduc and Wilson, 2013). Simultaneously, the diminishing long-term growth effects of infrastructure underscore the need for complementary policies that catalyze innovation, human capital development, and institutional reforms to sustain economic momentum (Hallegatte et al., 2019; Henckel and McKibbin, 2017). As nations strive to enhance resilience against climate risks and economic shocks, our reassessment of infrastructure taxonomies offers a data-driven framework for optimizing investment mixes, while ensuring fiscal sustainability.

The challenges and opportunities surrounding infrastructure investments transcend national boundaries, making this study's insights globally relevant. Many developed and developing countries confront similar quandaries—balancing short-term economic exigencies with long-term sustainable growth aspirations, managing the aftermath of economic shocks, and grappling with pressing climate concerns (Bhattacharya et al., 2019). Our findings on the evolving transmission mechanisms and shifting impacts of infrastructure offer valuable perspectives to policymakers worldwide. As nations strive to align infrastructure strategies with environmental goals (Chen et al., 2023) and enhance resilience (Chester and Allenby, 2019), our reassessment of infrastructure taxonomies provides a framework for identifying investments that foster economic growth while easing budgetary pressure. Furthermore, our analysis of front-loaded impacts and attenuated long-term effects resonates with the global discourse on the infrastructure's role in stimulating recovery and catalyzing sustained development (Henckel and McKibbin, 2017). By shedding light on these complex dynamics, this study empowers policymakers across diverse contexts to craft targeted, evidence-based strategies tailored to their specific economic conditions.

This study seeks to answer three critical policy questions by using the most recent, varied, and updated data. First, what types of infrastructure investments create the most significant long-term benefits for employment, private investment, and output? Second, what does the magnitude of the effects imply for potential future public budgetary pressure generated by these infrastructure investments? Third, what types of infrastructure investments create the most substantial short-term benefits for employment, private investment, and output?

We employ a vector autoregressive (VAR) model to estimate the short- and long-term effects of 12 infrastructure investments. This multivariate dynamic time-series approach was developed by Pereira and Flores (1999) and Pereira (2000, 2001). Combined with our expanded dataset spanning four decades, this allows us to disentangle the immediate demand-side impacts from longer-term supply side effects. This technique was subsequently applied to the U.S. in Pereira and Andraz (2003), Spain in Pereira and Roca Sagales (1999), Portugal in Pereira and Andraz (2005, 2006), Pereira and Pereira (2018a, 2019, 2020a, 2020b, 2020c), Rodrigues, Pereira and Pereira (2024), Pereira, Pereira, and Rodrigues (2019, 2021), and Canada in Pereira and Pereira (2018b).

For other VAR-based applications with an international focus see, for example, Agénor et al. (2005), Batina (1998), Belloc and Vertova (2006), De Frutos et al. (1998), Demetriades and Mamuneas (2000), Ghali (1998), Glaeser and Poterba (2021), Kamps (2005), Lau and Sin (1997), Ligthart (2002), Mamatzakis (1999), Matusche (2024), Mittnik and Newman (2001), Ocolisanu et al. (2022), Voss (2002), Ramey (2021), Sturm et al. (1999), and Suárez-Cuesta and Latorre (2023).

Pereira and Pereira (2018a) were the first to expand the scope to include non-transportation infrastructure, to decompose marginal products into their short- and long-term components, and finally to propose a three-category taxonomy classifying infrastructure investments as beneficial or detrimental to the economy and the public budget. This previous study provided a nuanced account of the estimated economic impacts of infrastructure investment in Portugal.

The data reveal significant shifts in infrastructure investment patterns across decades, with particularly notable changes in the 2010s. Overall infrastructure investment peaked at 4.96% of GDP in the 2000s before declining to 3.70% in the

2010s. This decline is reflected in the negative annual growth rate of −5.50% for infrastructure investment in the 2010s, in stark contrast to favorable growth rates of 6.52% in the 1980s, 10.22% in the 1990s, and 2.65% in the 2000s.

These trends in infrastructure investment diverge significantly from the patterns observed in gross fixed capital formation (GFCF) and GDP growth. While infrastructure investment declined sharply in the 2010s, GFCF showed a more moderate decrease, with an annual growth rate of −0.52%. This suggests a disproportionate reduction in infrastructure spending relative to overall capital formation.

In this study we reassess Pereira and Pereira (2018a)'s three-category taxonomy of infrastructure investments, identifying which types are most beneficial for output and public finances in Portugal's current context.

The remainder of this paper is organized as follows. Section 2 presents the data with an emphasis on the evolution of infrastructure investments. Section 3 introduces the methodological approach and presents preliminary results. Section 4 provides empirical evidence on the three key policy questions addressed in this study by examining the effects of distinct types of infrastructure investments. Section 5 compares the empirical evidence presented herein with the findings of Pereira and Pereira (2018a). Section 6 concludes the paper with a summary, policy implications, and possible extensions.

2. Data sources and stylized facts about infrastructure investments

2.1. On the aggregate data

This study uses annual economic data for Portugal from 1980 to 2019. All monetary values are expressed in millions of 2016 Euros. The data on output, employment, and investment used in our empirical work come from different annual issues in the National Accounts published by the Instituto Nacional de Estatística (Statistics Portugal) (https://bit.ly/3o9ekHf). Employment is measured in thousands of employees. The infrastructure investment data (version dated 21 December 2023) come from an updated version of the dataset developed by Pereira and Pereira (2016) and made available online by the Portuguese Ministry of the Economy (Ministério da Economia, 2023). **Table 1** provides a comprehensive overview of these investments, presenting their shares of GDP, proportion of total infrastructure investment, and annual growth rates across four decades.

By contrast, GDP growth remained positive in the 2010s, albeit at a modest annual rate of 0.84%. This creates a striking disparity between the trajectory of infrastructure investment and overall economic growth. This divergence is particularly noteworthy, compared to previous decades: in the 1980s and the 1990s, infrastructure investment growth outpaced GFCF and GDP growth. In the 2000s, infrastructure investment growth (2.65%) continued to outpace both GDP growth (0.93%) and GFCF growth (−1.09%), with GFCF showing a decline.

Table 1. Infrastructure investments.

	1980–1989	1990–1999	2000–2009	2010–2019	1980–2019
Percent of GDP (%)					
Infrastructure investment	**1.98**	**3.92**	**4.96**	**3.70**	**3.66**
Road transportation					
National road	0.21	0.50	0.49	0.08	0.32
Municipal road	0.21	0.35	0.34	0.19	0.27
Highway	0.04	0.25	0.45	0.09	0.21
Other transportation					
Railroad	0.09	0.32	0.32	0.09	0.21
Port	0.02	0.05	0.05	0.02	0.04
Airport	0.02	0.03	0.06	0.03	0.03
Social infrastructures					
Health	0.17	0.38	0.49	0.52	0.39
Education	0.32	0.48	0.55	0.6	0.49
Utilities					
Water	0.21	0.38	0.48	0.42	0.37
Electricity and gas	0.29	0.31	0.76	0.82	0.55
Petroleum	0.05	0.15	0.13	0.12	0.12
Telecommunications	0.35	0.72	0.84	0.72	0.66
Percent of infrastructure investment (%)					
Road transportation					
National road	10.69	13.07	9.85	1.98	8.90
Municipal road	10.45	8.93	6.93	5.18	7.87
Highway	2.28	6.45	9.29	2.22	5.06
Other transportation					
Railroad	4.61	7.87	6.53	2.38	5.35
Port	1.06	1.33	0.99	0.62	1.00
Airport	1.05	0.76	1.17	0.73	0.93
Social infrastructures					
Health	8.79	9.57	9.89	14.46	10.68
Education	16.40	12.30	11.17	16.61	14.12
Utilities					
Water	10.28	9.88	9.72	11.02	10.23
Electricity and gas	14.17	7.63	15.35	22.32	14.87
Petroleum	2.86	3.80	2.60	2.93	3.05
Telecommunications	17.36	18.41	16.51	19.55	17.96
Annual growth rate (%)					
GDP	**3.30**	**2.93**	**0.93**	**0.84**	**2.00**
Gross fixed capital formation	**2.74**	**5.45**	**−1.09**	**−0.52**	**1.64**
Infrastructure investment	**6.52**	**10.22**	**2.65**	**−5.50**	**3.40**

Table 1. (*Continued*).

	1980–1989	1990–1999	2000–2009	2010–2019	1980–2019
Road transportation					
National road	5.82	9.01	6.69	−24.50	−0.75
Municipal road	2.48	7.05	−1.01	−5.54	0.74
Highway	1.65	14.08	3.05	−2.90	3.97
Other transportation					
Railroad	1.41	16.49	−5.04	−8.45	1.10
Port	−2.41	12.13	−0.87	−8.63	0.05
Airport	16.33	−7.90	17.54	−15.53	2.61
Social infrastructures					
Health	3.83	12.77	1.21	1.35	4.82
Education	2.25	9.92	2.17	−2.18	3.06
Utilities					
Water	9.93	5.91	2.54	−2.70	3.92
Electricity and gas	5.74	8.87	9.59	−6.90	4.33
Petroleum	−17.50	25.33	−1.07	−7.96	−0.30
Telecommunications	17.53	10.56	−0.19	−5.83	5.52

Source: Authors' calculations. based on Gabinete de Estratégia e Estudos, Ministério da Economia—Base de dados de infraestruturas (Ministério da Economia, 2023).

2.2. On the disaggregated infrastructure investment data

We consider twelve types of infrastructure investments, categorized into four main groups: road transportation, other transportation, social infrastructures, and utilities.

Road transportation infrastructure investment has experienced volatile growth rates over the decades. After solid growth in the 1980s (8.10%) and the 1990s (8.93%), growth slowed to 3.71% in the 2000s before sharply declining to −11.56% in the 2010s. Road transportation decreased from 26.07% in the 2000s to 9.38% in the 2010s as a percentage of total infrastructure investment. In terms of GDP, it fell from 1.28% to 0.36% over the same period. Within this category, national roads saw the most substantial decline, dropping from 0.49% of GDP (9.85% of the total infrastructure) in the 2000s to 0.08% of GDP (1.98% of the total infrastructure) in the 2010s. Highways followed a similar pattern, whereas municipal roads showed greater resilience.

Other transportation infrastructure followed a similar pattern but with more extreme fluctuations. Growth was robust in the 1980s (8.33%) and even stronger in the 1990s (13.36%). However, it became negative in the 2000s (−2.37%) and declined to −9.66% in the 2010s. Its share of total infrastructure investment fell from 8.69% in the 2000s to 3.73% in the 2010s, while it decreased from 0.43% to 0.14% as a percentage of the GDP. Within this category, railroad investment fell from 0.32% of GDP (6.53% of the total infrastructure) to 0.09% of GDP (2.38% of the total infrastructure).

Social infrastructure investment demonstrated the most consistent growth over four decades. It showed modest growth in the 1980s (2.83%), accelerated significantly in the 1990s (11.12%), and maintained a positive growth in the 2000s (1.74%). While it turned negative in the 2010s (−0.50%), the decline was much less severe than that in the transportation infrastructure. Its share of total infrastructure investment increased from 21.06% in the 2000s to 31.07% in the 2010s, and as a percentage of GDP, it rose from 1.04% to 1.12%. Health infrastructure increased from 0.49% of GDP (9.89% of total infrastructure) to 0.52% of GDP (14.46% of total infrastructure), whereas education infrastructure showed similar resilience.

Utility infrastructure investment also showed a pattern of growth followed by a decline but was less extreme than transportation. Growth was strong in the 1980s (7.47%) and the 1990s (9.82%), moderate in the 2000s (3.42%), and negative in the 2010s (−5.77%). The share of total infrastructure investment increased from 44.18% in the 2000s to 55.82% in the 2010s, despite declining as a percentage of GDP from 2.21% to 2.08%. In this category, electricity and gas infrastructure saw increased investment from 0.76% of GDP (15.35% of the total infrastructure) to 0.82% (22.32% of the total infrastructure).

Over the entire period from 1980 to 2019, all four categories showed positive growth, with social infrastructures leading at 3.82%, followed by utilities at 3.64%, other transportation at 2.27%, and road transportation at 2.14%.

The global shift towards cleaner energy and the modernization of outdated infrastructure systems is reflected in Portugal's increased investment in electricity and gas infrastructure. The OECD (2024) report "Infrastructure for a Climate-Resilient Future" emphasizes this global transformation, with countries reducing emissions, enhancing resilience to climate change, and adopting renewable energy sources, such as solar and wind power. Public opinion plays a crucial role in driving the adoption of renewable energy (Qazi et al., 2019), and the United States is also preparing for climate-smart infrastructure, including clean electricity, energy storage, and resilient grids (Lashof and Neuberger, 2023). Sustainable infrastructure design is evolving to benefit urban areas through the integration of green infrastructure, smart cities, renewable energy, and resilient systems (Awasthi et al., 2024). However, the expansion of energy infrastructure involves complex socio-spatial dimensions and requires balancing diverse discourses on the common good (Cowell and Laurentis, 2022). Portugal's investment likely represents a strategic modernization effort to participate in the global transition towards a sustainable and climate-ready energy future. This transition requires an adaptive approach to energy governance that integrates supply and demand pathways, while facilitating the effective alignment of local agendas with broader systemic changes.

Figure 1 shows the disaggregated infrastructure investment data discussed in this subsection. It shows an overall decline in total infrastructure investment as a percentage of GDP in the 2010s, from 4.96% in the 2000s to 3.70%. It highlights the shift away from transportation infrastructure, with the share of road transportation falling from 26.07% to 9.38%. Conversely, social infrastructure investment, particularly health, exhibited resilience, increasing from 21.06% to 31.07%. This visual representation reinforces the key patterns in the data analysis, depicting evolving infrastructure investment trends in Portugal.

This reallocation raises important questions regarding long-term economic growth, productivity, and the evolution of Portugal's development strategy. Our subsequent analysis addresses these questions by examining the macroeconomic and budgetary impacts of various infrastructure investments.

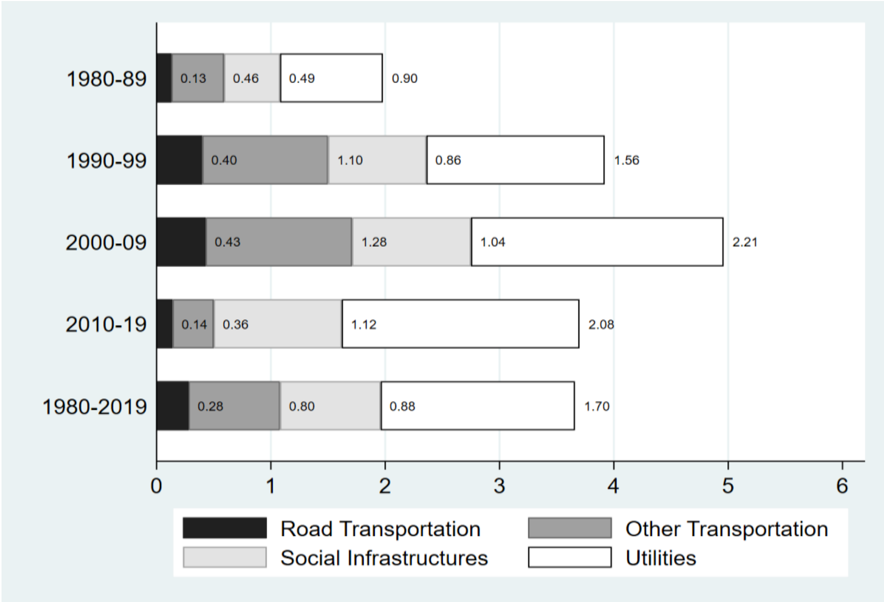

Figure 1. Components of infrastructure investment from 1980 to 2019 (percent of GDP).

Source: Authors' calculations, based on Gabinete de Estratégia e Estudos, Ministério da Economia - Base de dados de infraestruturas (Ministério da Economia, 2023).

3. Methodology and basic results

3.1. The methodological approach

This study employs the vector autoregressive (VAR) approach developed by Pereira (2000) and further refined by Pereira and Pereira (2018a). The VAR model is particularly well suited for analyzing the effects of the twelve types of infrastructure investments on output, employment, and private investment, as it captures the endogenous nature of these relationships and allows for the identification of both contemporaneous and dynamic feedback among the variables (Kamps, 2005).

The flexibility of the VAR model is especially relevant in the context of our study, as it can be interpreted as an unrestricted and reduced form of a structural model consisting of a production function, factor demand functions, and policy functions for each type of infrastructure investment (Pereira and Andraz, 2013). This approach is crucial for addressing potential reverse causality concerns, as infrastructure investments in different sectors may respond differently to economic conditions (Leduc and Wilson, 2013).

By estimating the long-term elasticities and marginal products of output, employment, and private investment with respect to each of the twelve types of infrastructure investment through impulse-response functions, we can effectively distinguish between the short-term demand-side effects and long-term supply side effects of these investments. This distinction is particularly important to understand the unique impact of each type of infrastructure on the economy over different time horizons.

To identify exogenous shocks to each type of infrastructure investment, we adopt the approach used in monetary policy literature (Christiano et al., 1999), imposing restrictions on the contemporaneous relationships between innovations in the VAR model. This assumes that innovations in each type of infrastructure investment lead to contemporaneous changes in other variables but not vice versa, allowing us to isolate the specific effects of each investment category.

3.2. Preliminary data analysis

We begin by examining the stationarity properties of the variables using Augmented Dickey-Fuller (ADF) *t*-tests (Dickey and Fuller, 1979) for each of the twelve types of infrastructure investment as well as output, employment, and private investment. Following Pereira and Pereira (2018a), we test for unit roots in both log levels and the first differences of the variables. The null hypothesis of a unit root cannot be rejected for log-level variables but is rejected for their first differences, suggesting that the variables are integrated of order one, I(1).

To test for cointegration among output, employment, private investment, and each type of infrastructure investment, we employ the Engle-Granger approach (Engle and Granger, 1987). This involves testing for unit roots in the residuals of the static long-term equilibrium relationships. The tests generally fail to reject the null hypothesis of no cointegration for all twelve infrastructure investment categories, indicating a lack of long-run equilibrium relationships among the variables in levels.

Based on these results and following the standard procedure in the literature (see, for example, Pereira and Frutos, 1999), we specify our VAR models using the growth rates of the original variables for each infrastructure investment category. This ensures that we operate with stationary time series for all twelve types of infrastructure investments.

The Bayesian Information Criterion (BIC) proposed by Schwarz (1978) is used to determine the appropriate VAR specification for each infrastructure investment category, considering different lag structures and deterministic components. Our results indicate that a first-order VAR specification is appropriate in most cases, with the preferred models generally including a constant, trend, and structural breaks corresponding to the inception of EU community support frameworks (1989, 1994, and 2000), consistent with the findings of Pereira and Pereira (2018a).

This methodology allows us to comprehensively assess the economic impacts of the twelve categories of infrastructure investment in Portugal, accounting for both short- and long-term effects. By applying this approach to each investment category separately, we can uncover the unique dynamics and contributions of different types of infrastructure to output, employment, and private investment, thus providing valuable insights for policymakers in prioritizing investment decisions.

The VAR approach is particularly well suited for this analysis, as it allows for the separation of short-term and long-term effects, which is crucial for understanding the impact of different types of infrastructure investments. The flexibility of the model in capturing the endogenous relationships among variables and addressing reverse causality concerns is especially important, given the diverse nature of the twelve infrastructure categories examined. Furthermore, by identifying exogenous shocks to each type of infrastructure investment, we can isolate the specific effects of each category on the economy, thus providing a more nuanced understanding of their individual contributions.

To estimate elasticities and marginal products, we designed an approach to mitigate concerns about the sensitivity of the model to its assumptions. We employed a vector autoregressive (VAR) framework, which is well established in empirical macroeconomics, allowing data to freely capture complex infrastructure-economy relationships without restrictive theoretical constraints. Rigorous pretesting ensured appropriate growth rate specifications, accounting for levels, while robust criteria determined the optimal lag structures and structural breaks. Our identification strategy is grounded in literature on monetary policy shocks and isolated exogenous infrastructure investment innovations. Computing elasticities and marginal products from accumulated impulse responses, a widely accepted technique, traces dynamic effects across horizons. Extensive sensitivity analyses confirm that our findings are robust across diverse specifications and subsamples. While modeling assumptions are inevitable, our multipronged approach, anchored in established practices, yields substantive conclusions from reliable estimates and not merely artifacts of arbitrary assumptions.

3.3. The key elasticity estimates

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.

The long-term elasticity estimates presented in **Table 2** reveal significant variations across infrastructure investments, underscoring the importance of disaggregating these investments to capture their distinct economic impacts.

Table 2. Long-term elasticities with respect to infrastructure investment.

	Private investment	**Employment**	**Output**
Road transportation			
National road	0.143	0.028	0.032
Municipal road	*	*	*
Highway	0.147	0.037	0.046
Other transportation			
Railroad	0.170	0.041	0.036
Port	0.022	0.007	0.010
Airport	0.059	0.012	0.012
Social infrastructures			
Health	0.332	0.070	0.093
Education	0.225	0.024	0.055

Table 2. (*Continued*).

	Private investment	Employment	Output
Utilities			
Water	0.231	0.062	0.075
Electricity and gas	*	*	*
Petroleum	*	*	*
Telecommunications	0.208	0.055	0.069

Note: Values marked with * are not statistically significant, as implied by the standard deviation bands around the impulse response functions. Specification: VAR (1) with constant and trend.

Road transportation investments yield noteworthy results. National roads and highways have substantially positive effects on private investment, employment, and output. Highways slightly outperform national roads with elasticities of 0.147, 0.037, and 0.046 for private investment, employment, and output, respectively. These figures indicate that investments in road infrastructure crowd in private investment and boost job creation and economic output. Interestingly, municipal roads fail to show significant effects, prompting questions about the nature and context of these more localized investments.

Other transportation modes present more varied outcomes. Railroad investments emerge as the top performer in this group, boasting the highest elasticities among transportation infrastructures at 0.170, 0.041, and 0.036. This demonstrates a robust crowding-in effect on private investment and a substantial positive impact on employment and output. While positive, ports and airports yield more modest effects, with ports showing the most negligible impact among all the significant infrastructure types.

Social infrastructures offer potent results. Health infrastructure investments dominate all other categories, with impressive elasticities of 0.332, 0.070, and 0.093, respectively. These figures indicate a powerful crowding-in effect on private investment and considerable positive impact on employment and output. Educational infrastructure has substantial positive effects, particularly on private investment (0.225) and output (0.055), although its employment impact (0.024) lags somewhat behind.

In utilities, water infrastructure investments stand out, demonstrating significant positive effects with elasticities of 0.231, 0.062, and 0.075, respectively. These numbers indicate a robust crowding-in effect on private investment, and a notable impact on employment and output. Telecommunication infrastructure has substantial positive effects, particularly on private investment (0.208). Curiously, electricity, gas, and petroleum infrastructure fail to show significant effects, raising questions about the specific characteristics of these investments in Portugal.

The prevalence of positive elasticities for private investments across multiple infrastructure types suggests widespread crowding-in effects. Rather than displacing private investment, public infrastructure investments appear to stimulate it. Health, education, water, and telecommunications infrastructures stand out with powerful crowding-in effects, boasting private investment elasticities above 0.2. This implies that these investments may be especially effective in catalyzing private-sector activities.

Health infrastructure investments take the lead for employment and output, followed closely by water and telecommunication investments. This hierarchy suggests that investments in these areas may yield exceptionally high returns on overall economic growth and job creation.

The absence of significant effects on municipal roads, electricity and gas, and petroleum infrastructure presents an intriguing puzzle. This unexpected result warrants a deeper investigation of the unique characteristics and contexts of these investments in Portugal.

The insignificant effects of municipal roads could be a result of their more localized nature, serving mainly local transportation needs rather than broader economic linkages. Their fragmented maintenance and upgrade cycles may also dilute their overall impacts. For electricity infrastructure, the lack of significant effects could be related to Portugal's energy mix, regulations, or the specific investment types carried out during this period. As a foundational infrastructure, the economic impacts of electricity likely manifest indirectly by enabling other industries, rather than directly affecting output, employment, and private investment. Thus, a more granular analysis of these investments' nature, timing, and complementarities is required to uncover the underlying reasons for statistical insignificance.

These findings offer a nuanced and valuable guide to policymakers. By illuminating the varying economic impacts of different infrastructure types, the results identify investments with the most significant potential to stimulate private investment, create jobs, and boost output. This detailed understanding can help shape targeted and effective infrastructure investment strategies, potentially leading to more robust and sustainable economic development in Portugal.

4. On the effects of infrastructure investment

4.1. On the long-term economic effects of infrastructure investments

Table 3 presents the long-term marginal products of the twelve infrastructure investments, offering valuable insights into their economic impact. These figures represent the total effects, combining immediate and cumulative effects over time.

Road transportation infrastructure is particularly effective in terms of private investment. National roads and highways generate substantial returns, with each million euros invested, yielding approximately 25 million euros of private investment. Airports also demonstrate a strong impact, producing approximately 28.4 million euros in private investment per million euros invested. These figures suggest that transportation infrastructure, especially roads and airports, is crucial for stimulating private sector investment.

Employment benefits most significantly from investments in highways, railroads, and airports. Approximately 1.1, 1.0, and 1.0 thousand jobs are created for every million euros invested in these infrastructure types, underscoring the importance of transportation infrastructure in job creation. Although social infrastructure and utilities show positive employment effects, their impact is less pronounced than that of transportation investment.

Table 3. Long-term marginal products with respect to infrastructure investment.

	Private investment (million per million €)	**Employment (thousand jobs per million €)**	**Output (million per million €)**
Road transportation			
National road	25.444	0.884	10.000
Municipal road	*	*	*
Highway	25.171	1.111	21.905
Other transportation			
Railroad	24.369	1.041	17.143
Port	12.487	0.676	25.000
Airport	28.445	1.026	40.001
Social infrastructures			
Health	8.622	0.320	23.846
Education	5.045	0.097	11.224
Utilities			
Water	7.469	0.355	20.270
Electricity and gas	*	*	*
Petroleum	*	*	*
Telecommunications	3.887	0.182	10.455

Note: Values marked with * are not statistically significant, as implied by the standard deviation bands around the impulse response functions.

Output gains are most substantial for airport investments, with each million euros invested generating approximately 40 million euros in output. Ports and health infrastructure also demonstrate strong output effects, producing 25 million and 23.8 million euros in output per million invested euros, respectively. Highways and water infrastructure follow closely, with output gains of 21.9 and 20.3 million euros per million invested.

Interestingly, while health infrastructure has a modest impact on private investment and employment compared with other categories, its effect on output is considerable. This finding suggests that health investment may significantly indirectly affect economic productivity.

Education and telecommunications infrastructure demonstrate lower marginal products than other infrastructure types while showing positive effects across all three economic variables. However, their importance should not be understated as they likely contribute to long-term economic growth through human capital development and improved connectivity.

Municipal roads, electricity and gas, and petroleum infrastructure investments do not show statistically significant effects, mirroring the findings from the elasticity analysis. This consistent lack of significant impact warrants further investigation of the specific circumstances surrounding these investments in Portugal.

In summary, the long-term effects on output reveal a clear hierarchy among infrastructure investments. Airports lead, generating an impressive 40 million euros in output per million invested, underscoring air transportation's critical role in boosting GDP. Ports follow closely, yielding 25 million euros, highlighting the significance of maritime infrastructure. Health infrastructure demonstrates a surprisingly strong impact, producing 23.8 million euros per million invested, also suggesting far-reaching effects on productivity. Highways and water systems round out the top five, with substantial output gains of 21.9 and 20.3 million euros per million invested.

4.2. On the long-term budgetary effects of infrastructure investments

Table 4 presents the long-term budgetary effects of various infrastructure investments, revealing a key proportionality: the relationship between long-term fiscal revenue increases and long-term GDP. This proportionality means that the ranking of investments by fiscal impact directly mirrors their ranking by the long-term GDP effects.

Table 4. Long-term budgetary effects of infrastructure investments.

	Equilibrium tax rate (%)	**Fiscal revenues (€) with a tax rate of 25%**	**Payoff period (years) with a tax rate of 25%**
Road transportation			
National road	10.00	2.50	12.0
Municipal road	*	*	*
Highway	4.57	5.48	5.5
Other transportation			
Railroad	5.83	4.29	7.0
Port	4.00	6.25	4.8
Airport	2.50	10.00	3.0
Social infrastructures			
Health	4.19	5.96	5.0
Education	8.91	2.81	10.7
Utilities			
Water	4.93	5.07	5.9
Electricity and gas	*	*	*
Petroleum	*	*	*
Telecommunications	9.57	2.61	11.5

Note: Values marked with * are not statistically significant, as implied by the standard deviation bands around the impulse response functions.

The fiscal revenue column in **Table 4** quantifies this relationship. For every million euros invested, airports generate 10 million euros in long-term fiscal revenue, followed by ports (6.25 million), health facilities (5.96 million), highways (5.48 million), and water systems (5.07 million). These figures directly correspond to the long-term GDP effects, reinforcing the link between sustained economic growth and fiscal outcomes over time.

This proportionality extends to the payoff periods in **Table 4**. Airports with the highest long-term fiscal revenue have the shortest payoff period of 3 years. The payoff periods increase as we move down the table, reaching 5.9 years for water systems among the top performers. These periods reflect how quickly long-term GDP increases translate into fiscal benefits.

While not in the top tier, railroads still demonstrate positive long-term fiscal outcomes with 4.29 million euros in revenue and a 7-year payoff period, aligning with their moderate long-term GDP effects.

The lower portion of **Table 4** shows that national roads, education, and telecommunications infrastructure yield lower long-term fiscal returns (2.5 to 2.81 million euros) with more extended payoff periods (10 to 12 years), consistent with their more minor impact on long-term GDP.

The equilibrium tax rate column in **Table 4** further illustrates this proportionality. Lower rates for top performers (2.5% for airports and 4% for ports) indicate their ability to generate substantial long-term fiscal benefits even at low tax levels, reflecting their long-term solid GDP effects. Higher rates for lower-performing investments (9.57% for telecommunications and 10% for national roads) suggest weaker long-term GDP effects, and consequently, lower fiscal benefits.

This proportional relationship between long-term fiscal revenues and long-term GDP increases implies that infrastructure investments, which top **Table 4**, can significantly reduce future public budgetary pressures. They recoup their costs and generate surplus revenue over time, potentially funding other public needs or reducing debt. Conversely, investments with lower long-term fiscal returns, while still beneficial in the long run, may create prolonged budgetary pressures.

Thus, **Table 4** underscores the importance of considering long-term GDP effects and fiscal sustainability in selecting infrastructure investments. By prioritizing investments with strong long-term fiscal effects, as shown in the table, policy-makers can potentially create a virtuous cycle of sustained economic growth and fiscal stability. This approach can ease long-term budgetary pressures and foster sustained development without compromising financial prudence by leveraging the proportional relationship between long-term GDP increases and fiscal outcomes.

4.3. On the short-term economic effects of infrastructure investments

Table 5 provides a detailed analysis of how various infrastructure investments influence private investment, employment, and output both in the short term and over time. This breakdown sheds light on the economic effects of different infrastructure types.

Table 5. Long-term marginal products versus effects on impact.

		Private investment	Employment	Output
Road transportation				
	Total effect	25.444	0.884	10.000
National road	On impact	20.198	0.618	7.600
	(% of total)	(79%)	(70%)	(76%)
	Total effect	*	*	*
Municipal road	On impact	*	*	*
	(% of total)	*	*	*
	Total effect	25.171	1.111	21.905
Highway	On Impact	16.790	0.717	15.334
	(% of total)	(67%)	(65%)	(70%)

Table 5. (*Continued*).

		Private investment	Employment	Output
Other transportation				
	Total effect	24.269	1.041	17.143
Railroad	On impact	19.047	1.169	19.543
	(% of total)	(78%)	(112%)	(114%)
	Total effect	12.478	0.676	20.000
Port	On impact	21.433	1.257	34.000
	(% of total)	(172%)	(186%)	(136%)
	Total effect	28.445	1.026	40.001
Airport	On impact	32.492	1.533	66.400
	(% of total)	(114%)	(149%)	(166%)
Social infrastructure				
	Total effect	8.622	0.320	23.846
Health	On impact	5.522	0.254	11.446
	(% of total)	(64%)	(79%)	(48%)
	Total effect	5.045	0.097	11.224
Education	On impact	6.656	0.164	14.816
	(% of total)	(132%)	(169%)	(132%)
Utilities				
	Total effect	7.469	0.355	20.270
Water	On impact	7.366	0.342	18.851
	(% of total)	(99%)	(96%)	(93%)
	Total effect	*	*	*
Electricity and gas	On impact	*	*	*
	(% of total)	*	*	*
	Total effect	*	*	*
Petroleum	On impact	*	*	*
	(% of total)	*	*	*
	Total effect	3.887	0.182	10.455
Telecommunications	On impact	2.483	0.110	6.586
	(% of total)	(64%)	(60%)	(63%)

Note: Values marked with * are not statistically significant, as implied by the standard deviation bands around the impulse response functions.

Airports emerge as the frontrunner in immediate economic impact. Per million euros invested, they generate a substantial on-impact boost of €32.5 million in private investment, 1533 jobs, and €66.400 million in output. These immediate effects exceed their long-term totals, with percentages of 114%, 149%, and 166% respectively. This pattern indicates that investing in airports makes economic activity surge upon completion, followed by a slight tapering over time. The initial boom likely stems from increased connectivity and business opportunities, whereas the subsequent moderation reflects market adjustments or capacity constraints.

The ports exhibited a similar pattern of immediate outsized impacts. Per million euros invested, they inject €21.4 million into private investment, boost employment by 1257 jobs, and elevate output by €34 million in the short term. These figures represent 172%, 186%, and 136% of their respective total effects, respectively, suggesting rapid growth followed by gradual settling. This trend may reflect the immediate surge in trade and economic activity that ports facilitate, with some moderation, as the economy adjusts to the new equilibrium.

Railroads present a more balanced picture. While their immediate effect on private investment (€19 million, 78% of the total) suggests some delayed benefits, they exhibit more substantial short-term impacts on employment (1169 jobs per million, 112%) and output (€19.5 million, 114%). This pattern might reflect the immediate job creation and economic stimulus of rail construction coupled with the gradual attraction of private investment as new economic corridors develop.

Water infrastructure demonstrates remarkably consistent effects across time, with immediate impacts accounting for 99% of private investment (€7.4 million), 96% of employment (342 jobs per million euros), and 93% of output (€18.9 million) total effects. This stability suggests that the water infrastructure delivers its full economic potential quickly, with benefits materializing almost entirely upon completion.

Highways show a more gradual realization of benefits, with immediate effects accounting for 67% of private investment (€16.8 million), 65% of employment (717 jobs per million euros), and 70% of output (€15.3 million). This pattern may reflect the time businesses and labor markets need to fully leverage improved connectivity.

Education infrastructure exhibits strong immediate effects that slightly exceed the long-term totals for all metrics. It generates €6.7 million in private investment (132% of the total), 164 jobs per million euros (169% of the total), and €14.8 million in output (132% of the total). This surprising result might indicate an initial surge in construction-related economic activity, followed by a slight contraction, as the focus shifted from building to operating educational facilities.

Health infrastructure presents a mixed picture, with moderate immediate impacts on private investment (€5.5 million, 64% of total) and employment (254 jobs per million euros, 79% of total), but a lower short-term effect on output (€11.4 million, 48% of total). This suggests that while health infrastructure quickly stimulates investment and job creation, its full impact on economic output takes time to materialize, possibly as population health improvements gradually enhance productivity.

National roads demonstrate robust short-term effects, particularly in terms of private investment (€20.2 million, 79% of the total). They also generate 618 jobs per million euros (70% of the total) and €7.6 million in output (76% of the total). This could reflect an immediate boost from construction activities and the rapid adoption of new transportation links by businesses.

Telecommunications infrastructure shows the most gradual impact, with immediate effects accounting for only 60%–64% of the total effects across all metrics. It generates €2.5 million in private investment, 110 jobs per million euros, and €6.586 million in short-term output. This pattern likely reflects the time required for businesses and consumers to adopt and fully leverage new communication technologies.

Negative dynamic effects occur when short-term impacts exceed 100% of the total effects and warrant careful interpretation. Rather than indicating a net negative impact over time, this phenomenon likely reflects the reallocation of resources within the economy. The initial surge may partly draw resources from other sectors, leading to a subsequent rebalancing. Additionally, the full utilization of new infrastructure may lead to congestion effects or diminishing returns.

In summary, **Table 5** reveals a clear hierarchy of the short-term impact of infrastructure investments on output. From the most to least impactful, the ranking emerges as airports, ports, railroads, water, highways, education, health facilities, national roads, and telecommunications. This order holds for the impact on private investment and employment with minor variations.

5. What has changed?

Understanding the shifts in infrastructure impacts between the previous study (1978–2011) and the present study (1980–2019) is crucial for informing policy decisions. Let us examine these changes in detail, focusing on the long-term economic performance, long-term budgetary effects, and short-term economic performance.

5.1. On the best strategy in terms of long-term economic performance

The present study reveals significant changes in the long-term economic impact of various infrastructure investments. Airports retain their top position, but with a slight decrease in total marginal product from €47.5 million to €40 million. Despite this 15.8% decline, airports remain the most productive infrastructure investment.

Ports have seen a significant improvement, with their total marginal product more than doubling from €12 million to €25 million, an increase of 108.3%. This surge propelled ports from fifth to second in long-term impact rankings.

Health facilities, now ranked third, have experienced a slight decrease in the total output effect from €25.4 million to €23.8 million, a 6.2% decline. Despite this minor reduction, health infrastructure continues to play a crucial role in the long-term economic performance. The changes in marginal products for output are summarized in **Table 6**.

The most remarkable improvement is observed on highways, which have seen their total marginal product skyrocket from €7.2 million to €21.9 million, a staggering 204.7% increase. This has catapulted highways from the lowest rank to the fourth place in terms of long-term impact.

Water infrastructure has also shown substantial improvement, with its total marginal product rising from €9.7 million to €20.3 million, an increase of 109.5%. This growth has moved water infrastructure up one rank to fifth place.

Railroads, while slipping from third to sixth place, still saw an increase in total marginal product from €14.3 million to €17.1 million, a 20% increase. Education infrastructure improved its total marginal product from €8.6 million to €11.2 million, a 30.5% increase, while maintaining its seventh-place ranking.

Telecommunications and national roads have experienced relative declines in their long-term impact rankings. Telecommunications experienced a 16.1% decrease in total marginal product, from €12.5 million to €10.5 million, dropping from fourth to eighth place. Despite an 18.2% increase in total marginal product from €8 million to €10 million, national roads have moved to the lowest rank because of more substantial improvements in other infrastructure types.

Table 6. Comparing the effects on output with results in the previous study.

	Marginal products: total		**Fiscal revenues**		**Marginal products: on impact**	
	Present study	**Previous study**	**Present study**	**Previous study**	**Present study**	**Previous study**
	1980–2019	**1978–2011**	**1980–2019**	**1978–2011**	**1980–2019**	**1978–2011**
Road transportation						
National road	10.000	8.462	2.50	2.12	7.600	**9.985**
Municipal road	*	*	*	*	*	*
Highway	**21.905**	7.188	5.48	1.80	**15.334**	2.012
Other transportation						
Railroad	17.143	**14.282**	4.29	3.71	**19.543**	3.285
Port	**25.000**	**12.000**	6.25	3.00	**34.000**	**5.760**
Airport	**40.001**	**47.500**	10.00	11.88	**66.400**	**32.775**
Social infrastructures						
Health	**23.846**	**25.435**	5.96	6.36	11.466	**6.109**
Education	11.224	8.600	2.81	2.15	14.816	**5.160**
Utilities						
Water	**20.270**	9.677	5.07	2.42	**18.851**	4.258
Electricity and gas	*	*	*	*	*	*
Petroleum	*	*	*	*	*	*
Telecommunications	10.455	**12.465**	2.61	3.11	6.586	5.107

Note: Values marked with * are not statistically significant, as implied by the standard deviation bands around the impulse response functions.
Note: The values for the previous study, Pereira & Pereira (2018a), were modified from the originally reported values in that for comparison we used the whole sample averages to calculate the marginal products.

5.2. On long-term budgetary effects

The changes in marginal products directly translate into shifts in fiscal revenues generated by these investments. Airports continue to generate the highest fiscal revenue per euro invested, decreasing slightly from €11.88 to €10.00. Ports generate €6.25 in fiscal revenues per euro invested, up from €3.00, an increase of 108.3%.

Health facilities show a slight decrease in fiscal revenue generation from €6.36 to €5.96 per euro invested. Highways demonstrate the most significant improvement in fiscal impact, now generating €5.48 in fiscal revenue per euro invested, up from €1.80, a 204.4% increase.

Water infrastructure now generates €5.07 in fiscal revenues per euro invested, up from €2.42, an increase of 109.5%. Railroads show a 15.6% increase in fiscal revenue generation, from €3.71 to €4.29 per euro invested.

Education infrastructure generates €2.81 in fiscal revenues per euro invested, up from €2.15, an increase of 30.7%. Telecommunications show a decrease in fiscal revenue from €3.11 to €2.61 per euro invested. National roads now generate €2.50 in fiscal revenue per euro invested, up from €2.12, an increase of 17.9%.

5.3. On the best strategy in terms of short-term economic performance

The on-impact effects of infrastructure investments have undergone significant changes between the two studies. Airports maintain their top position, with their on-impact marginal product increasing from €32.8 million to €66.4 million, an increase of 102.6 %. This reinforces their role as immediate economic stimulants.

Ports have experienced remarkable improvements in their immediate impacts. Their on-impact marginal product surged from €5.8 million to €34 million, an increase of 490.3%. This substantial growth has elevated ports from fourth to second place in short-term impact rankings, highlighting their enhanced ability to generate immediate economic benefits.

Railroads have made an impressive leap in terms of their immediate impact. Their on-impact marginal product rose from €3.3 million to €19.5 million, an increase of 495.0%. This significant improvement propelled railroads from eighth to third place in the short-term rankings, indicating a more substantial capacity for immediate economic stimulation.

Water infrastructure has also shown substantial improvements. Its on-impact marginal product increased from €4.3 million to €18.9 million, a 342.7% rise, moving it to fourth place. This finding suggests that investments in water systems now yield more immediate economic returns than previously observed.

Highways demonstrate one of the most striking improvements in terms of immediate impact. Their on-impact marginal product increased from €2.0 million to €15.3 million, an increase of 662.1 %. This remarkable growth has moved highways from the lowest rank to the fifth place in terms of short-term impact, indicating a significantly enhanced ability to stimulate immediate economic activity.

Education infrastructure's on-impact marginal product has increased from €5.2 million to €14.8 million, an 187.1% rise. However, despite this substantial improvement, its ranking dropped slightly from fifth to sixth because of the larger gains observed in other infrastructures.

Despite an 87.7% increase in on-impact marginal product from €6.1 million to €11.5 million, health facilities have dropped from third to seventh place in short-term rankings. This change in ranking is not due to poor performance but rather to the more substantial improvements seen in other infrastructure types.

National roads experienced a modest 23.8% decrease in the on-impact marginal product from €9.9 million to €7.6 million. This resulted in a drop from second to eighth place, suggesting a relative decline in their ability to generate immediate economic impacts compared to other infrastructure investments.

Telecommunications show the smallest improvement in immediate impact, with a 29.0% increase in on-impact marginal product from €5.1 million to €6.6 million. This relatively modest growth has moved telecommunications to the lowest rank in terms of short-term impact, indicating that other infrastructure types offer more substantial immediate economic benefits.

5.4. Infrastructure dynamics: Structural change and change in scarcity

Table 7 reveals significant shifts in the relationship between infrastructure investment and economic performance in Portugal. These changes stem from two key factors: evolving economic structures reflected in elasticity changes, and fluctuations in the relative scarcity of infrastructure stocks.

Table 7. Effects of structural changes and changers in scarcity.

	Change in marginal product: present/previous	**Change in elasticity: present/previous**	**Change in scarcity: present/previous**
Road transportation			
National road	1.18	**0.73**	1.62
Municipal road	*	*	*
Highway	3.05	2.00	1.52
Other transportation			
Railroad	1.20	**0.84**	1.43
Port	2.08	1.67	1.25
Airport	**0.84**	**0.63**	1.33
Social infrastructures			
Health	**0.94**	**0.79**	1.18
Education	1.31	1.28	1.02
Utilities			
Water	2.09	2.50	**0.84**
Electricity and gas	*	*	*
Petroleum	*	*	*
Telecommunications	**0.84**	**0.97**	**0.86**

Note: Values marked with * are not statistically significant, as implied by the standard deviation bands around the impulse response functions.

Road transportation infrastructure exhibits varied trends. National roads experienced a notable increase in scarcity, with a 62% rise offsetting a 27% decrease in elasticity. This results in an 18% increase in marginal product, suggesting that, while the economy's responsiveness to national road investments has diminished, their increased scarcity has bolstered their overall economic impact. Highways present a more robust picture, with increasing elasticity and scarcity. The doubling of elasticity coupled with a 52% rise in scarcity has led to a substantial 205% increase in marginal product, underscoring the growing importance of highways in Portugal's economy.

Other transportation shows mixed results. Railroads mirror the pattern seen on national roads, with a 43% increase in scarcity counterbalancing a 16% decrease in elasticity, resulting in a 20% increase in marginal product. This indicates that, despite reduced economic responsiveness, the scarcity of railroad infrastructure has enhanced its overall impact. Ports demonstrate strong positive trends in elasticity and scarcity, leading to a 108% increase in the marginal product. This finding suggests that ports have become increasingly crucial to the Portuguese economy. However, airports present a more complex picture. Despite a 33% increase in scarcity, a significant 37% decrease in elasticity results in a 16% decline in marginal product, indicating reduced economic responsiveness to airport investments.

Social infrastructure exhibits divergent trends. Health infrastructure has seen an 18% increase in scarcity; however, this is outweighed by a 21% decrease in elasticity, resulting in a 6% decline in marginal product. This suggests a de-linking of health infrastructure investment from overall economic performance. Conversely, educational infrastructure shows positive trends in both elasticity and scarcity, albeit with a stronger emphasis on elasticity. The 28% increase in elasticity and a modest 2% rise in scarcity have led to a 31% increase in marginal product, highlighting the growing economic importance of education infrastructure.

Utilities present some of the most striking results. The water infrastructure has experienced a remarkable 150% increase in elasticity, which has more than compensated for a 16% decrease in scarcity. This resulted in a 109% increase in the marginal product, indicating a significant enhancement in the economic importance of water infrastructure despite its relative abundance. Telecommunications, however, show negative trends in both elasticity and scarcity. The 3% decrease in elasticity and 14% decrease in scarcity have led to a 16% decline in the marginal product, suggesting that telecommunications infrastructure has become more abundant and less impactful on the economy.

These findings highlight the complex dynamics in Portugal's infrastructure policy. Infrastructure types, such as highways, ports, and water infrastructure, have seen strengthened links to macroeconomic performance and increased marginal products, marking them as potentially high-impact areas for future investment. Conversely, infrastructure types such as national roads, railroads, and airports show signs of delinking from macroeconomic performance despite increased scarcity in some cases. This suggests the need for careful reassessment of investment strategies in these areas.

Our analysis is grounded in a dynamic model of the economy utilizing an econometric approach that frames an economic understanding of the effects of public infrastructure on economic performance. This model conceptualizes the economy as employing a production technology based on capital, labor, and public infrastructure to generate output. Within this framework, the private sector determines input demand and output supply in response to market conditions and public infrastructure availability, whereas the public sector engages in infrastructure investment guided by a policy rule linking public infrastructure to economic variables.

The estimated VAR system can be interpreted as a dynamic reduced-form system for a production function and three input-demand functions: employment, private investment, and infrastructure investment (serving as a policy function). This comprehensive framework captures the multifaceted role of public infrastructure investment as a direct input to production, an indirect influence on output through its impact on labor and private capital demand, and as a production externality.

Our approach emphasizes the dynamic nature of the infrastructure-economy relationship at three distinct levels. First, it explicitly addresses contemporaneous relationships in the innovations of each variable. Second, it incorporates a dynamic intertemporal feedback structure among the variables. Third, it accommodates the potential existence of long-run equilibrium relationships among variables.

A critical aspect of this approach is its focus on identifying the effects of publicly financed infrastructure investments as externalities of private production. Consequently, as infrastructure investments that were previously public progressively transitioned to exclusive private ownership, they were no longer considered in our estimation of macroeconomic effects. The telecommunications sector is a prime example, where most infrastructure investments have now become strictly private.

The unique position of water infrastructure, with its strong positive structural effect despite its decreased scarcity, warrants particular attention. This indicates that investments in this sector may yield significant economic benefits, even in the face of a relative abundance. The telecommunications sector, showing negative trends in both structure and scarcity, presents a challenging case that may require a fundamental rethinking of investment approaches.

5.5. Shifting impacts: Front-loading of infrastructure investment effects

Table 8 reveals a significant change in how infrastructure investments affect the Portuguese economy. Our estimates using the updated dataset show that these investments now produce more substantial immediate effects but weaker long-term impacts than Pereira and Pereira (2018a).

Table 8. Changes in structural effects.

	Total change: present-previous	Over time: present-previous	On impact: present-previous
Road transportation			
National road	−0.012	0.016	−0.028
Municipal road	*	*	*
Highway	0.023	−0.002	0.025
Other transportation			
Railroad	−0.007	−0.038	0.031
Port	0.004	−0.007	0.011
Airport	−0.007	−0.014	0.007
Social infrastructures			
Health	−0.024	−0.041	0.017
Education	0.012	−0.035	0.047
Utilities			
Water	0.045	−0.011	0.056
Electricity and gas	*	*	*
Petroleum	*	*	*
Telecommunications	−0.002	−0.017	0.015

Note: Values marked with * are not statistically significant, as implied by the standard deviation bands around the impulse response functions.

Water infrastructure leads with the most significant positive total change (0.045) in structural effects, closely followed by highways (0.023). Conversely, health infrastructure shows the most significant negative shift (−0.024). However, these overall figures mask the nuanced story that emerges when we break down the changes into immediate and long-term effects.

The “On impact” column of **Table 8** displays mostly positive values, indicating more substantial immediate effects for all infrastructure types except national roads. Water infrastructure tops the list with a substantial increase of 0.056, followed by education (0.047) and railroads (0.031). This trend suggests that new infrastructure delivers a more significant economic boost right out of the gate.

In contrast, the "Over time" column presents largely negative values, indicating weaker long-term effects. Railroads experience the steepest decline (−0.038), followed by health (−0.041) and education (−0.035). Only national roads buck this trend, showing a modest positive change over time (0.016).

This pattern of more substantial immediate effects paired with weaker long-term impacts stands out among the top performing infrastructure types. Airports, ports, health facilities, highways, and water infrastructure follow this trend, highlighting a fundamental shift in how infrastructure investments shape economic outcomes. This is also true for the top five infrastructure investments in terms of their short-term marginal product.

Our findings reveal a crucial insight: infrastructure investments in Portugal boost economic indicators such as private investment, employment, and output. Although these increases are permanent and long-lasting, they do not significantly affect the growth rates of these variables. This distinction is important because it challenges the idea that infrastructure acts as an engine of self-sustaining economic growth.

Considering Portugal's experience, the country's average GDP growth rate has remained stubbornly stable despite substantial infrastructure investments, including significant funding from the EU Structural Funds. The disconnection between hefty investments and stagnant growth rates raises essential questions. Why have these infrastructure investments not translated into an accelerated economic expansion? What factors may limit their impact on long-term growth?

The puzzling relationship between infrastructure investment and economic growth in Portugal requires further investigation. Understanding these underlying causes could provide valuable insights for policymakers, potentially leading to more effective strategies for stimulating sustained economic development.

6. Summary, policy implications, and possible extensions

As Portugal shapes its post-austerity and post-pandemic economic strategies, renewed attention has been placed on infrastructure investments. Indeed, under the country's Recovery and Resilience Plan (PRR), part of the Next Generation EU program, a substantial amount of funds has been set aside for infrastructure development. Against this backdrop, this study uses updated data from 1980–2019 to reassess the impact of investments in twelve infrastructure types on the Portuguese economy and its public finances.

Our findings reveal significant changes since the Pereira and Pereira (2018a) study, offering policymakers valuable new insights. They underscore the need for a nuanced infrastructure-type-specific approach that considers both the changing economic impacts and their timing, as well as the evolving scarcity of different infrastructure types. These insights are particularly relevant, given Portugal's current infrastructure plans. Our findings emphasize the importance of using these resources wisely to support both rapid economic recovery and long-term sustainable increases in output. They also highlight the crucial need to complement infrastructure investments with policies that effectively boost economic growth.

6.1. Summary of results and policy implications

Our results and their policy implications can be summarized as follows.

First, the results reveal a clear differentiation among the long-term accumulated effects of the different infrastructure types. This hierarchy offers crucial insights for policymakers, favoring targeted investment strategies. We show that investing in airports, ports, health facilities, highways, and water systems yields the greatest long-term economic benefit. In turn, investments in railroads, education, telecommunications, and national roads, while still positively contributing to output, yield comparatively lower returns. These infrastructure types may need to be justified based on benefits beyond their direct effects on GDP, such as improved connectivity, human capital formation, and regional equity. The effects of the remaining infrastructure types—municipal roads, electricity, and refineries—are not statistically significant. Encouragingly, all infrastructure investments with statistically significant effects generate additional tax revenue over time to pay for themselves, supporting the financial soundness of such projects within Portugal's Recovery and Resilience Plan.

The impacts of highways and ports on long-term output can be vividly illustrated through recent major projects in Portugal. The A6 highway, connecting Marateca to Caia and completed in 2017, has facilitated the movement of goods and people, reducing logistics costs for businesses and enabling better integration of regional markets (Vicente, 2021). It is a vital part of the broader European route E90, which stretches all the way from Lisbon, Portugal, to Kaliningrad, Russia. Consequently, the regions along the A6 corridor have witnessed increased industrial activity, job creation, and new investments. Similarly, the expansion of the Port of Sines, one of Europe's largest Atlantic ports, has boosted Portugal's export competitiveness by increasing cargo-handling capacity and improving intermodal connectivity (Moreira, 2012). The modernized port has emerged as a significant logistics hub, attracting foreign investment across various sectors, from automotive to energy. These tangible examples underscore how strategic infrastructure investments in transportation can drive long-term economic growth and productivity gains.

Second, we find that a good part of the long-term effects of several infrastructure investments are front-loaded; that is, they occur in the short term or on impact. Stronger short-term effects occur with investment in railroads, ports, airports, and water infrastructure. These are the infrastructure investments policymakers should focus on for countercyclical purposes, in order to quickly and effectively stimulate the economy.

Front-loaded impacts have advantages, such as aligning short- and long-term goals through fast results without having to compromise, but this potential benefit is weighed against reduced impacts over time and limited growth rate effects. Differences among infrastructure types further complicate matters, with health facilities maintaining solid long-term effects, while education investments show negative impacts over time, perhaps due to contrasting local economic dynamics.

Third, the weakened effects over time suggest that infrastructure investments may not drive sustained economic growth as effectively as they did before. This necessitates a reevaluation of long-term investment strategies. Importantly, we find that infrastructure investments primarily influence economic levels rather than growth rates, challenging the notion that infrastructure is an engine of self-sustaining economic growth.

These findings, particularly relevant to Portugal's Recovery and Resilience Plan, suggest a need to balance leveraging short-term benefits with developing new approaches to foster long-term growth. Indeed, weaker long-term effects mean that policymakers need to broaden their approach. They must look beyond infrastructure and explore other strategies to boost long-term economic growth, such as education reforms, R&D investments, and policies to boost private sector productivity.

Fourth, comparisons with the previous results highlight significant changes in how infrastructure investments affect economic performance. This is an important change in how these investments affect the economy over time. Infrastructure investments now provide a stronger immediate boost, but weaker over time effects than we saw before. This shift marks a significant change from Pereira and Pereira (2018a). Their study highlighted how infrastructure investments could drive long-term performance; however, our new evidence points to a more complex picture.

Along the same lines, our research shows that national roads, highways, railroads, airports, and ports have become relatively scarcer over the last decade, which in most cases translates into larger long-term economic impacts. Addressing these areas should be a top priority for removing potential obstacles to economic growth. The analysis uncovered essential structural changes in the economy's responsiveness to different types of infrastructure. Some traditional infrastructure types, such as national roads and airports, exhibit signs of delinking from macroeconomic performance. This trend suggests that policymakers may need to reassess and potentially recalibrate their approaches to these types of infrastructure. Finally, highways, ports, and water infrastructure show the largest increases in marginal products compared with the previous estimates. This finding suggests that investments in these areas can yield significant economic benefits.

6.2. The relevance of this evidence for Portugal

Overall, our findings provide a clear roadmap for guiding prioritization, promoting the efficient use of public resources, and improving outcomes. Opportunities for innovation have emerged, such as the strong performance of water infrastructure, despite decreased scarcity, hinting at the potential for new development and management models.

The shift from the long-term growth focus to the more immediate economic boosts we see now highlights the need for flexible, forward-thinking policies. As Portugal moves past austerity and recovers from the pandemic, smart infrastructure investments play a key role. However, policymakers also face broader challenges. They must leverage the powerful short-term stimulus these investments provide while also developing new strategies to support long-term, sustainable growth.

While the results present a mix of opportunities and challenges, they ultimately strengthen the policymaker's position by providing a more precise roadmap for infrastructure development and by offering evidence-based guidance for prioritizing investments. This enhanced understanding of infrastructure dynamics can lead to more targeted, effective, and economically beneficial policy decisions. As Portugal continues to shape its infrastructure strategy, these findings offer a valuable compass, guiding policymakers towards choices that can maximize the economic impact and address critical needs in the face of changing economic realities.

The guidance that emerges from this study suggests that policymakers adopt a nuanced approach tailored to each infrastructure type, considering shifting economic impacts and changing scarcity. This informs decisions to maximize the economic impact while addressing critical needs in a changing landscape. Uncovering the structural changes in the responsiveness of the economy enables better strategy adaptation and intervention. Fine-tuning approaches are essential to match infrastructure investments with evolving economic needs. Some traditional types show signs of decoupling from macroeconomic performance, suggesting a need for reassessment and recalibration, while telecommunications presents a complex challenge that requires action as digital infrastructure grows in importance.

6.3. General relevance of the results

To conclude, although this study is primarily intended to be directly relevant to policymakers 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 being increasingly recognized. Indeed, in recent years, across international organizations such as the G20 (Bhattacharya et al., 2019), the World Bank (Hallegatte et al., 2019), the International Monetary Fund (IMF, 2020), the Organisation for Economic Co-operation and Development (OECD, 2024), the European Investment Bank (EIB, 2024), the European Union Council and the Commission (Letta, 2024), and the Asian Development Bank (ADB, 2017), there has been a renewal of interest in public investment and, in particular, in infrastructure investments.

Accordingly, while the numerical results are specific to Portugal, the broader implications resonate with economies facing similar post-crisis conditions of austerity, shrinking investment, and slow growth. Policymakers worldwide can relate to strong short-term stimuli contrasted with diminished long-term growth impacts, aligning with the need for rapid recovery tools after economic shocks. These weaker long-term effects highlight the global challenge of fostering sustained development across borders.

6.4. Directions for future research

Although our study offers valuable insights, it also points to areas for further research. Future studies could explore why long-term effects have weakened, look at the best mix of infrastructure investments to balance short- and long-term growth, examine how other policies might boost long-term impacts, analyze how infrastructure affects different regions, and study how infrastructure investments work together with other economic policies to drive growth.

This study highlights new research areas, including investigating the reasons behind weakening long-term effects, identifying optimal investment mixes for balanced growth, crafting policies to enhance long-term impacts, analyzing regional effects, and examining the interplay between investments and growth-accelerating policies.

6.5. Caveats

Our results project the long-term effects of current infrastructure investments, reflecting the synergies between these investments and economic conditions as well as the relative scarcity of various infrastructure types that are implicit in the 1980-2019 data. These findings are relevant for guiding current policy decisions. However, it is important to consider whether the relationship between infrastructure investments and their economic impact may evolve in the future.

The motivation behind updating our 2018 study stems from the expectation that significant events, such as financial crises or pandemics, or policy shifts, such as reduced public support for infrastructure investments, could alter the dynamics of the infrastructure investment effects. This underscores the importance of periodically reassessing and updating our analyses to capture changing economic realities.

Nevertheless, like any empirical approach, our analysis has limitations in capturing the effects of disruptive innovations in infrastructure technologies or entirely new infrastructure types. This shortcoming is particularly significant, given the growing need for innovative infrastructure investments, especially in areas related to energy generation, distribution, consumption, and environmental issues. As we focus on the historical patterns of infrastructure investment, our methodology may not fully account for the potential impact of groundbreaking advancements or novel infrastructure categories that could reshape the economic landscape.

In light of these considerations, policymakers and researchers should interpret our results as a valuable baseline to understand the current impact of infrastructure investments while remaining open to the possibility of future shifts in these relationships. Continued research and adaptive policymaking will be crucial in the years to come to address the challenges and opportunities presented by emerging technologies and evolving infrastructure needs.

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