

**INFRASTRUCTURE INVESTMENT, LABOR PRODUCTIVITY,
AND INTERNATIONAL COMPETITIVENESS:
THE CASE OF PORTUGAL***

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This study analyzes the effects of infrastructure investment on labor productivity at the industry level using a new data set for Portugal. We consider twenty-two sectors and twelve infrastructure assets. We focus on the differential effects on traded and non-traded sectors. We find, first, that investment in national roads have positive effects, particularly large for public services, while the effects of investments in municipal roads are mixed, and investments in highways have mostly benefited non-traded sectors. Second, we find that railroad investments, and, to a lesser extent, airports have gains clearly biased toward non-traded sectors, while the effects of port investments are more muted and mixed. Third, for social infrastructures, the effects tend to be large and again particularly favorable to non-traded sectors. Fourth, for public utilities the effects are in general small, with the exception of telecommunications, which have large positive effects mainly on non-traded sectors. We conclude that infrastructure investments have contributed to the growth of labor productivity but have done so in a way that has benefited mostly non-traded goods sectors. This may be a matter of concern for a small open economy in a currency union and with a development model greatly reliant on exports.

Keywords: Infrastructure Investment, Labor Productivity, Traded and non-Traded Sectors, VAR, Portugal

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1. INTRODUCTION

The importance of labor productivity improvements in creating a favorable

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investment environment and in fostering competitiveness is well understood. Similarly, it is also well known that the international competitiveness of a small open economy depends, in no small part, on differences in labor productivity growth between traded and non-traded goods sectors. This is particularly true for members of a currency union, such as the European Monetary Union, who are unable to devalue their currency to stimulate exports. It follows that no discussion of development strategies in countries such as Portugal, Ireland, Italy, Greece, and Spain can ignore the issue of how to improve labor productivity in general and, particularly, in the traded-goods sector, as a way to ultimately sustain improved standards of living (EU, 2014a, 2014b; IMF, 2013, 2014; OECD, 2013, 2014; and WEF, 2014a).

In the last three decades, in these same countries, notably in Portugal, infrastructure investment has played a pivotal role in the structural and cohesion policies designed to encourage convergence to EU standards of living. Thus, much of the economic growth and development strategies over this period were directly linked to infrastructure investments. Infrastructures are critically important for private sector growth, their availability increasing labor productivity directly as an externality, as well as indirectly through a more efficient use of private inputs.

This was, naturally, a reasonable strategy. Together with a stronger institutional framework, an extensive and efficient infrastructure network is considered a good macroeconomic environment. Furthermore, well-functioning health and education systems are also a key basic requirement for competitiveness (see, for example, WEF, 2014a). To some extent, this also seems to have been a successful strategy. According to the World Economic Forum Global Competitiveness Index (WEF, 2014a), Portugal ranks 36th in the world among 144 countries. Of the twelve comprehensive competitiveness pillars, including infrastructures, that are used to form this index, Portugal ranks the highest in the infrastructure pillar - 17th. If we consider the more detailed individual competitiveness indicators, Portugal ranks 12th on the overall quality of infrastructures and an impressive 2nd in the quality of the road network (as a reference point Portugal only ranks in the top ten in the world in nine of these almost one hundred and twenty individual competitiveness indicators).

Uncovering the empirical evidence on the link between infrastructure investments and labor productivity is therefore of crucial importance. Besides identifying the magnitude of the aggregate effects of infrastructure investments on labor productivity, there are important unanswered questions as to the effects of different types of infrastructure assets. More importantly, what is not known is the effect of these infrastructure investments on labor productivity in different industries, in particular as it relates to the traded/non-traded goods divide. And yet, this is a critical issue for a small open economy in its quest to improve global competitiveness. Aggregate improvements in labor productivity may be driven by larger effects in sectors which trade internationally, or be driven by industries that do not, or may be due to effects that are balanced across traded and non-traded industries.

These alternative situations have very different policy implications as they affect

international competitiveness in opposite ways. Are improvements in labor productivity coming mostly from traded goods sectors and thereby enhancing international competitiveness? In this case, improvements in standards of living are more sustainable and maybe even self-reinforcing. Or are labor productivity improvements occurring mostly in non-traded goods sectors? In this case, these gains may mask a potential loss in international competitiveness gains, and standards of living unlikely to be sustainable in the longer term.

The body of empirical literature on the economic effects of infrastructure investment is extensive (see, for example, Munnell, 1992; Gramlich, 1994; Romp and de Haan, 2007; and Pereira and Andr az, 2013; for literature surveys as well as the literature review in Kamps, 2005). Yet, the empirical evidence on the impact of infrastructure investments on the international competitiveness of the domestic economy - as implied by differential effects of infrastructure investments on labor productivity in traded and non-traded sectors - is surprisingly scant.

Although several studies for the US make reference to specific industries, essentially they have a regional focus (see, for example, Evans and Karras, 1994; Moomaw and Williams, 1991). The sectoral dimension is more directly relevant in the studies of Fernald (1993), Gokirmak (1995), Nadiri and Mamuneas (1994, 1996), Greenstein and Spillar (1995), Holleyman (1996), Pinnoi (1992), and Pereira and Andr az (2003). International evidence at the industry level is even more limited. It includes contributions such as Berndt and Hansson (1991) for Sweden, Seitz (1994), Seitz and Licht (1995) for Germany, Lynde and Richmond (1993) for the U.K., Shah (1992) for Mexico, and Pereira and Roca (2001) for Spain, and Pereira and Andr az (2007) for Portugal. It also includes contributions with a multi-country focus, such as Evans and Karras (1993). Rarely is the whole spectrum of economic activity considered as a frame of reference to understand the disaggregated nature of the aggregated effects of infrastructure investments. And, the issue of the effects of infrastructure investments on labor productivity at a disaggregated level is largely ignored.

In this paper, we address the issue of the industry-specific effects of infrastructure investments on labor productivity in Portugal with an eye on the differences between traded and non-traded goods sectors. From a methodological perspective, we use a multivariate dynamic time series approach, based on the use of industry-infrastructure specific vector autoregressive (VAR) models including industry output, employment, and private investment, in addition to different types of infrastructure investments. We consider investment in twelve infrastructure assets and twenty-two sectors spanning the whole spectrum of economic activity. This approach was developed in Pereira and Flores (1999) and Pereira (2000, 2001), and was subsequently applied to the US in Pereira and Andr az (2003, 2004), to Portugal in Pereira and Andr az (2005, 2007, 2011), and to Spain in Pereira and Roca-Sagales (2001, 2003, 2007). This econometric approach highlights the dynamic nature of the relationship between infrastructure investments and the economy.

Finally, it should be pointed out that although our approach is eminently empirical, it

is not atheoretical. Indeed, our analysis is grounded in a dynamic model of the economy which helps understand the effects of infrastructure investments on labor productivity. In this model, the economy uses a production technology based on the use of capital and labor, as well as infrastructure, to generate output. Given market conditions and the availability of infrastructures, private agents decide on the level of input demand and the supply of output. In turn, the public sector engages in infrastructure investment based on a policy rule that relates infrastructure to the evolution of the remaining economic variables. The estimated VAR system can be seen as a dynamic reduced form system for a production function and three input demand functions - for employment and private investment as well as infrastructure investment. This framework captures the direct role of infrastructures as inputs in production as well as the indirect role through their effect on the demand for the other inputs.

This paper is organized as follows. Section 2 presents both the infrastructure investment data and the economic data. Section 3 presents the econometric results including the VAR model specification and discusses the identification of exogenous shocks to infrastructure investment, as well as the measurement of their effects. Section 4 presents the empirical results on to the impact of infrastructure investments on labor productivity. Section 5 presents a summary, policy implications, and concluding remarks.

2. DATA SOURCES AND DESCRIPTION

2.1. The Infrastructure Investment Data Set

The data for infrastructure investment are from a new data set developed by Pereira and Pereira (2016) and covers the period between 1978 and 2011. Infrastructure investment is measured in millions of 2005 euros. We consider total infrastructure investment as well as investment in twelve individual types of infrastructures grouped in five main categories: road transportation infrastructure, other transportation infrastructure, social infrastructures, and utilities infrastructure. Table 1 presents some summary information for infrastructure investment effort, as a percent of GDP, as well as a percent of total infrastructure investment.

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

The largest component of road transportation investments for the sample period was national road investment, amounting to 0.61% of GDP and 12.21% of total infrastructure investment. What is most striking, however, is the substantial increase in investment in

highways since 2000. In the last decade, highway infrastructure investment amounted to 0.73% of GDP and surpassed national road infrastructure investment in importance, with highway investment amounting now to 11.70% of total infrastructure investment. In contrast, the past thirty years have seen a steady decline in municipal road infrastructure investments.

Table 1. Infrastructure Investment by Type of Asset

	1980-2011	1980-1989	1990-1999	2000-2009
Percent of GDP				
Infrastructure Investment	4.18	2.88	4.40	5.04
Road Transportation	1.19	0.74	1.32	1.52
National Roads	0.52	0.33	0.61	0.57
Municipal Roads	0.36	0.34	0.41	0.36
Highways	0.32	0.07	0.30	0.59
Other Transportation	0.38	0.22	0.47	0.46
Railroads	0.29	0.15	0.37	0.35
Ports	0.05	0.03	0.06	0.06
Airports	0.04	0.03	0.03	0.06
Social Infrastructures	0.96	0.81	1.08	1.02
Health Facilities	0.46	0.28	0.47	0.60
Educational Buildings	0.50	0.53	0.60	0.41
Utilities	1.65	1.11	1.53	2.04
Water Infrastructures	0.31	0.14	0.27	0.42
Petroleum Refining	0.16	0.09	0.18	0.15
Electricity and Gas	0.61	0.46	0.38	0.87
Telecommunications	0.57	0.41	0.70	0.61
Percentage of Total Infrastructure Investment				
Infrastructure Investment	100.00	100.00	100.00	100.00
Road Transportation	28.49	25.99	30.35	30.23
National Roads	12.46	11.52	14.09	11.43
Municipal Roads	9.16	11.90	9.47	7.10
Highways	6.86	2.56	6.79	11.70
Other Transportation	8.91	7.57	10.52	9.21
Railroads	6.64	5.17	8.31	6.92
Ports	1.21	1.23	1.40	1.08
Airports	1.06	1.17	0.81	1.21
Social Infrastructures	23.76	28.41	24.52	20.13
Health Facilities	10.82	9.89	10.73	11.97
Educational Buildings	12.94	18.52	13.79	8.16
Utilities	38.85	38.04	34.61	40.43
Water Infrastructures	6.99	4.90	5.98	8.17
Petroleum Refining	3.64	3.22	4.06	2.83
Electricity and Gas	14.44	15.97	8.45	17.53
Telecommunications	13.77	13.94	16.12	11.89

Other transportation infrastructures include railroads, airports and ports, and account for 9.0% of total infrastructure investment. These investments reached their greatest levels in the nineties with the modernization of the railroad network and port expansion projects, while the last ten years also saw substantial growth in investment in airports. In absolute terms, this reflects an increase from 0.22% of GDP in the 1980s to 0.48% in the last decade of the sample period.

Railroads represent the bulk, nearly 75%, of investment in other transportation infrastructures. Investment in railroad infrastructures amounted to 0.34% of GDP over the sample period, reaching 0.45% of GDP during the 1990s. Investment in ports and airports represented relatively smaller investment volumes due to the rather limited number of major airports and major ports in the country. Nonetheless, very substantial investments in the airports of Lisbon and Porto were undertaken in the last decade with investment volumes reaching 0.08% of GDP, nearly double that seen in the 1980s.

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

Investment in health facilities amounted to 0.55% of GDP or 10.7% of total investment while investment in educational facilities amounted to 0.60% of GDP or 13.1% of total investment. While both are comparable in terms of their relative magnitude over the sample period, their evolution was markedly different. Investment in health facilities increased steadily both as a percent of GDP and as a percent of total infrastructure investment, the opposite being the case in general terms for investment in educational buildings. Indeed, investment in educational facilities reached their highest level in the nineties with 0.73% of GDP while investment in health facilities reached its greatest volumes in the last decade with 0.75% of GDP.

Public utilities include electricity and gas infrastructures, water supply and treatment facilities, and petroleum refining plants, and account for 25.72% of total infrastructure investment in the sample period. Investment in public utilities reached a high level in the 1980s, driven by substantial investment in coal powered power plants and in refineries. More recently, investments in renewable energies and natural gas network have contributed to sustained growth in investment in utilities. In absolute terms, the importance of these investments increases from 0.94% of GDP in the eighties to 1.78% in the last decade.

Investment in electricity and gas infrastructures, the most important of the public utility assets in terms of the investment effort, averaged 0.73% of GDP or 14.34% of total infrastructure investment. In the 2000s, it reached 1.09% of GDP, and accounted for 17.53% of total infrastructure investment. In turn, water and waste water investments averaged 0.37% of GDP or 6.80% of total investment for the period with a clear increasing trend while investments in refineries averaged 0.22% of GDP or 4.58% of total investment with a declining trend over the last two decades.

Finally, investments in **telecommunications** amounted to 0.67% of GDP, or 13.34% of total investment over the sample period. In the nineties, with the expansion of mobile communications networks, they reached their peak with 0.85% of GDP, accounting for 16.12% of total infrastructure investments.

Overall, infrastructure investments grew substantially over the past thirty years, averaging 2.92% of the GDP in the 1980s, 4.45% in the 1990s and 5.17% over the last decade. The increase in infrastructure investment levels is particularly pronounced after 1986, the year in which Portugal joined the EU, and in the 1990s in the context of the EU Structural and Cohesion Funds, with the Community Support Framework I (1989-1993) and the Community Support Framework II (1994-1999). The investment effort decelerated substantially during the last decade during the Community Support Framework III (2000-2006) and the QREN (2007-2013). These landmark dates for joining the EU, as well as the start of the different community support frameworks, are all considered as potential candidates for structural breaks in every single step of the empirical analysis that follows.

2.2. The Industry Data Set

The data on industry-specific output, employment, and private investment are obtained from different annual issues of the National Accounts published by National Institute of Statistics and available on-line at <http://www.ine.pt>. Output and private investment are measured in millions of constant 2005 Euros, while employment is measured in thousands of employees.

We consider twenty-two industries divided in four main groups. The different sectors are grouped into two primary industries (agriculture and mining), seven manufacturing (food, textiles, paper, chemical and pharmaceutical, non-metallic minerals, metallic, and machinery), ten private services industries (electricity, water, construction, trade, transportation, hospitality, telecommunications, finance, real estate, and professional services) and three public services industries (administration, health and education). In Table 2 we include details on the definition of the different sectors.

We use the share of exports in the sector output over the last decade to identify the sectors producing internationally traded goods and those which do not. We define ten industries - the two primary industries, the seven manufacturing industries, and the transportation industry (S14) as comprising the traded goods sectors. The remaining nine private service industries, as well as the three public service industries are defined as non-traded. Here, however, we will find useful to identify five private service industries such as water (S11), hospitality (S15), telecommunications (S16), finance (S17) and professional services (S19) as comprising an emerging traded goods sector. In these industries, international trade plays a small but possibly increasing role.

Summary statistics on the industry mix during the sample period are provided in Table 3. The output share of the primary and the manufacturing sectors declined sharply over the sample period. The primary sector was 14.1% of output in the 1980s, and

declined to 3.4% in the last decade. The manufacturing sector, declined from 20.5% to 15.1%. Transportation declined in the 1990s but has somewhat rebound over the last decade.

Table 2. Industry Classification Grouped by Sector

Primary Sector - Agriculture	
Agriculture (S1)	Agriculture, forestry and fishing
Mining (S2)	Mining and quarrying
Secondary Sector - Manufacturing	
Food (S3)	Manufacture of food products, beverages and tobacco products
Textiles (S4)	Manufacture of textiles, wearing apparel and leather products
Paper (S5)	Manufacture of wood and paper products, and printing
Chemical and Pharmaceutical (S6)	Manufacture of chemicals and chemical products. Manufacturing of basic pharmaceutical products and pharmaceutical preparations.
Non-metallic minerals (S7)	Manufacture of rubber and plastics products, and other non-metallic mineral products
Basic metals (S8)	Manufacture of basic metals and fabricated metal products, except machinery and equipment
Machinery and equipment (S9)	Manufacture of computer, electronic and optical products; Manufacture of electrical equipment; Manufacture of machinery and equipment; Manufacture of transport equipment; Manufacture of furniture; other manufacturing; repair and installation of machinery and equipment
Tertiary Sector - Private Services	
Electricity and gas (S10)	Electricity, gas, steam and air-conditioning supply
Water (S11)	Water, sewerage, waste management and remediation activities
Construction (S12)	Construction
Wholesale and retail trade (S13)	Wholesale and retail trade, repair of motor vehicles and motorcycles
Transportation and storage (S14)	Transportation and storage
Hospitality (S15)	Accommodation and food service activities
Telecommunications (S17)	Telecommunications
Finance (S17)	Financial and insurance activities
Real estate (S18)	Real estate activities
Professional services (S19)	Publishing, audiovisual and broadcasting activities; Computer programming, consultancy and related activities; information service activities; Legal and accounting activities; activities of head offices; management consultancy activities; architecture and engineering activities; technical testing and analysis; Scientific research and development; Advertising and market research; other professional, scientific and technical activities; veterinary activities; Administrative and support service activities; Arts, entertainment and recreation; Other services activities
Tertiary Sector - Public Services	
Public administration (S20)	Public administration and defense; compulsory social security
Education (S21)	Education
Health (S22)	Human health services; Social work activities

Table 3. Share of GDP by Industry

	1978-2009	1980-1989	1990-1999	2000-2009
Agriculture	8.6	14.1	6.6	3.4
Agriculture (S1)	6.7	10.2	5.6	2.9
Mining (S2)	1.9	3.9	1.0	0.5
Manufacturing	18.1	20.5	18.5	15.1
Food (S3)	2.1	2.0	2.2	2.1
Textiles (S4)	3.7	4.2	4.2	2.7
Paper (S5)	2.2	2.4	2.2	1.8
Chemical and pharmaceutical (S6)	1.7	2.3	1.5	1.2
Non-metallic minerals (S7)	2.7	3.4	2.6	2.0
Basic metals (S8)	2.5	3.5	2.1	1.8
Machinery and equipment (S9)	3.3	2.7	3.7	3.7
Private Services	56.3	52.7	56.7	60.3
Electricity and gas (S10)	2.1	1.8	2.4	2.2
Water (S11)	0.6	0.5	0.6	0.9
Construction (S12)	7.1	6.8	7.0	7.7
Wholesale and retail trade (S13)	15.4	16.8	15.1	14.1
Transportation and storage (S14)	4.6	5.2	4.3	4.6
Hospitality (S15)	3.7	2.7	3.9	4.7
Telecommunications (S16)	1.9	1.4	2.0	2.3
Finance (S17)	6.3	6.3	6.1	6.6
Real estate (S18)	7.5	6.0	7.4	8.0
Professional services (S19)	7.2	5.2	7.8	9.1
Public Services	17.0	12.8	18.2	21.2
Public administration (S20)	8.5	7.2	8.9	9.9
Education (S21)	5.3	3.6	6.0	6.8
Health (S22)	3.2	2.0	3.3	4.5
Total	100.0	100.0	100.0	100.0

The industries producing traded goods overall declined from 39.8% of output in the 1980s to 23.1% in the last decade, a decline that would be more pronounced, were it not for the small increase in the relative role of transportation and storage services over the last two decades. Private services, net of transportation, increased slightly from 47.5% of output in the 1980s to 55.7% in the last decade, led by a large increase in the role of professional services. The large increase over the sample period was in public services, which rose from 12.8% in the 1980s to 21.2% in the last decade, a change due to large increases in each of its components.

Given the focus of this paper, we also want to consider some basic statistical information about the evolution of labor productivity, focusing on simple measures such as output per worker. The relevant figures are presented in Table 4. Overall, and for the economy as a whole, despite a rather sluggish development over the 1990s and 2000s, we see a clear improvement when we compare labor productivity in the 1980s, on one hand, with the 1990s and 2000s, on the other hand. For the primary sector, however, we see a sharp decline, while the improvements in manufacturing are in line with the

aggregate effects. Overall, labor productivity in the private services industries improved by around 20% in the 2000s, compared to the 1980s, while the largest improvement occurred in public services - 72.4% over the same reference frame.

Table 4. Output per Worker by Industry

	1978-2009	1980-1989	1990-1999	2000-2009
Total Economy	23.0	19.5	26.1	26.8
Agriculture	11.1	13.1	11.3	9.0
Agriculture (S1)	9.5	10.3	10.2	8.0
Mining (S2)	38.0	42.9	35.4	37.6
Manufacturing	19.1	16.0	20.5	22.4
Food (S3)	18.2	12.6	19.9	24.0
Textiles (S4)	11.4	9.2	13.2	13.0
Paper (S5)	22.1	19.0	23.8	25.6
Chemical and pharmaceutical (S6)	44.7	39.1	50.1	49.1
Non-metallic minerals (S7)	29.2	29.8	30.5	28.3
Basic metals (S8)	23.9	25.7	23.4	22.4
Machinery and equipment (S9)	18.4	11.3	21.0	24.9
Private Services	28.7	26.1	29.3	31.2
Electricity and gas (S10)	152.0	67.2	146.6	250.7
Water (S11)	18.9	8.5	19.1	31.3
Construction (S12)	15.4	12.6	16.7	18.0
Wholesale and retail trade (S13)	25.2	27.2	24.9	24.0
Transportation and storage (S14)	29.9	26.6	30.9	35.5
Hospitality (S15)	19.1	14.4	21.1	23.6
Telecommunications (S16)	116.2	54.9	123.1	189.9
Finance (S17)	63.4	49.2	59.2	85.1
Real estate (S18)	460.5	529.6	305.5	300.2
Professional services (S19)	21.3	23.3	20.3	21.2
Public Services	23.6	17.4	24.9	30.0
Public Administration (S20)	28.7	22.4	30.0	34.8
Education (S21)	21.3	14.8	23.1	27.8
Health (S22)	18.9	12.4	19.8	26.1

Let us consider, more specifically, the evolution for the industries on the two sides of the traded/non-traded divide. We observe that among the ten traded goods industries, agriculture (S1), mining (S2), non-metallic minerals (S7), and basic metals (S8) were the only four not showing progress over the sample period, the same being true for professional services (S19) among the five emerging traded goods industries. In turn, among the seven non-traded goods industries only trade (S13) and real estate (S18) did not show progress. It should be noted as well that the greatest gains in labor productivity seem to have occurred in non-traded sectors such as electricity and gas (S10), water (S11), telecommunications (S16), finance (S17), education (S21) and health (S22).

3. PRELIMINARY DATA ANALYSIS

Given the large number of tests and preliminary data analysis that have to be performed when considering three private-sector variables for each of twenty two industries as well as twelve different types of infrastructure investments, we have decided not to present the preliminary data analysis results in any detail and rather focus on a general discussion. These results are available from the authors upon request.

3.1. Unit Roots, Cointegration, and VAR Specification

We start by using the Augmented Dickey-Fuller t-tests to test the null hypothesis of a unit root in the different variables. We use the Bayesian Information Criterion (BIC) to determine the number of lagged differences, the deterministic components, and the dummies for the potential structural breaks to be included. We find that stationarity in first differences is a good approximation for all series under consideration. This evidence is consistent with the conventional wisdom in the macroeconomic literature that aggregate output, employment, and private investment are all $I(1)$. Although our series are more disaggregated, the same pattern of stationarity comes as no surprise.

We test for cointegration among output, employment, private investment, and infrastructure investment for each of the different infrastructure types. We use the standard Engle-Granger approach. We have chosen these procedures over the often used Johansen alternative for two reasons. First, since we do not have any priors that suggest the possible existence of more than one cointegrating relationship, the Johansen approach is not strictly necessary. More importantly, however, for smaller samples based on annual data, Johansen's tests are known to induce strong bias in favor of finding cointegration where, in fact, there is none (Gonzalo and Pitarakis, 1994). Again, we use the BIC to determine the number of lagged differences, the deterministic components, and dummies for the potential structural breaks to be included. As a general rule, our tests cannot reject the null hypothesis of no cointegration. This is consistent with the view that it is unlikely to find cointegration at a more disaggregated level when we fail to find cointegration at the aggregate level.

The absence of cointegration is neither surprising nor problematic and is, in fact, consistent with results in the relevant literature (see, for example, Pereira (2000) and Pereira and Andraz (2003) for the US case, Pereira and Roca (1999, 2001) for the Spanish case, and Pereira and Andraz (2005) and Pereira and Andraz (2007) for the Portuguese case). On one hand, it is not surprising to find lack of evidence for long-term equilibrium relationships for an economy that has a long way to go in its process of real convergence towards the level of its EU peers. This is so at a more aggregated level and even more so when we consider the data at the sector-specific level and its interaction with aggregate infrastructure investment variables. On the other hand, the absence of cointegration is not problematic as it only implies that a less simultaneous and dynamic approach based exclusively on OLS univariate estimates using these variables would

lead to spurious results. Specifically, the existence of cointegration means that two variables tend to a fixed ratio, meaning that in the long-term they grow in tandem. Absence of cointegration thus suggests that they do not grow at the same rate, that is, there are differentiated effects of infrastructure investments on the levels of each of the other variables.

Having determined that all of the variables are stationary in first differences and that there is no evidence of cointegration, we follow the standard procedure in the literature and determine the specifications of the VAR models using growth rates of the original variables.

The generic VAR model of order p can be written as:

$$z_t = a + \sum_{i=1}^p A_i z_{t-i} + e_t, \quad e_t \sim iid(0, \Sigma)$$

where z_t is a column vector (4x1) of observations on the current values of all variables in growth rates, a is a column vector (4x1) of deterministic components, and A_i are (4x4) square matrices of parameters. In turn, e_t is a column vector (4x1) of random errors with zero mean, time-independent variance, with zero autocorrelation, but assumed to be contemporaneously correlated with one another, such that their covariance matrix Σ , is not necessarily zero for $j \neq k$, that is:

$$\Sigma = E(e_t e_t') = \begin{bmatrix} \sigma_1^2 & \sigma_{12} & \sigma_{13} & \sigma_{14} \\ \sigma_{21} & \sigma_2^2 & \sigma_{23} & \sigma_{24} \\ \sigma_{31} & \sigma_{32} & \sigma_3^2 & \sigma_{34} \\ \sigma_{41} & \sigma_{42} & \sigma_{43} & \sigma_4^2 \end{bmatrix}.$$

We estimate twelve VAR models for each of the twenty-two industries, one for each of the different infrastructure types for a total of 264 different models. Each VAR model includes output, employment, and private investment in the sector as well as the relevant infrastructure investment variable. This means that, consistent with our conceptual arguments, the infrastructure investment variables are endogenous throughout the estimation procedure. We use the BIC to determine structural breaks and deterministic components, to be included. Our test results suggest that a VAR specification of first order with a constant and a trend, as well as structural breaks in 1989, 1994, and 2000 is the preferred choice in the overwhelming majority of the cases.

One important point to mention in terms of the VAR estimates is that the matrices of contemporaneous correlations between the estimated residuals, Σ , typically display a block diagonal pattern. Specifically, the contemporaneous correlations between innovations in infrastructure investment and the other variables tend to be substantially smaller, albeit significantly different from zero, than the correlations between the different pairs of innovations among the other variables. As a corollary, the effects of the

innovations in infrastructure investment are very robust to the orthogonalization mechanisms, a matter that we further discuss below.

3.2. Identifying Exogenous Innovations in Infrastructure Investment

While the infrastructure investment variables are endogenous in the context of the VAR models, the central issue in determining the economic impact of infrastructure investment is the identification of exogenous shocks to these variables. These exogenous shocks represent innovations in infrastructure investments that are not contaminated by other contemporaneous innovations and avoid contemporaneous reverse causation issues. This is a problem since the matrices of contemporaneous correlations between the estimated residuals Σ , are typically not triangular.

In dealing with this issue, we draw from the approach typically followed in the literature on the effects of monetary policy (Christiano, Eichenbaum and Evans, 1996, 1999; Rudebusch, 1998) and adopted by Pereira (2000) in the context of the analysis of the effects of infrastructure investment.

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

In the central case, we assume that the relevant information set for the policy function includes past but not current values of the economic variables. In the context of the standard Choleski decomposition, this is equivalent to assuming that innovations in investment lead innovations in economic variables. This means that, while innovations in infrastructure investment affect the economic variables contemporaneously, the reverse is not true. Specifically, the orthogonal innovations are obtained from original model by multiplying it by a triangular matrix H , with units on the main diagonal, that is $H'\Sigma H = I$, where I is a diagonal matrix and Σ is the covariance matrix of the error term ε_t . Vector ε_{t-i} is the vector of innovations, independent from each other; that is, a vector of impacts induced for particular variables (see Hamilton (1994) for discussion and a number of related results).

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

Furthermore, this assumption is also reasonable from a statistical perspective. This is so, for two main reasons. First, invariably, the policy functions point to the exogeneity of the innovations in infrastructure investment, i.e., the evolution of the different infrastructure investments does not seem to be affected by the lagged evolution of the remaining variables. This is to be expected because infrastructure investments were very much linked to EU support programs and, therefore, unresponsive to the ongoing economic conditions. Regardless, we would not expect any single industry, by its own, to have an impact on decision making for infrastructure investments at the national level. Second, and in a more technical vein, when we added to the policy functions contemporaneous values for the economic variables in addition to the lagged values, again, invariably, the estimated coefficients were not significant. This is consistent with the block diagonal patterns we found for the matrices of contemporaneous correlations among the estimated residuals.

3.3. Measuring the Effects of Innovations in Infrastructure Investment

We consider the effects of a one-percentage point, one-time shock in the rates of growth of the different types of infrastructure investment on industry-specific output, employment, and private investment. We expect these temporary shocks in the growth rates of infrastructure investment to have temporary effects on the growth rates of the other variables. They will, however, also have permanent effects on the levels of these variables. All of these effects are captured through the impulse response functions and accumulated impulse response functions associated with the estimated VAR models.

The accumulated impulse-response functions show the cumulative effects of shocks on infrastructure investments based on the historical record of thirty-five years of data, as filtered through the VAR and the reaction function estimates described above. Without exception, we observe that the accumulated impulse response functions converge within a relatively short time period suggesting that most of the growth rate effects occur within the first ten years after the shocks occur. Accordingly, we present the accumulated impulse response results for a twenty-year horizon.

The error bands surrounding the point estimates for the accumulated impulse responses convey uncertainty around estimation and are computed via bootstrapping methods. We consider 90% confidence intervals, although bands that correspond to a 68% posterior probability are the standard in the literature (Killian, 1998; Sims and Zha, 1999). Employing one standard deviation bands narrows the range of values that characterize the likelihood shape and only serves to reinforce and strengthen our results. Similarly, placing too great a weight on the intervals presented in evaluating significance is unwarranted in all but the most extreme cases. Thus, the bands presented are wider than the true coverage would suggest. From a practical perspective, when the 90% error bands for the accumulated impulse response functions include zero in a way that is not marginal (to allow for the difference between the 90% and 68% posterior probability), we consider the effects to be not significantly different from zero.

To measure the effects of infrastructure investments on labor productivity, we calculate the long-term elasticities of output and employment for each industry with respect to each type of infrastructure investment. The effects of infrastructure investment on labor productivity can be simply obtained from the values of the elasticities of output and employment, as the sign of the change in the output-to-labor ratio is the same as that of the difference between the elasticities of output and employment.

The elasticities of output and employment with respect to infrastructure investment are calculated as the total accumulated percentage-point long-term change in output or employment per one-percentage point accumulated long-term change in infrastructure investment. As such, our concept of elasticity departs from conventional definition because it is not based on *ceteris paribus* assumptions, but instead includes all the dynamic feedback effects among the different variables. Naturally, this is the relevant concept from the standpoint of policy making.

We present our estimates of the effects on labor productivity of infrastructure investments in each one of the twelve assets on each of the twenty-two industries in Tables 5-8. In addition, and to help check the consistency of the results across different levels of aggregation, as well as to frame the more disaggregated results, we also present the effects of each of the twelve infrastructure assets at the aggregate level and at the level of each of the four main sectors of activity that make up the twenty-two individual industries.

Given the scope of the analysis, we are dealing with three hundred and twenty-four different individual infrastructure-industry specific effects. Accordingly, it is useful to frame the results overall. The largest positive effects are from railroad investments on real estate (S18), 0.80, and the largest 10% of the effects range upwards from 0.15. In turn, the smallest impact is from national roads on water and wastewater (S11), -0.54, and the smallest 10% of the effects range downward from -0.10. In our upcoming discussion, we focus on the top 25% of the effects, meaning effects larger than 0.05 and the bottom 25% of the effects, that is, effects that are smaller than -0.03.

4. ON THE EFFECTS OF INFRASTRUCTURE INVESTMENTS ON LABOR PRODUCTIVITY

4.1. Preliminary Conceptual Remarks

To help frame the effects of infrastructure investments on labor productivity, it is useful to understand the different mechanisms through which these investments and the related assets affect economic performance. In general terms, infrastructures either fall in the public goods category or are considered production externalities - i.e., they provide services that, although being necessary for private sector activity, would not be available or would be in short supply if totally left to the initiative of the private sector. As such, their provision is either public or done through close public tutelage. For some

assets, such as public utilities and telecommunications, technological advances and the evolution of the domestic and international markets has led to a fully private provision.

In this context, we can see infrastructure investments and the assets they generate affecting economic activity through different channels, each with rather different impact on what one would expect in terms of the industry-specific incidence of the effects. First, there is what we could call a “functional channel”. Infrastructures fulfill a role as production inputs, directly relevant for the activity in question. Transportation services for example, need a good road or other transportation network, while industries that are either more labor intensive or rely more on skilled labor, such as finance, telecommunications or professional services, will have their productivity affected directly by the network of social infrastructures. This is, therefore, essentially a supply side channel. The ultimate effects on labor productivity are going to depend on the direct relevance of the infrastructure as an additional input to production as well as on the nature of the relationship between infrastructure and private inputs - labor and private capital.

While the functional channel is the most recognized - and, often, the only recognized channel - it is neither the only channel, nor necessarily the most important one. A second channel is what we could call the “construction channel”. These investment projects inevitably use vast pools of resources, engaging the rest of the economy in the process itself of constructing these assets. Making available a road, or a port, a hospital or a waste management facility, directly engages the construction industry and, through it, the rest of the economy. These are demand-side effects on output and employment that, although reverberating throughout the economy, are expected to be short-lived.

A third channel through which infrastructures affect economic performance is the “operation and maintenance channel”. Operating and maintaining existing infrastructures creates needs for use of resources - goods and services, as well as specialized labor. While the effects of the economic effort involved in operation and maintenance of a road infrastructures, for example, could easily be neglected, the same cannot be said about operating and maintaining a port, an airport, a hospital or even a school. This is also a demand side effect but, unlike the previous one, it is more long lasting.

Finally, there is what we could call a “site location channel”. The existence of certain infrastructures, such as certain transportation infrastructures, schools, and hospitals, serve as an attractor for population and business. There should follow important effects, for example, for trade and real estate. Naturally, the opposite is true for airports, waste and wastewater facilities or power plants and refineries which have a negative effect on the desirability of where they are located.

Considering these different channels is important to understand industry incidence of the effects of infrastructure investments on labor productivity. The reverse is also true. The type of industry-specific effects we estimate offer a glimpse into what channels seem to be the most important for each infrastructure asset.

4.2. The Effects of Investments in Road Transportation Infrastructures

The effects of investments in road transportation infrastructures on labor productivity are reported in Table 5. At the most aggregate level, the effects of investments in different road infrastructure assets are actually quite different, as we see a large effect from national road investment, 0.0484, a negative effect from municipal roads, -0.0119, and a moderate effect from highway investment, 0.0138. When we consider the effects on the four main sectors of economic activity, we see that national roads have had meaningful positive effects across all sectors, particularly large for public services, while the effects of investments in municipal roads are mixed, particularly detrimental for the primary sector, and investments in highways have mostly benefited private and public services.

Table 5. Effects on Labor Productivity by Industry: Road Transportation

	Elasticity of Labor Productivity		
	National Roads	Municipal Roads	Highways
Total Economy	0.0484	-0.0119	0.0138
Agriculture and Mining	0.0410	-0.1190	-0.0161*
Agriculture (S1)	0.1389	-0.1460	-0.0037*
Mining (S2)	-0.1728*	-0.0150*	-0.0662
Manufacturing	0.0685	0.0245	0.0028*
Food (S3)	0.0966	0.1172	0.0027*
Textiles (S4)	0.1457	0.0493	-0.0039*
Paper (S5)	0.1080*	-0.1645	0.0287
Chemical and pharmaceutical (S6)	-0.0468*	-0.1989	-0.0089*
Non-metallic minerals (S7)	0.2129	0.0569	0.0188
Basic metals (S8)	-0.0805*	0.0929*	-0.0029*
Machinery and equipment (S9)	0.2754	-0.0639*	0.0320
Private Services	0.0477	0.0129	0.0203
Electricity and gas (S10)	-0.3935	0.0146*	0.0175*
Water (S11)	-0.5398	-0.0061*	0.0206*
Construction (S12)	0.3192	-0.0151*	0.0379
Wholesale and retail trade (S13)	0.0309*	0.0712	-0.0075
Transportation and storage (S14)	0.0506*	0.0366	-0.0114*
Hospitality (S15)	0.0107*	0.1443	-0.0020*
Telecommunications (S16)	-0.0192*	-0.0683	0.0033*
Finance (S17)	-0.0561*	0.1056*	0.0562
Real estate (S18)	0.5367	-0.1123*	0.1825
Professional services (S19)	-0.1128	-0.0499*	-0.0200
Public Services	0.1853	-0.0086*	0.0260
Public administration (S20)	0.0769*	-0.0103*	0.0177
Education (S21)	0.2711	-0.0267*	0.0393
Health (S22)	0.1507	0.0322*	0.0260

Note: The estimates marked with asterisk are not significantly different from zero as implied by the standard deviation bands around the difference between the accumulated impulse response functions for output and employment.

When considering the effects of investments in **national roads** we see large effects on non-metallic minerals (S7) and machinery (S9), and moderate effects on agriculture (S1), food (S3), and textiles (S4). For the remaining traded sectors, the effects are not significantly different from zero. As to the non-traded goods sectors, we see large positive effects on construction (S12), real estate (S18), education (S21), and health (S22). In turn, negative effects are estimated for electricity (S10), water (S11), and professional services (S19). The remaining five effects are not statistically significant.

In terms of **municipal roads**, this type of infrastructure investment has moderately positive effects on labor productivity on food (S3), textiles (S4), and non-metallic minerals (S7), among the traded goods, and trade (S13) and hospitality (S15), among the non-traded ones. In turn, they have large negative effects for agriculture (S1), paper (S5) and chemical (S6), among traded sectors and for telecommunications (S16), among non-traded. In addition, three of the effects on the ten traded sectors and nine of the twelve traded goods sectors are not statistically different from zero.

For **highway infrastructure** investment, most of the effects are small, with effects not statistically significant for six of the ten traded goods industries and four of the twelve non-traded industries. We see a moderate negative effect on labor productivity on mining (S2) and, on the flip side, a moderate positive effect on finance (S17), and a large positive effect on real estate (S18).

Overall, there are significant benefits for both traded and non-traded goods sectors from investments in road transportation, in particular national roads, with more pervasive gains for food (S3), textiles (S4), and non-metallic minerals (S7) among the traded sectors, and real estate (S18) among the non-traded sectors. On the negative side one could highlight the effects on mining (S2).

4.3. The Effects of Investments in Other Transportation Infrastructures

The effects of investments in other transportation infrastructures on labor productivity are reported in Table 6. At the aggregate level, the most important effects come from railroad infrastructure investment, 0.0271, the effects of infrastructure investment in airports being more moderate, 0.0118, and the effects from port investments being statistically zero. When we consider the four main industry aggregates, we see that railroad investments and, to a lesser extent, airports have labor productivity gains that are clearly biased toward the private and public services, while the effects of port investment are more muted and mixed.

In terms of investments in **railroad infrastructure**, and in a more disaggregated setting, we find significant effects for four of the traded goods industries and eight of the non-traded. We see large positive effects for electricity (S10), water (S11), and real estate (S18) and moderate positive effects for construction (S12), trade (S13), public administration (S20), and education (S21). These are non-traded good industries. In turn, we identified negative effects for agriculture (S1), paper (S5), and machinery (S9). All of these belong to the traded goods sector. We also find moderate negative effect for the

non-traded industry of professional services (S19). Overall, railroad infrastructure investment affects labor productivity positively, in a strong or moderate manner, in 7 of 12 non-traded industries and affects labor productivity negatively, in a strong or moderate manner, in 3 of the 10 traded industries. Railroad investments have decisively favored non-traded industries.

Table 6. Effects on Labor Productivity by Industry: Other Transportation

	Elasticity of Labor Productivity		
	Railroads	Airports	Ports
Total Economy	0.0271	0.0118	-0.0020*
Agriculture and Mining	-0.0798	-0.0146*	0.0026*
Agriculture (S1)	-0.0635	0.0047*	-0.0011*
Mining (S2)	-0.0976*	-0.0725*	-0.0296*
Manufacturing	-0.0328	-0.0005*	0.0103
Food (S3)	0.0355	0.0247	0.0245
Textiles (S4)	-0.0275*	-0.0038*	0.0134
Paper (S5)	-0.1108	-0.0424	0.0252
Chemical and pharmaceutical (S6)	-0.0731*	0.0079*	-0.0271
Non-metallic minerals (S7)	-0.0319*	0.0061*	0.0148
Basic metals (S8)	-0.0223*	-0.0003*	0.0205
Machinery and equipment (S9)	-0.1209	0.0103*	-0.0049*
Private Services	0.0437	0.0131	-0.0014*
Electricity and gas (S10)	0.2421	0.1652	-0.0312*
Water (S11)	0.2260	0.1405	-0.0356*
Construction (S12)	0.0955	0.0069*	-0.0148*
Wholesale and retail trade (S13)	0.0557	0.0071*	-0.0045
Transportation and storage (S14)	-0.0476*	-0.0461	0.0124
Hospitality (S15)	0.0118*	0.0248	0.0262
Telecommunications (S16)	0.0215*	-0.0184*	-0.0088*
Finance (S17)	0.0495*	0.0360*	0.0278
Real estate (S18)	0.7975	-0.0446*	0.0183*
Professional services (S19)	-0.0920	-0.0284*	0.0032*
Public Services	0.0486	0.0276	0.0088*
Public administration (S20)	0.0489	-0.0029*	0.0009*
Education (S21)	0.0509	0.0431	0.0025*
Health (S22)	0.0321*	0.0211*	0.0083*

Note: The estimates marked with asterisk are not significantly different from zero as implied by the standard deviation bands around the difference between the accumulated impulse response functions for output and employment.

For investments in **airport infrastructures**, we find that most effects are small, and fifteen of the twenty-two not statistically significant. There are, however, large positive effects on electricity (S10) and water (S11). In turn, we find moderate negative effects for paper (S5) and transportation (S14) which are traded industries. Overall, in relative terms, we again seem to have a pattern of investments in airport infrastructures leading mostly to labor productivity gains in non-traded goods.

Finally, for port infrastructure investments we also find that most effects on labor productivity are very small even when significant, again with twelve of the twenty-two effects not statistically different from zero. As such, investments in ports do not seem to have played a major role in the evolution of the labor productivity. We find small positive effects for food (S3), paper (S5), and basic metals (S8) as well as hospitality (S15) and finance (S17) and small negative effects for chemicals (S6).

Overall, we find that the bulk of the effects of investments in other transportation infrastructures go to non-traded goods industries, with railroad investment playing a greater role than investments in ports or airports.

4.4. The Effects of Investments in Social Infrastructures

The effects of investments in social infrastructures on labor productivity are reported in Table 7. At the most aggregate level, health infrastructure investments have a large effect on labor productivity, 0.0408, while the effects of investment in education infrastructures are more moderate, 0.0159. At a more disaggregated level, for health infrastructure investments, we found a large positive aggregate effect which was particularly large for private services, and significant for manufacturing. Education infrastructure investment, has a large negative effect on the primary sector, and large positive effects on services, in particular public services.

In terms of the effects of **health infrastructures** at a more disaggregated level, among the traded industries, we find large positive effects on labor productivity for mining (S2), transportation (S14) and moderate on paper (S5), non-metallic minerals (S7) and machinery (S9). In addition, we find moderately negative effects for chemicals (S6). For traded goods, only four of the ten industries show effects that are not statistically significant. In turn, for the non-traded goods industries we find large positive effects for construction (S12) and real estate (S18), and actually a large negative effect for electricity (S10) and water (S11). The remaining eight effects are not significant.

At the fully disaggregated level, we find that **education infrastructure** investments strongly affect construction (S12), finance (S17) and education (S21), and moderately professional services (S19), public administration (S20), and health (S22). Overall, six of the twelve non-traded goods industries show a clear gain in labor productivity, while the effects on the remaining six sectors are not statistically significant. In terms of the traded goods industries, large improvements occur in non-metallic minerals (S7), machinery (S9), and more moderate on food (S3), paper (S5), and transportation (S14), while moderate negative effects ensue to textiles (S4), and basic metals (S8) and large

negative effects for agriculture (S1) and mining (S2), and chemicals (S6).

Table 7. Effects on Labor Productivity by Industry: Social Infrastructures

	Elasticity of Labor Productivity	
	Health	Education
Total Economy	0.0408	0.0159
Agriculture and Mining	0.0183*	-0.1339
Agriculture (S1)	-0.0194*	-0.1707
Mining (S2)	0.1881	-0.3516
Manufacturing	0.0202	0.0217
Food (S3)	-0.0395*	0.0533
Textiles (S4)	-0.0142*	-0.0928
Paper (S5)	0.0693	0.0980
Chemical and pharmaceutical (S6)	-0.0964	-0.1785
Non-metallic minerals (S7)	0.0884	0.1021
Basic metals (S8)	-0.0078*	-0.0844
Machinery and equipment (S9)	0.1319	0.1596
Private Services	0.0994	0.0593
Electricity and gas (S10)	-0.2341	-0.1789*
Water (S11)	-0.2422	-0.0570*
Construction (S12)	0.1703	0.1419
Wholesale and retail trade (S13)	0.0067*	0.0036*
Transportation and storage (S14)	0.1888	0.0777
Hospitality (S15)	0.0197*	0.0725*
Telecommunications (S16)	0.0140*	-0.0114*
Finance (S17)	0.0555*	0.2021
Real estate (S18)	0.2019	0.2523*
Professional services (S19)	-0.0067*	0.0785
Public Services	-0.0169*	0.1413
Public administration (S20)	0.0047*	0.1278
Education (S21)	-0.0145*	0.1437
Health (S22)	0.0140*	0.1351

Note: The estimates marked with asterisk are not significantly different from zero as implied by the standard deviation bands around the difference between the accumulated impulse response functions for output and employment.

Overall, health infrastructure investments seem to have improved labor productivity for both traded and non-traded industries, without clearly affecting the balance between the two. In turn, given the nature of the effects and the relative size of the different sectors, it is clear that investments in education infrastructures, while affecting positively both traded and non-traded sectors, have benefited most labor productivity in non-traded goods sectors.

4.5. The Effects of Investments in Public Utilities and Telecommunications

The effects on labor productivity of investments in public utilities and in telecommunications are reported in Table 8. At the aggregate level, we estimate a moderate effect from investments in water and wastewater, 0.0115, while the effects from investments in refineries and electricity and gas are negligible. The effects of investments in telecommunications however are positive and large. Across the four main sectors of economic activity, the effects of public utilities tend also to be small, with sizable negative effects of water on public services and small positive effects of electricity in manufacturing and refinery in public services. For telecommunications, however, we estimate very substantial effects for private and public services.

Table 8. Effects on Labor Productivity by Industry: Public Utilities

	Elasticity of Labor Productivity			
	Water	Electricity	Refineries	Telecom.
Total Economy	0.0115	-0.0033*	0.0029*	0.0461
Agriculture and Mining	-0.0162*	-0.0017*	-0.0034*	-0.0139*
Agriculture (S1)	-0.0483	-0.0166	-0.0020*	-0.0008*
Mining (S2)	0.1056	-0.0032*	-0.0156*	-0.1048*
Manufacturing	0.0046*	0.0114	0.0020*	0.0092*
Food (S3)	0.0294	-0.0203	0.0029*	0.0121*
Textiles (S4)	0.0144*	-0.0080*	-0.0013*	-0.0423*
Paper (S5)	-0.0564	0.0180	0.0147	0.0549*
Chemical and pharmaceutical (S6)	-0.0532	-0.0294	-0.0207	-0.0472*
Non-metallic minerals (S7)	0.0163*	-0.0067*	-0.0006*	0.0362
Basic metals (S8)	0.0115*	0.0219	0.0064*	0.1025
Machinery and equipment (S9)	-0.1272	-0.0017*	-0.0049*	-0.0005*
Private Services	-0.0008*	-0.0057*	0.0044*	0.0759
Electricity and gas (S10)	-0.0493*	-0.0338	-0.0372	0.0599*
Water (S11)	-0.0421*	-0.0192*	-0.0097*	0.0937*
Construction (S12)	-0.0193*	-0.0120*	0.0097*	0.0880
Wholesale and retail trade (S13)	0.0297	-0.0038*	0.0032*	0.0187*
Transportation and storage (S14)	0.0232	-0.0129	-0.0051*	-0.0136*
Hospitality (S15)	0.0626	-0.0038*	0.0011*	0.0247*
Telecommunications (S16)	-0.0157*	-0.0029*	0.0016*	-0.0400*
Finance (S17)	0.0493*	-0.0421	0.0117	0.2326
Real estate (S18)	-0.1724	-0.0756*	0.0050*	0.3854
Professional services (S19)	-0.0291*	0.0702	0.0126	-0.0397*
Public Services	-0.0313	-0.0047*	0.0106	0.0540
Public administration (S20)	-0.0225	-0.0035*	0.0128	0.0771
Education (S21)	-0.0203	-0.0130*	0.0096*	0.0495
Health (S22)	-0.0099*	0.0023*	0.0078*	0.0042*

Note: The estimates marked with asterisk are not significantly different from zero as implied by the standard deviation bands around the difference between the accumulated impulse response functions for output and employment.

Investments in **water and wastewater infrastructure** are a mixed bag when it comes to the effects on traded versus non-trade industries. Moderate positive effects occur in mining (S2), and hospitality (S15). In turn, agriculture (S1), paper (S5), and chemicals (S6) have moderate negative effects while machinery (S9), a traded industry and real estate (S18) a non-traded one have large negative effects.

Electricity and gas infrastructure investments have in general small effects on labor productivity, with only nine of the twenty-two effects statistically significant. The exceptions are moderate positive effects on professional services (S19) and moderate negative effects on electricity (S10) and finance (S17).

The effects of investments on **refinery infrastructures** are also overwhelmingly small at the most disaggregate level and mostly non-significant - only six of the twenty-two effects are statistically different from zero. The only exception is a moderate negative effect on electricity (S10). In general, however, and despite their small magnitude, most of the positive effects are on non-traded industries.

Finally, for **telecommunication infrastructures**, we identified very large positive effects with special incidence on the non-traded industries. Indeed, among the non-traded industries, we observe very large positive effects on finance (S17) and real estate (S18) and moderate positive effects on construction (S12), public administration (S20) and education (S21). The remaining seven effects are not statistically significant. In turn, for the traded industries we observe moderate positive effects for basic metals (S8) and small for non-metallic minerals (S7), the remaining eight effects being statistically null. Overall the pattern on greater positive influence on the non-traded industries is clear.

4.6. The Effects on Labor Productivity from an Industry Perspective

We can also summarize the effects of the different investments in infrastructure assets at the sector level from an industry perspective. It is just another way of looking at the info in Tables 5-8.

For the **primary sector**, industries producing traded goods, there are very few positive effects on labor productivity from infrastructure investments, most noticeably national roads on agriculture (S1) and health and water on mining (S2). The negative effects are much more prevalent and sizable the largest being from municipal roads and education on agriculture (S1) and education for mining (S2). It can be ascertained that infrastructure investments have played a role in the decline of labor productivity in the primary sector.

As to the **manufacturing sector**, which are all producers of traded goods, we find in general positive effects from national road investments [food (S3), textiles (S4), non-metallic minerals (S7), and machinery (S9)], from municipal roads [food (S3), textiles (S4), and non-metallic minerals (S7)], from health [paper (S5), non-metallic minerals (S7), and machinery (S9)], education [food (S3), paper (S5), non-metallic minerals (S7), and machinery (S9)], and telecommunications [basic metals (S8)].

Interestingly only chemicals (S6) does not seem to benefit from investments in any infrastructure assets in terms of improvements in labor productivity, and this despite the important gains present in the data. On the negative side, meaningful effects can also be observed from municipal roads [paper (S5) and chemicals (S6)], from railroads [paper (S5) and machinery (S9)], health [chemicals (S6)], education [textiles (S4), chemicals (S6), and basic metals (S8)], and water [paper (S5), chemicals (S6), and machinery (S9)].

The **private services** sector, which except for transportation (S14) comprises non-traded industries, benefits from investments in national roads [construction (S12) and real estate (S18)], municipal roads [trade (S13), transportation (S14), and hospitality (S15)], railroads [electricity (S10), water (S11), construction (S12), trade (S13), and real estate (S18)], airports [electricity and gas (S10) and Water (S11)], health [construction (S12), transportation (S14), and real estate (S18)], education [construction (S12), transportation (S14), and finance (S17)], and telecommunications [construction (S12), finance (S17), and real estate (S18)].

It should be noted that trade (S13) and real estate (S18) seem to greatly benefit in terms of labor productivity improvements induced by infrastructure investments despite the fact that productivity was either stagnant over the sample period – in trade, or actually saw a sharp decline - as in real estate. The only industries that do not seem to benefit from any type of infrastructure investments is telecommunications (S16), which actually saw a substantial increase in labor productivity over the sample period, closely followed by professional services (S19), an industry where labor productivity was stagnant. In turn, electricity (S10) and water (S11) show sizable labor productivity losses induced by investments in national roads and health. This despite the fact they actually show a substantial overall improvement in labor productivity over the sample period.

Finally, the **public services** sector producing non-traded goods, benefits from moderate or large effects on labor productivity from investments in national roads [education (S21), and health (S22)], railroads [public administration (S20) and education (S21)], education [public administration (S20), education (S21), and health (S22)], and telecommunications [public administration (S20) and education (S21)]. As such, overall infrastructure investments in all major types of infrastructure assets, including telecommunications but excluding the other public utilities, have a positive effect on labor productivity in the sector.

As a final remark, the fact that a sector sees an evolution in labor productivity in the sample period that goes in the opposite direction of the effects we identify here from infrastructure investments poses no more a contradiction or a puzzle than the fact that the country has a top ranking infrastructure and yet the overall performance in terms of international competitiveness is much less stellar. Besides infrastructure investments, many other factors affect the productivity of each individual industry. Therefore, the actual effects of infrastructure investments we have teased out are hidden under a myriad of other factors (to recall, the World Economic Forum used one hundred-and-twenty-four individual factors affecting productivity, only nine of which

are somewhat related to infrastructures). Naturally, we do not claim that infrastructure investments are the only or even the main driver of labor productivity gains.

5. SUMMARY AND CONCLUDING REMARKS

In this paper our aim is to identify the empirical effects of infrastructure investments in Portugal on labor productivity at the industry level. We want to identify the effects as they relate to the divide between the effects on traded and non-traded sectors and, as such, on the evolution of international competitiveness and the long-term prospects of the domestic economy to achieve improvements in standards of living.

Our main conclusions can be summarized as follows. We find, first, that investments in national roads have positive effects, particularly large for public services, while the effects of investments in municipal roads are mixed, and investments in highways have mostly benefited the non-traded sectors. Second, we find that railroad investments and, to a lesser extent, airports have clearly biased labor productivity gains toward the non-traded sectors, while the effects of port investment are more muted and mixed. Third, for social infrastructure investments, the effects tend to be large and again particularly favorable to the non-traded sector. Fourth, for public utilities, the effects are in general small, with the exception of investments in telecommunications which have large positive effects mainly on the non-traded sector.

From an industry perspective, the traded goods industries benefit in some cases, but never very strongly. Pretty much across the board, infrastructure investment has led to a decline in labor productivity for the primary industries, while the manufacturing industries have somewhat benefited from investment in road infrastructure and social infrastructures, and have either negative or small effects from the remaining three main types of infrastructure assets. Private services and public services sectors, which are mostly non-traded industries, benefit from large effects from investments in road infrastructure, other infrastructure, social infrastructure, and telecommunications. Only public utilities seem to have a marginal impact on the labor productivity of these industries.

There are several important policy implications of these results. First, from a retrospective standpoint, these results help to understand how the patterns of infrastructure development over the last few decades have affected labor productivity, in general, and international competitiveness, as measured by the differential effects on traded and non-traded goods sectors. The last three decades saw substantial renewal of the investment efforts in national roads, highways, railroads, health, electricity and gas, telecommunications and, to a lesser extent, water and wastewater infrastructure. We have found that national roads had a widespread large positive impact on labor productivity, in particular for public services, while highway, railroad, health and telecommunication investments decisively biased labor productivity gains in favor of the non-traded goods industries. Finally, the impact of water and wastewater and electricity

and gas are much more subdued and with overall effects less discernible. All in all, infrastructure investments seem to have reduced any competitive edge the traded sector might have had in terms of differentials in labor productivity vis-à-vis the traded good sector. Naturally, this is not meant to imply that infrastructure investments are the only or even the most important factor behind the observed changes, but instead it serves to argue that infrastructure investments seem to have played a role in those shifts.

Second, from a prospective standpoint, there is the issue of what can be expected from the infrastructure investments that are currently being considered for the future. It would seem that the great focus for the next few decades will be on non-road transportation, in particular railroad and ports, and social infrastructure, which includes health and education facilities. Indeed, the time has passed for any focus on road infrastructure, which is now widely perceived as having already achieved a high level of maturity - the Portuguese road infrastructure network is ranked second in the world by the Global Competitive Report (WEF, 2014b). In addition, investments in public utilities are now mostly in the hands of the private sector, and therefore less directly affected by economic policy. As per our results, investments in railroad, health and education facilities will all have a strong bias towards greater labor productivity gains in non-traded goods industries. The effects of investments in ports and airports will be less significant and in the case of ports more evenly distributed.

Equally, from a prospective standpoint, there is the issue of the effects of these infrastructure investments on the labor productivity of industries that are increasingly viewed as emerging traded-industries, sectors which have traditionally been non-traded but which are showing signs of increased international competition. These are the cases of the private services industries such as telecommunications, and professional services and, to a lesser extent, hospitality and finance. We want to consider for these industries the effects of future infrastructure investments on railroads, ports, health and education, as currently being considered. Our results suggest that, the water sector is poised to see improvements in labor productivity from railroad investments but losses from the remaining three; labor productivity in the telecommunications will be essentially unaffected by these all of these investments, while labor productivity in professional services will be negatively affected by railroad and airports but positively by education. In turn, labor productivity in hospitality services will be positively affected but only by education while in the financial services will be affect positively by all in particular education. Overall, investments in railroads and in particular education are the most likely to benefit these increasingly internationalized industries.

The results in this paper open the door to several important research avenues. An important next step would be to advance towards the fiscal multiplier literature and to explore how nonlinearities may affect the effects of infrastructure investments. In particular, it would be interesting to consider the issue of regime switching, i.e., if it makes any difference if infrastructure investments start during a boom or during a bust, as well as the issue of the potential differential effects between investment increases and decreases. In addition, a closer look at the timing of the effects, that is, the issue of

whether most of the effects occur in the short-term or over a longer time frame would help in understanding the nature of the mechanisms behind these effects. Finally, exploring the panel dimension of the data could bring new insights into the results and obviate any concerns about relative small sample sizes, a common critique in the literature.

To conclude, it should be mentioned that, although this paper is an application to the Portuguese case, its interest is far from parochial. The quest for policies that promote long-term growth in a framework of fragile public budgets is widespread. In the EU context, Greece, Ireland, Portugal and, to a lesser extent Italy and Spain, benefited after the early 1990s from important community structural transfers in no small part targeting infrastructure developments. At the same time, all of these countries, being small open economies, depend critically on improved international competitiveness to sustain improvements in standards of living. Whether labor productivity improvements induced by infrastructure investments are biased towards traded or non-traded goods is, therefore, a critical piece of information when designing development strategies that rely to a meaningful extent on infrastructure development.

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