March 2015

Infrastructure Investment, Labor Productivity, and International Competitiveness: The Case of Portugal (*)

Alfredo Marvão Pereira and Rui Manuel Pereira
Department of Economics
The College of William and Mary
Williamsburg VA 23187

Abstract

This study analyzes the effects of infrastructure investment on labor productivity at the industry level using a newly developed data set for infrastructure investments in Portugal. We employ a vector autoregressive approach and consider twenty two sectors of activity and twelve infrastructure assets to estimate industry-infrastructure specific effects on labor productivity. This allows us to highlight the differential effects on traded and non-traded sectors. 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 sectors. Fourth, for public utilities the effects are in general small with the exception of investments in telecommunications which have large positive effects mainly on non-traded sectors. As a corollary of our results, we conclude that infrastructure investments in the last three decades have contributed to the growth of labor productivity in the country but have done so in a way that is rather uneven across sectors and has benefitted 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 depending on exports.

Keywords: Infrastructure Investment, Economic Performance, Industry Mix, Traded and non-traded sectors, VAR, Portugal.
JEL Classification: C32, E22, H54, O52, L90, L98

(*) This working paper is part of a research project on "Infrastructure Investments in Portugal: A New Data Set and New Empirical Evidence" developed under the auspices of the FFMS - Fundação Francisco Manuel dos Santos. We would like to thanks Pedro Magalhães, Susana Peralta and an anonymous FFMS reader for very helpful comments and suggestions. The usual disclaimers apply.

Infrastructure Investment, Labor Productivity, and International Competitiveness: The Case of Portugal

1. Introduction

The importance of labor productivity improvements in creating a favorable investment environment and in fostering competitiveness is well understood. It is also well understood 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 encourage export growth. 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 sustaining improved standards of living [see, for example, 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, its 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. An extensive and efficient infrastructure network is considered together with proper institutions, a good macroeconomic environment and a good health and education systems, as key basic requirement for competitiveness [see, for example, WEF

(2014a)]. It also seems to have been, at least by some measures, a successful strategy. According to the World Economic Forum Global Competitiveness Index [WEF (2014a)], Portugal ranks 36 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 – 17. If we consider the more detailed individual competitiveness indicators, Portugal ranks 12 on the overall quality of infrastructures and an impressive 2 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 very important. 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 for improved global competitiveness. Aggregate improvements in labor productivity may be driven by larger effects in sectors which trade internationally, concentrated in industries that do not, or reflect a more balanced effect across industries.

These alternative situations have very different policy implications as they impact 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 sustainable and maybe even self-reinforcing. Or are labor productivity improvements mostly in non-traded goods sectors in which case they mask a loss in international competitiveness? In this case gains, in standards of living are likely not 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 Andraz (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 scant.

Although several studies for the US make reference to specific industries they have essentially a regional focus [see, for example, Evans and Karras (1994), and Moomaw and Williams (1991)]. The sectorial 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 more recently Pereira and Andraz (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 Andraz (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 U.S. in Pereira and Andraz (2003, 2004), to Portugal in Pereira and Andraz (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 a-theoretical. 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 [a policy function]. 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 preliminary econometric results including the VAR model specification and discusses the identification of exogenous shocks to infrastructure investment as well as the measurement of their effects. Section 4 presents the 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 (2015) 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. This corresponds in absolute terms to an increase from 0.75% of the GDP in the 1980s to 1.56% in the last decade.

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.

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

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 the 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 the 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 the 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 and 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 economic data – 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 sectors (agriculture and mining), seven manufacturing (food, textiles, paper, chemical and pharmaceutical, non-metallic minerals, metallic, and machinery), ten private services sectors (electricity, water, construction, trade, transportation, hospitality, telecommunications, finance, real estate, and professional services) and three public services sectors (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 good and those which do not. We define ten sectors, the two primary sectors, the seven manufacturing sectors, and the sector of transportation (S14) as being traded goods sectors. The remaining nine private service sectors as well as the three public service sectors are defined as non-traded. Here, however, we will find useful to identify five private service sectors such as water (S11), hospitality (S15), telecommunications (S16), finance (S17) and professional services (S19) as emerging traded goods sectors. In these sectors 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 7.1% of output in the 1980s and declined to 3% in the last decade. The manufacturing sector, declined from 15.7% to 10.7%. Transportation (S14) declined in the

1990s but has somewhat rebound in the last decade. The sectors producing traded goods overall declined from 27.9% of output in the 1980s to 21.6% in the last decade, a decline that would be more pronounced if it weren't for the increase in the relative role of transportation and storage services (S14). Private services, net of transportation, increased slightly from 61.1% of output in the 1980s to 62.3% in the last decade, led by a large increase in the role of professional services (S19). The large increase over the sample period was in public services, which rose from 11% in the 1980s to 16.1% in the last decade, a change led directly by public administration services (S20).

Given the focus of this paper we want also to consider some basic statistical information about the evolution of labor productivity, simple measures as output per worker. The relevant figures are presented in Table 4. Overall, and for the economy as a whole, despite a rather sluggish evolution over the 1990s and 2000s, we see a clear 37.4% improvement when we compare labor productivity in the 1980s and in the 2000s. For the primary sector we see, however, a sharp decline, while the improvements in manufacturing are in line with the aggregate effects. Labor productivity in the private services sectors overall improved by about 20% in the 2000s compared to the 1980s while the largest improvement occurred in public services – 72.4% over the same reference frame.

Let's 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 sectors, agriculture (S1), mining (S2), basic metals (S8), and machinery and equipment (S9) 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 sectors. In turn, among the seven non-traded goods sectors 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

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, as well as 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 macro literature that aggregate output, employment, and private investment are I(1). Although our series are more disaggregated, the same pattern of stationarity is not surprising.

We test for co-integration for each region 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 approach for two reasons. First, since we do not have any priors that suggest the possible existence of more than one co-integration 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 co-integration when it does not exist (although, arguably, the Engle Granger approach suffers from the opposite problem). Again, we use the BIC to determine the number of lagged differences, the deterministic components as well as dummies for the potential structural breaks to be included. As a general rule our tests cannot reject the null hypothesis of no co-integration. This is consistent with the view that it is unlikely to find co-integration at a more disaggregated level when we fail to find co-integration 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 converging to the level of its peers in the European Union. This is so at a more aggregated level and even more so when we consider the data at the regional 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 that is that in the long-term they grow at the same rate. Absence of cointegration suggests that they do not grow at the same rate, that is, there are differentiated effects of infrastructure investments on the levels of the each of the other variables.

Having determined that all of the variables are stationary in first differences and that they do not seem to be cointegrated, we follow the standard procedure in the literature and determine the specifications of the VAR models using growth rates of the original variables. We estimate twelve VAR models for each of the twenty two industries, one for each of the different infrastructure types. 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 variables 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 display typically a block diagonal pattern. Specifically, the contemporaneous correlations between innovations in infrastructure investment and the other variables tend to be substantially smaller, if 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.

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

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 this 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. This is equivalent in the context of the standard Choleski decomposition 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.

We have 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 information gathering and public decision making.

Furthermore, this assumption is reasonable also 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 not responsive to the ongoing economic conditions and regardless we would not expect any single economic sector 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 one-percentage point, one-time shock in the rates of growth of the different types of infrastructure investment on output, employment, and private investment. We expect these temporary shocks in the growth rates of infrastructure investment to have temporary effects on the growth rates of the other variables. They will, however, have permanent effects on the levels of these variables. All of these effects are captured through the impulse response functions and accumulated impulse response functions associated with the estimated VAR models.

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. We observe that without exception 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% intervals although bands that correspond to a 68% posterior probability are the standard in the literature (Sims and Zha, 1999). Employing one standard deviation bands narrows the range of values that characterize the likelihood shape and only serves to reinforce and strengthen our results. Further evidence exists that nominal coverage distances may under represent the true coverage in a variety of situations (Kilian, 1998). Similarly, placing too great a weight on the intervals presented in evaluating significance in 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 that the effects are 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 sector 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 rather include all the dynamic feedback effects among the different variables. Naturally, this is the relevant concepts 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 sectors in Tables 5-8. In addition, and to help both check the consistency of the results across different levels of aggregation and 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 is 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 is from national roads on water and wastewater (S11), -0.54, and the smallest 10% of the effects range from downward from -0.10. In our discussion below, we will 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 fall in the category public goods or of externalities - 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 private sector mechanisms. 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 full 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 and other transportation network, while sectors that are either more labor intensive or rely more on skilled labor, such as finance or telecommunications, 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. A second channel is what we could call the construction channel. These investment projects inevitably use vast pools of resources, engage 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 - construction materials, etc. 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 and 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 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 sector 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 a 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.

When consider 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), paper (S5). For the remaining traded sectors, the effects are large negative for mining (S2) and not significantly different from zero for the other three. 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**, investments have 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. 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 sectors and four of the twelve non-traded sectors. 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 is statistically zero. When we consider the four main industry aggregates, we see that railroad investments, and to a lesser extent airports have clearly biased labor productivity gains 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 sectors 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 sectors. In turn, we identified negative effects for agriculture (S1), paper (S5), and machinery (S9). All of these are traded goods sectors. We also find moderate negative effect for the non-traded sector of professional services (S19). Overall, railroad infrastructure investment affects labor productivity positively, in a strong or moderate manner, in 7 of 12 non-traded sectors and affects labor productivity negatively, in a strong or moderate manner, in 3 of the 10 traded sectors. Railroad investments have decisively favored non-traded sectors.

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 sectors. 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 fifteen 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), textiles (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 sectors, but with railroad investment playing a greater role that investments in ports or airports.

4.4 The Effects of Investments in Social Infrastructures

The effects of investments in social infrastructure on labor productivity are reported in Table 7. At the most aggregate level, health infrastructure investments have a large effect of 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 effects which was particularly large for private services, and significant for primary and 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 sectors, 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 good, only four of the ten sectors show effects that are not statistically significant. In turn, for the non-traded goods sectors we find large positive effects for construction (S12) and moderately positive effects real estate (S18) and actually a large negative for electricity (S10) and water (S11). The remaining eight effects are nor significant. Overall, health infrastructure investments seem to have improved labor productivity for both traded and non-traded sectors, without clearly affecting the balance between the two.

At the full disaggregated level we find that **education infrastructu**re investments affects strongly finance (S17) and education (S21), and moderately construction (S12), professional services (S19), public administration (S20), and health (S22). Overall six of the twelve non-traded goods sectors see a clear gain in labor productivity, the effects on the remaining six sectors not being statistically significant. In terms of the traded goods sectors, 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). Given the nature of the effects and the relative size of the different sectors, it is clear that these investments, 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. We estimate at the aggregate level a moderate effect from investments in water and waste water, 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 very 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 the primary sector and 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 and a moderate negative effect on labor productivity in the primary sector.

Investments in **water and waste water infrastructure** have mixed effects on traded versus non-trade sectors. 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 sector and real estate (S18) a non-traded 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 very small 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 sectors. Indeed, among the non-traded sectors, 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 sectors 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 sectors 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 sectors**, sectors producing traded good, 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 sectors.

As to the **manufacturing sectors**, 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, and this despite the important gains in labor productivity present in the data. On the negative side, meaningful effects can also be observed from municipal roads [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)].

Private services sectors, which except for transportation (S14) are non-traded sectors, benefit 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)], 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) seems 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 sectors 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), a sector 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, **public services**, sectors producing non-traded goods, benefit 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, except 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 competitiveness is less stellar. The fact is that, besides infrastructure investments many other factors affect the productivity of each individual sector. 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 of which only nine are 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 we aim at identifying the empirical effects of infrastructure investments 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 sectors. Fourth, for public utilities the effects are in general small with the exception of investments in telecommunications which have large positive effects mainly on non-traded sectors.

From an industry perspective, the traded goods sectors benefit in some cases but never very strongly. Infrastructure investment has led pretty much across the board to a decline in labor productivity for the primary sectors while the manufacturing sectors 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 sectors, 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 sectors.

There are several important policy implications of these results. First, from a retrospective standpoint these results help understand how the patterns of infrastructure development over the last few decades have affected labor productivity overall 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 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 sectors. 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 sectors might have had in terms of differentials in labor productivity vis-à-vis the traded good sectors. Naturally, this is not meant to imply that infrastructure investments are the only or even the most important factor behind the observed changes but rather 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, health and education facilities. Indeed, the time has passed for any focus on road infrastructure which is perceived as having already achieved a high level of maturity if not outright overinvestment - 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 sectors. The effects of investments in ports and airports will be less significant and in the case of ports more evenly distributed.

Equally from a perspective standpoint there is the issue of the effects of these infrastructure investments on the labor productivity of sectors we could consider emerging traded-sectors, sectors which have traditionally been non-traded but which are showing signs of increased openness and participation in the international markets. These are the cases of the private services sectors of water, telecommunications, and professional services, and to a lesser extent hospitality, and finance. We want to consider for these sectors 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 sectors.

The results in this paper open the door to several important research avenues, technical and yet directly relevant for policy making. An important next step would be going more in the direction of the fiscal multiplier literature and to explore how non-linearities may affect the effects of infrastructure investments. In particular, it would interesting to consider the issue of regime switching, i.e., if it makes a different if the investments occur in a boom or 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 so common in this literature.

To conclude, it should be mentioned that although this paper is an application to the Portuguese case and is intended to be directly relevant from the perspective of policy making in Portugal, its interest is far from parochial. The quest for policies that promote long-term growth in a framework of fragile public budgets is widespread. 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. The same is true in more recent years for the more recent EU entrants from Eastern Europe. At the same time, all of these countries, as small open economies, depend critically on improved international competitiveness to maintain 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.

References

1. Berndt, E., and B. Hansson (1991), "Measuring the Contribution of Public Infrastructure Capital in Sweden," *Scandinavian Journal of Economics* 94, 151-168.

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

3. Christiano, L., M. Eichenbaum, C. Evans (1999), "Monetary Policy Shocks: What Have we Learned and to What End?" in *Handbook of Macroeconomics* Vol. 1A, Eds. John B. Taylor and Michael Woodford. North-Holland.

4. European Union (2014a), *Reindustrializing Europe, Member State's Competitiveness Report 2014*, A Europe 2020 Initiative, European Commission.

5. European Union (2014b), *Helping Firms Grow, European Competitiveness Report 2014*, , European Commission.

6. Evans, P., and G. Karras (1994), "Are Government Activities Productive? Evidence From a Panel of U.S. States," *Review of Economics and Statistics* 76(1), 1-11.

7. Fernald, J. (1993), "How Productive is Infrastructure? Distinguishing Reality and Illusion with a Panel of US Industries," mimeo.

8. Gokirmak, H. (1995), "Infrastructure and Economic Performance," Ph.D. Dissertation, American University.

9. Gramlich, E. (1994), "Infrastructure investment: A review essay," *Journal of Economic Literature* 32, 1176-96.

10. Greenstein, S. and P. Spiller (1995), "Modern Telecommunications Infrastructure and Economic Activity: An Empirical Investigation," *Industrial and Corporate Change* 4(4), 647-665.

11. Holleyman, C. (1996), "Industry Studies of the Relationship between Highway Infrastructure Investment and Productivity," *Logistics and Transportation Review* 32(1), 93-117.

12. Instituto Nacional de Estatística www.ine.pt

13. International Monetary Fund (2013), "Anchoring Growth: The Importance of Productivity-Enhancing Reforms in Emerging Markets and Developing Economies," IMF Staff Discussion Note SDN/13/08.

14. International Monetary Fund (2014), "Adjustment in Euro Area Deficit Countries: Progress, Challenges and Policies," IMF Staff Discussion Note SDN/14/07.

15. Kamps, C. (2005), "The dynamic effects of public capital: VAR evidence for 22 OECD countries," *International Tax and Public Finance* 12, 533-558.

16. Kilian, Lutz (1998), "Small-Sample Confidence Intervals for Impulse Response Functions," *Review of Economics and Statistics* 80, 218-230.

17. Lynde, C., and J. Richmond (1993), "Public Capital and Long-Run Costs in U.K. Manufacturing," *Economic Journal* 103, 880-893.

18. Moomaw, R., and M. Williams (1991), "Total Factor Productivity Growth in Manufacturing: Further Evidence from the States," *Journal of Regional Science* 31(1), 17-34.

19. Munnell, A. (1992), "Policy watch, infrastructure investment and economic growth," *Journal of Economic Perspectives*, Vol. 6, No. 4, 189-198.

20. Nadiri, M., and T. Mamuneas (1994), "The Effects of Public Infrastructure and R&D Capital on the Cost Structure and Performance of U.S. Manufacturing Industries," *Review of Economics and Statistics*, 76(1), 22-37.

21. OECD (2013), *OECD Compendium of Productivity Indicators*, OECD Statistics Directorate and Directorate for Science, Technology and Industry.

22. OECD (2014), *Portugal – Deepening Structural Reform to Support Growth and Competitiveness*, Better Policy Series, OECD Secretariat.

23. Pereira, A. (2000), "Is all public capital created equal?" *Review of Economics and Statistics* 82, pp. 513-518.

24. Pereira, A. (2001), "Public capital formation and private investment: what crowds in what?" *Public Finance Review* 29, 3-25.

25. Pereira, A. and Andraz, J. (2003), "On the impact of public investment on the performance of US industries," *Public Finance Review* 31, 66-90.

26. Pereira, A. and Andraz, J. (2004), "Public highway spending and state spillovers in the USA," *Applied Economics Letters* 11, 785-788.

27. Pereira, A. and Andraz, J. (2005), "Public investment in transportation infrastructures and economic performance in Portugal," *Review of Development Economics* 9, 177-196.

28. Pereira, A. and Andraz, J. (2007), "Public investment in transportation infrastructures and industry performance in Portugal," *Journal of Economic Development Economics* 32, 1-20.

29. Pereira, A. and Andraz, J. (2011), "On the Economic and Fiscal Effects of Investment in Road Infrastructure in Portugal," *International Economics Journal* 25 (3), 465-492.

30. Pereira, A. and Andraz, J. (2013), "On the economic effects of public infrastructure investment: a survey of the international evidence," *Journal of Economic Development* 38 (4), 1-37.

31. Pereira, A. and Flores, R. (1999), "Public capital accumulation and private-sector performance in the U.S.", *Journal of Urban Economics* 46, 300-322.

32. Pereira, A. and R. Pereira (2015), *Investimentos em Infraestruturas em Portugal: Dados e Factos Estilizados*. Fundação Francisco Manuel dos Santos, forthcoming.

33. Pereira, A. and O. Roca-Sagales (2001), "Public Capital and Private Sector Performance in Spain: A Sectorial Analysis," *Journal of Policy Modeling*, 23, 371-384.

34. Pereira, A. and Roca-Sagales, O. (2003), "Spillover effects of public capital formation: evidence from the Spanish regions", *Journal of Urban Economics* 53, 238-256.

35. Pereira, A. and Roca-Sagales, O. (2007), "Public Infrastructures and Regional Asymmetries in Spain," *Revue d'Economie Regionale et Urbaine*, 503- 520.

36. Pinnoi, N. (1992), "Public Investment and Private Production: Measuring Relative Contributions," *Journal of Economic Behavior and Organization*, 23(2), 127-48.

37. Romp, W. and de Haan, J. (2007), "Public capital and economic growth: a critical survey," *Perspektiven der Wirtschaftspolitik*, 8, Special Issue, April, 6-52

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

39. Seitz, H. (1994), "Public Capital and the Demand for Private Inputs," *Journal of Public Economics* 54, 287-307.

40. Shah, A. (1992), "Dynamics of Public Infrastructure, Industrial Productivity and Profitability," *Review of Economics and Statistics* 74(1), 28-33.

41. Sims, Christopher A. and Tao Zha. (1999), "Error Bands for Impulse Responses," *Econometrica*. Vol. 67, no. 5. pp. 1113-1155.

42. World Economic Forum (2014a), *Europe 2020 Competitiveness Report – Building a More Competitive Europe*, Insight Report.

43. World Economic Forum (2014b), *Global Competitiveness Report 2014-2015*, Insight Report.

Table 1 Infrastructure Investment by Type of Asset

% of GDP	1978-2009	1980-89	1990-99	2000-09
Road Transportation	**1.42**	**0.89**	**1.59**	**1.88**
National Roads	0.61	0.39	0.73	0.71
Municipal Roads	0.44	0.40	0.50	0.45
Highways	0.37	0.09	0.36	0.73
Other Transportation	**0.46**	**0.26**	**0.56**	**0.57**
Railroads	0.34	0.18	0.45	0.43
Airports	0.05	0.04	0.04	0.08
Ports	0.06	0.04	0,07	0.07
Social Infrastructures	**1.15**	**0.97**	**1.30**	**1.26**
Health	0.55	0.34	0.57	0.75
Education	0.60	0.63	0.73	0.51
Public Utilities	**1.32**	**0.94**	**1.00**	**1.78**
Water and Wastewater	0.37	0.17	0.32	0.52
Electricity and Gas	0.73	0.55	0.46	1.09
Petroleum Refining	0.22	0.11	0.22	0.18
Telecommunications	**0.67**	**0.49**	**0.85**	**0.75**
% of Infrastructure Investment	**1978-2009**	**1980-89**	**1990-99**	**2000-09**
Road Transportation	**28.20**	**25.95**	**30.35**	**30.23**
National Roads	12.21	11.52	14.09	11.43
Municipal Roads	9.33	11.90	9.47	7.10
Highways	6.67	2,56	6.29	11.76
Other Transportation	**8.98**	**7.57**	**10.52**	**9.21**
Railroads	6.72	5.17	8.31	6.92
Airports	1.03	1.17	0.81	1.21
Ports	1.23	1.23	1.40	1,08
Social Infrastructures	**23.76**	**28.41**	**24.52**	**20.13**
Health	10.74	9.89	10.73	11.79
Education	13.02	18.52	13.79	8.16
Public Utilities	**25.72**	**24.09**	**18.50**	**28.53**
Water and Wastewater	6.80	4.90	5.98	8.17
Electricity and Gas	14.34	15.97	8.48	17.53
Petroleum Refining	4.58	3.22	4.06	2.83
Telecommunications	**13.34**	**13.94**	**16.12**	**11.89**

Table 2 Industry Classification

Industry 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	1980-89	1990-99	2000-09
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**

Table 4 Output per Worker by Industry

	1978-2009	1980-89	1990-99	2000-09
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

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

(*) 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.

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*

(*) 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.

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

(*) 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.

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*

(*) 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.