Land Transport Infrastructure and Productivity: A Comparison between Italy and Spain

Abstract:

Using a fixed effects panel for the years 2000 to 2015, this paper empirically examines the relationship between rail and road infrastructure investment and the regional economic performance of Italy and Spain. As proxies for infrastructure investment, road and rail densities were used, while for economic performance, GDP, GDP per capita and GDP per hours worked at a regional level were considered. In addition, the extent that the economic effect of transport infrastructure is influenced by EU macroeconomic conditions and whether the effect changes depending on the country is also analyzed. Results differ depending on the type of infrastructure: the effects are positive for rail and negative for road. Furthermore, when differences between countries are investigated, productivity in Italy is negatively affected by investment in road infrastructure compared to Spain, but no difference is present when rail is considered.

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Date final version: November 13, 2017

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1. Introduction

Improvements in transport infrastructure have led to decreases in costs and increases in accessibility, thus impacting the costs of transport-using firms, the mobility of households, the overall demand for goods and services, and the efficiency gains (Anderson and Lakshmanan, 2007; Lakshmanan, 2011). In the long run, these effects translate into market expansion, causing a shift in the economy from local or regional autarky to a situation of increased trade and specialization, and hence higher production (Lakshmanan, 2011).

When analyzing the role that investment in transport infrastructure has on a country's or region's economic performance, the literature takes on two approaches: the microeconomic (*ex-ante*), cost-benefit analysis (CBA) which focuses on the balance between the forecasted economic benefits for households and firms, and the project's and operational costs (Anderson and Lakshmanan, 2007); and the macroeconomic (*ex-post*), econometric analysis that assesses the economic contributions of the infrastructure investment.

Given their impact on the mobility of people and resources both inside and outside a country, investment in transport infrastructure have been presented by politicians as something that has virtually no negative effects on the economy (Banister and Berechman, 2000). However, the economic results of these investments have been varied: in some cases there have been modest growth effects, while in other instances activity decline and negative economic effects have prevailed (Anderson and Lakshmanan, 2007). As it is the government's role to provide the infrastructure, it is important to understand what factors determine the positive or negative economic outcomes of these investments.

Thus, all these considerations led to the following research question:

To what extent does investment in road and rail infrastructure translate into productivity?

This analysis will focus on Italy and Spain for the period 2000 until 2015. In the case of Spain, it has experienced significant investments in the transportation, especially road, infrastructure (Estache, 2001; Holl, 2004b), while in the case of Italy, the 1990s witnessed governmental incentives to encourage freight transportation on railways (OECD, 2005), leading to a series of significant investments in the railway sector. Results differ depending on the type of infrastructure: the effects are positive for rail and negative for road. Furthermore, when time fixed effects are added, road retains its negative effect while rail becomes insignificant. Also, when differences between countries are investigated, productivity in Italy is negatively affected by investment in road infrastructure compared to Spain, but no difference is present when rail is considered.

The rest of the paper is organized as follows. Section 2 presents a review of the literature. The data and methodology employed are discussed in Section 3, while the results are presented in Section 4. Lastly, conclusion and policy recommendations are given in Section 5.

2. Literature review

Ever since the first studies in the late 1980s, the economic impact of public infrastructure[1] has sparkled the interest of policymakers and has been widely explored by scholars. The literature review consists of the following parts: first, an overview on the relation between economic growth and transport infrastructure, both from a theoretical and empirical perspective, will be presented. This will be followed by a brief presentation of the various methods used to quantify the economic impact. Subsequently, the topics of the Trans-EU Transport Networks and Cohesion Fund will be considered, especially in relation to their roles in aiding the development of infrastructure in both Italy and Spain. Lastly, the section will conclude with an overview of the infrastructure situation in Italy and Spain.

2.1 The relation between economic growth and transport infrastructure

For policymakers, the concept of economic growth entails an array of factors including decrease in unemployment, rise in incomes and quality of life, and environmental awareness (Matoon, 2004). According to Rodrigue and Notteboom (2017) the main channels through which transportation affects the economy as a whole are: geographic specialization which gives rise to comparative advantages, cost reductions and increases in reliability due to an efficient transportation system which facilitates large-scale production, and increased competition because as transportation becomes more efficient, the potential market size increases and so does competition. Complementarily, Immergluck (1993) identifies three channels through which infrastructure impacts firm's output: highways and railways are unpriced[2] elements that go directly into the production function, infrastructure may indirectly increase the supply of other inputs[3] and lastly, infrastructure may interact with other inputs and affect their productivity.

Empirically, the link between the level of transport investment (measured by public capital's rate of return) and economic growth has been widely explored, with Aschauer (1989a, b) being a pioneer in this area. What was striking about his analysis (done on a national scale) was that the estimated coefficients were very high, prompting a heated debate among academics and policymakers: if the public capital's rate of return in the United States was 146% a year, it would

[1] Although the term *public infrastructure* encompasses transportation infrastructure, water and sewage systems, public buildings (i.e. schools and hospitals), telecommunications, and electric and gas facilities (Munnell, 1990), in this thesis it will strictly refer to transport infrastructure. Thus, both terms will be used interchangeably.
[2] Whether a good is priced or unpriced depends on the extent in which that good can be exclusive (Immergluck, 1993).
[3] Such as improving amenities that are important to labor and/or capital (Immergluck, 1993).

likely be even higher for countries with less developed infrastructure (Demetriades and Mamuneas, 2000). Although giving consensus on statistical significance, subsequent studies performed at a state or regional level had varying estimates of the effect, though they were all much smaller than the ones calculated by Aschauer (1989a) (Immergluck, 1993). An alternative explanation for the mixed results is provided by Haughwout (1999) who suggests that the benefits from infrastructure investments are mostly place-specific and decline as the distance from the infrastructure increases. Henceforth, infrastructure can redistribute growth from dense urban areas to the less densely populated ones, diminishing the agglomeration benefits as well (Haughwout, 1999).

Munnell (1992) points out a series of criticisms for Aschauer's (1989a) analysis, the main ones being: common trends in public infrastructure and output lead to spurious correlation, causation most probably runs from public capital to output and not vice versa, and the wide range of results from subsequent studies makes the validity of Aschauer's (1989a) results questionable. With regards to the methodology used, Aschauer (1989a) uses a first-difference approach, yet Munnell (1992) stresses that not only would no one expect the growth in capital stock in one year to be correlated with the output growth of that same year, but that a first-difference approach also destroys any long-term relationship in the data. With respect to the heterogeneity of the results from other studies, the estimates are overall similar, with the variation coming predominantly from the differences in the units of observation: as geographical focus narrows, the estimated impact of infrastructure becomes smaller. The most reasonable explanation for it is that concentrating on a smaller geographical scale hinders the observance of leakages, thus underestimating the total payoff of an infrastructure investment (Munnell, 1992).

2.1.1 Empirical evidence

Following, a restricted selection of study cases in Spain, the United States and Portugal will be presented.

In 2005, Cantos et al. researched the effects that transport infrastructure, for the different transportation modes, has on economic growth in the various regions and economic sectors of Spain. To achieve this, they calculated the output elasticity by applying two different methodologies: the Production Function Approach and the Total Factor Productivity Approach[4]. Both methods gave similar results, which overall confirmed the positive role that transportation infrastructure has on the private sector's productivity in the Spanish regions.

Another study based in Spain for the decade 1984 to 1994 was performed by Montolio and Solé-Ollé in 2007. They concluded that public investment in roads has, on average, enhanced the productivity of the Spanish regions. Furthermore, they also focused on the effects that congestion may have on the growth rate of Total Factor Productivity[5], and they found that congestion did have a negative effect. To address the issues of endogeneity and reverse causality, interaction terms were used and lagged values for the independent variables were taken (Montolio and Solé-Ollé, 2007).

Chandra and Thompson (2000) performed a study in the United States for the years 1969 to 1993, with the main hypothesis being that the impact of highways on output differed among industries, with those benefitting more from lower transportation costs growing at a faster rate than those which did not. An interesting aspect of their study was the rather strong assumption that the construction of a new highway was unrelated to past economic growth – thus eliminating any reverse causality problems. Their results found that the construction of a new highway increased the rate of economic growth for the areas where the infrastructure directly passed through. However, they also observed that the magnitude of the impact decreased in the adjacent areas, supporting the hypothesis that highway investments led to regional relocation of the economic activity.

[4] The difference between the two approaches is that in the Production Function Approach, an econometric estimation is used in order to determine the output elasticity; while in the Total Factor Productivity Approach, first a regression on the indices of Total Factor Productivity is run, and then an accounting approach is used to determine the elasticities (Cantos et al., 2005).

[5] Also referred to as *Multi-Factor Productivity*. It is the part of output that is not directly determined by factor inputs, but by how efficiently and intensively said inputs are used in production (Munnell, 1990).

Centering her attention on the extent that transport network improvements affected the spatial distribution of firms, Holl (2004a, b) tested the hypothesis that road infrastructure had a significant impact on the location choice of firms in Portugal and Spain. The conclusions drawn from her study in Spain indicated that new road infrastructure mattered as it had allowed manufacturing firms to locate at a greater distance from urban centers, thus taking advantage of localization economies (Holl, 2004b). The results for Portugal were a bit more intricate, as the positive effects of the transport investments were unambiguously positive when concentrated in the proximity of the corridors, but they lead to negative spillovers in the adjacent areas (Holl, 2004a).

2.2 Measuring the economic impact of transport infrastructure

A strand of literature highlights how transport improvements generate savings in time and in direct and indirect costs for the firms through logistic reorganization. Another branch, in which the large majority of the studies conducted falls into, focuses on the economic influence of transport infrastructure on an aggregate level, usually focusing on the Gross Domestic Product (GDP). Finally, there is a developing area of research capturing the general equilibrium effects, thus outlining the mechanisms involved in turning transportation improvements into economic impacts (Lakshmanan and Anderson, 2004). Next, each of these approaches will be presented in greater detail.

2.2.1 The microeconomic approach

This type of approach focuses on an assessment of a specific project's rate of return (Matoon, 2004). Microeconomic benefits entail improvements in transport infrastructure that can led to cheaper transport costs for the individual firm, hence increasing its productivity. The cost reduction can be achieved by increasing the density of the network through the construction of new roads and the expansion of the pre-existing infrastructure, thus decreasing the distance travelled and the congestion (Lakshmanan and Anderson, 2004). Cost-Benefit Analysis (CBA) has been the predominant approach used for determining the microeconomic impacts of transport infrastructure. Most specifically, it describes the *ex-ante* direct and indirect time and cost savings from the transportation improvements (Lakshmanan, 2011).

Matoon (2004) asserts that the CBA approach is the preferred one of local policymakers due to its easy computation and because the evaluation of any investment project is based solely on whether the project's net present value is positive. Nonetheless this approach does have its drawbacks, the most prominent of which is its inability to incorporate the general equilibrium effects of transport improvements into the analysis. As cited by Lakshmanan and Anderson (2004), such effects would include:

- Logistical adjustments: in addition to transportation costs, there are also logistic costs – which include the costs of procuring, dispatching and carrying out the inventory. The emergence of the "just-in-time" inventory approach, with its increased number of shipments and reliability of delivery time, reduced these costs and turned inventory-related and transportation inputs into substitutes. Hence, if an investment in infrastructure reduces transportation costs, firms will use the transportation services more, and as a results decrease the logistics costs.
- Consolidation of facilities: a reduction in transportation costs can potentially allow firms to concentrate production or distribution into a limited number of facilities, and possibly benefit from economies of scale, which in turn would increase firms' output. However, a trade-off of this process is that, on average, the length of the shipments will be longer, hence increasing firms' reliance on transportation.
- Location effects: improvements in transportation infrastructure can affect a firm's location choice, and as a consequence its productivity, in a variety of ways. For example, infrastructure promotes productivity when firms can take advantage of agglomeration economies. Another instance is through the increased range of accessible locations for the production of goods and services. More specifically, an efficient transport network can allow firms to locate their production wherever it would be more advantageous.
- Value added from transportation: microeconomic benefits do not only compromise cost reductions, but also add value to the output of the transport service provider and the firm using said service.

Furthermore, Aschauer (1991) identifies additional disadvantages of this method. Firstly, the observation of leakages is excluded as CBA focuses only on small geographical areas[6]. Secondly, CBA applies discount rates that are generally too high. Thirdly, from a political perspective it is

[6] Refer to Munnell (1992) for a more extensive discussion.

preferable for infrastructure projects to be self-financing in the long run, resulting in a rate of return higher than that of private investments (Aschauer, 1991).

2.2.2 The macroeconomic approach

Counterbalancing the shortfalls of the CBA approach, macroeconomic models recognize that there are externalities to investments in public infrastructure, mainly output expansions and economy-wide reductions in costs. They hence focus on an *ex-post* analysis of the infrastructure's economic impact and view the introduction of infrastructure as an additional factor in the production function, alongside the traditional capital and labor inputs (Lakshmanan and Anderson, 2004). Although studies have overall observed a positive relationship between infrastructure and productivity (using GDP as a proxy), the magnitude of the impact varies broadly (for example, Aschauer, 1989a vs. Munnell, 1990).

Nevertheless, this approach is still not perfect. A main shortfall is that it does not consider the spatial dimension of the impact, disregarding the role which factors, such as the development stage of the network, play on the magnitude of the impact (Lakshmanan and Anderson, 2004). A second downside is its treatment of the production factors (labor, capital and infrastructure) on an aggregate level, hence excluding the chance of determining each individual element's contribution to the overall outcome (Lakshmanan and Anderson, 2004). Given these considerations, attention should be directed to a particular type of macroeconomic approach: the general equilibrium model.

2.2.2.1 The general equilibrium model

These types of models focus on measuring the benefits of transportation originating from regional specialization and technological changes, while also emphasizing the importance of geography in determining the extent of the benefits (U.S. Department of Transportation, 2004).

One such benefit is regional specialization. As each region is endowed with a different mix of attributes, the types of goods produced and a firm's ability to survive varies according to the location. Consequently, as a region specializes in the production of a certain good or range of goods, economies of scale arise resulting in lower costs and greater production. Nonetheless, the extent of these benefits is conditioned on the transportation infrastructure: as transport becomes more reliable and less costly, trade will increase (U.S. Department of Transportation, 2004).

More importantly, however, is the model's ability to capture the presence of comparative advantage; which is a general equilibrium benefit as it is the *redistribution* of production that leads to greater aggregate output, and not just the increased productivity of individual firms (U.S. Department of Transportation, 2004). Yet, it is important to note that gains from trade can be realized solely to the extent that they exceed transportation costs.

2.3 Trans-EU corridors and Cohesion Fund

With the enlargement of the European Union (EU) the topic of transportation infrastructure and its ability to be a driver in decreasing inequalities between the core regions and the periphery had a revival.

2.3.1 Trans-European Transport Networks

The Trans-European Transport Networks (TEN-T) are a subset of the wider Trans-European Networks (TENs), which also includes a telecommunication network (eTEN) and an energy network (TEN-E), and were established by the Maastricht Treaty of 1992 (Mestres and Domènech, 2017). The Priority Projects can be seen as the pillars of the TEN-T policy[7].

AECOM (2012) identifies the main weaknesses of the European transport system as: incompleteness of the internal market, insufficient infrastructure investment in certain geographical areas, safety deficiencies, inefficient organization of international rail operations, and presence of bottlenecks preventing efficient multimodal transport flows, among others.

In several aspects, T-TEN can be seen as the main transportation policy that the EU has in order to achieve territorial cohesion (López et al., 2008). Critics, however, have argued that many of the connections do not link the peripheral countries, but rather strengthen the accessibility already present in the core region (Schürmann et al, 2002).

[7] For a complete overview of all of the 30 Priority Projects, refer to https://ec.europa.eu/transport/themes/infrastructure/ten-t-policy/priority-projects_en

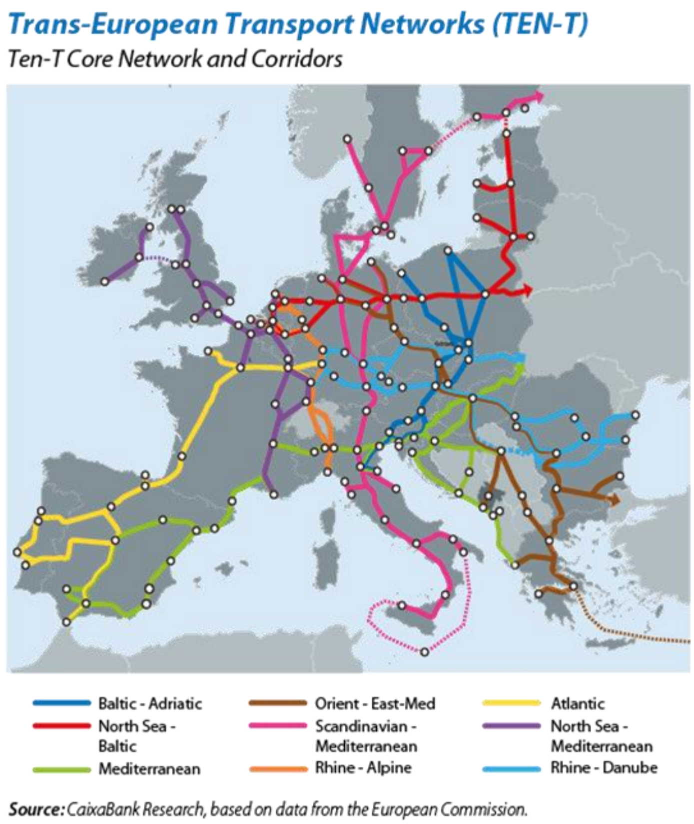

Figure 1: Trans-European Transport Networks. Source: CaixaBank Reseach, based on data from the European Commission

2.3.2 Cohesion Fund

Since its accession to the EU in the 1980s, Spain has benefitted from structural assistance and the implementation of the Cohesion Fund (AECOM, 2012). The fun's declared aim is to "*promote and strengthen the economic, social and territorial cohesion of the EU*"[8]. Looking specifically at the Cohesion Fund projects, they have been extensively used in addressing problems of congestion and increasing the accessibility in remote regions. This would in turn translate into aiding at reducing disparities among regions and promote cohesion.

Spain witnessed a significant investment in its road infrastructure between 2000 and 2009 (Ortega et al., 2016). Reasons for this were a mix between the economic boom, the political support for infrastructure expansion, the funds provided by the EU, and the use of Public-Private Partnerships to gather additional funds from the private sector. With regards to the railways, the EU funds sent to Spain were employed for the development of the high speed rail network (AECOM, 2012).

[8] As stated in the Fact Sheets on the European Union (2017). Retrievable at http://www.europarl.europa.eu/ftu/pdf/en/FTU_5.1.3.pdf

2.4 Country-specific situations: an overview

Taking as a reference point the country-specific economic surveys published by the OECD with an 18-month recurrence, an overall image of the evolution and current state of the transport infrastructure in Italy and Spain will be presented. In addition to issues concerning the development of the road and/or rail network extensions, other related aspects such as the state of the competition in the transport sector will be discussed.

2.4.1 Italy

During the 1990s, the transport volumes increased at a faster rate than GDP (OECD, 2005b). As the OECD (2005b) report further illustrates, in 2001 road transport constituted the highest share for both passenger and freight, although the volumes were average when compared to other OECD member countries; whereas rail transport represented a negligible part. The disadvantageous position of the railways was a result of the budgetary cuts in the capital transfers to the railway sector which occurred in both 1993 and 1996 (OECD, 1997). More recently, the rail sector has undergone significant reforms, most notably the approval of new legislation in 2003[9] giving access to both foreign and domestic companies to the freight and passenger international transport network (OECD, 2005b). Additionally, the government has also introduced financial incentives to encourage road freight transport companies to use railways in their long-distance transfers (OECD, 2005b). With regards to road freight transport, entry into the market is still restricted (OECD, 2005b); and as of 2014, no actions[10] have been taken (OECD, 2015).

Insofar as competition is concerned, the state control in the transportation sector is still high relative to other OECD countries (OECD, 2007). Most significantly, the Italian government still retains "golden shares"[11] in divested companies, and although they have not been exercised, the fact that the government might veto strategic decisions might discourage private investors, and thus reduce the overall efficiency of the sector (OECD, 2017a).

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[9] Decreto Legislativo 8 luglio 2003, n.188, "*Attuazione delle direttive 2001/12/CE, 2001/13/CE e 2001/14/CE in materia ferroviaria*".

[10] On multiple occasions, the OECD (2005; 2007; 2015; 2017) has encouraged the Italian government to implement legislation that would liberalize the road transport sector; for instance, eliminating price control for road freight transport services and allowing private enterprises to tender for long-distance road passenger transport provision.

[11] A type of share that gives its owner veto power over proposed changes to a company's charter.

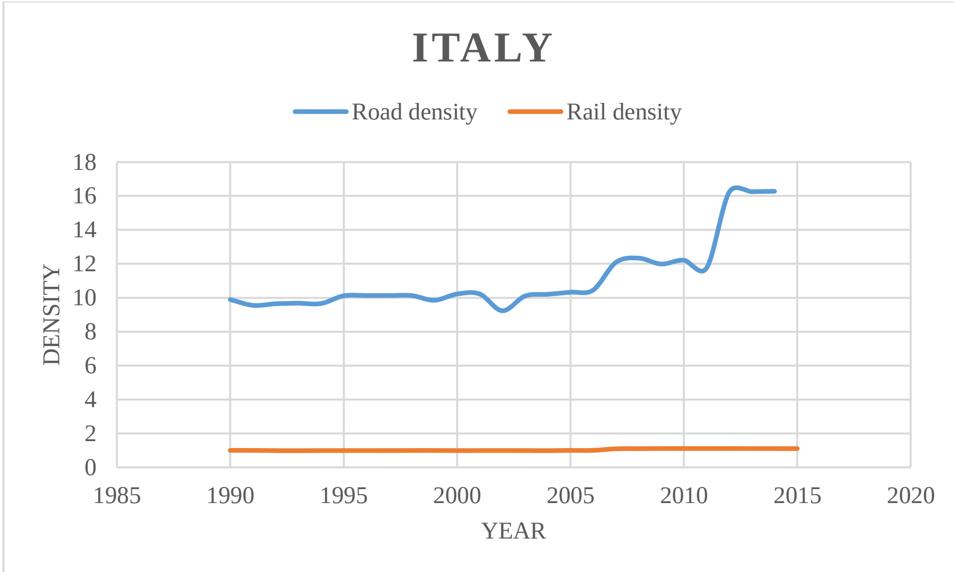

Figure 2: Rail density (Total rail length in km/Area in sq. km) and Road density (Total road length in km/Area in sq. km) in Italy. Source: Eurostat and own calculations

2.4.2 Spain

The heavily subsidized state-owned rail company operating at a loss has been a problem plaguing Spain since the 1990s. The low freight volume and the delayed infrastructure investments make the rail service less attractive, feeding into a vicious circle (OECD, 1998b). Thus, it does not come as a surprise that more than 95% of internal transport of merchandise is done by road (OECD, 2008b). Even if during the 2000s both local and international freight rail transport has been liberalized, the quantity of private operators remains limited (OECD, 2008b).

Concerning road transport, limited liberalization is the pivotal problem. Already in the late 1990s, recommendations for the removal of the quotas in the number of passenger service and freight vehicles had been expressed (OECD, 1998b). Nevertheless, by the end of the 2000s, the requirements for obtaining operating licenses for heavy merchandise transportation were still expensive in relation to other OECD member countries (OECD, 2008b).

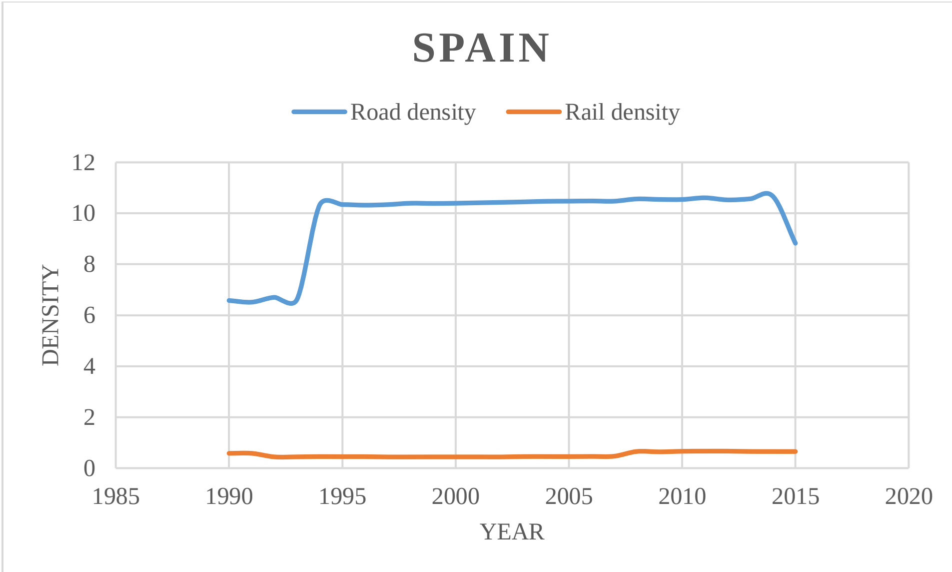

Figure 3: Rail density (Total rail length in km/Area in sq. km) and Road density (Total road length in km/Area in sq. km) in Spain. Source: Eurostat and own calculations

2.5 Concluding remarks and hypotheses

All in all, the literature highlights a series of important aspects. Firstly, investments in transportation have positive effects on economic productivity in the majority of cases. Aschauer (1989a and b) was the first to empirically test the relation between transport investment and economic growth. The resulting high coefficients from his studies sparked a growing debate on the economic effects of transport infrastructure. The study cases presented support the positive relation, however Chandra and Thompson (2000) and Holl (2004b) find that this relation is not uniform but changes depending on the area's proximity to the infrastructure. Secondly, given their positive impact on productivity, investments in transport infrastructure have been used as policy instruments to stimulate economic prosperity in lagging regions, as it can be observed in the EU's implementation of the T-TENTs as a way to mitigate the countries' disparities and enhance the Common Market. Thirdly, the countries' overviews highlight how all of them have similarities in their prolonged focus on the road network and in the limited competition in both road and rail transport; and also how they differentiate in the extent that they are implementing measures to increase liberalization in the sector.

As a consequence, three hypotheses have been formulated:

H1: *At a regional level, investment in road and rail infrastructure has a positive impact on economic performance*.

To test this, a baseline model will be run with country dummies

H2: *The effect of investment in road and rail infrastructure on regional productivity was affected by EU macroeconomic conditions*

In order to test this, time dummies will be added to the baseline model.

H3: *At a regional level, the investment in rail and road infrastructures has a different effect in the two countries under analysis*

To test this third hypothesis, the baseline model will be re-run with the inclusion of two interaction terms (*Ln Rail density X Italy* and *Ln Road density X Italy*).

3. Data and methodology

3.1 Data sources

All data was obtained from the Eurostat database, where all variables were taken at the NUTS-2 level (see Appendix A for regional codes). As data on road and rail investment was not available, the length of the road and rail regional network (measured in km) was used as a proxy. Furthermore, to take into consideration the differences in sizes between the regions, the road and rail network densities have also been computed. A full list of the variables used and their source can be found in Appendix B.

3.2 Dependent variables

Three dependent variables were used to represent economic performance: GDP, GDP per capita and GDP per hours worked. For ease of comparison among the different countries, all of them have been measured with Purchasing Power Standard (PPS)[12].

GDP measures the total economic output of a country, while GDP per capita is the total output divided by the population, i.e. the average output for each person. The third indicator, GDP per hours worked, is a labor productivity measure. It provides a measure of how efficiently labor input (average number of weekly hours of work of all employed people)[13] is used.

3.3 Independent variables

Given that investments in roads and railways at a regional level were not available, a physical measure was used instead: total length of roads and railways. To control for the size difference between regions, road and rail density was calculated (total length of road or railway divided by the total area of the region). Upon running the analysis, both measures gave the same results, thus only rail and road densities are reported. An advantage of this type of measure is that it is generally available for many countries and for extensive time periods. However, an infrastructure's physical measure does not take into account its state of deterioration; and in addition, it may not fully reflect public spending as private investment could also be involved (Romp and de Haan, 2007).

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[12] Purchasing Power Standard is an artificial currency unit developed by Eurostat. Source: Eurostat. (2007). *Eurostat-OECD Methodological Manual on Purchasing Power Parities.* Retrieved from https://stats.oecd.org/glossary/detail.asp?ID=7184

[13] A more thorough description can be retrieved from the OECD iLibrary website: http://dx.doi.org/10.1787/1439e590-en

3.4 Control variables

Population density has been calculated as the ratio of regional population divided by the total area of the region. It was used as an indicator for the demand and supply of the economy, and thus generator of economic activity. Larger population encourages greater specialization due to assimilation of ideas (Becker et al., 1999) and also has a positive effect on technological progress (Galor and Weil, 2000). Thus it is expected for population density to have a positive effect on the dependent variables.

Unemployment and *Human capital* were measured as percentage of GDP. The unemployment rate is used as an economic efficiency indicator (Maitah and Urbánková, 2015): hence, an increase in it is expected to have a negative effect on the overall economy. Lastly, similarly to population density, human capital can be seen as a factor that foments greater specialization and foster the development of high-skill processes; so it is expected for it to have a positive impact.

To control for trade, *Imports* and *Exports* were considered. Both are measured in Million Tonne-Kilometer. Studies have shown that exports and imports have a positive and significant impact on economic performance (Busse and Königer, 2012).

A dummy variable (*Financial crisis*) was used to proxy for the occurrence of the 2008 financial crisis and its prolonged effects on the countries' economies, taking the value of 1 on the year that it happened and in the years following to indicate the recession, and 0 otherwise. It is expected to for it to have a negative impact on the dependent variables.

3.5 Descriptive statistics

Table 1 summarizes the data used in this research. It can be seen that the dependent variables used are not normally distributed[14]. Thus, the natural log has been taken for all of them. Same applies to the independent variables and the controls *Population density*, *Road imports* and *Road exports.* Regarding the independent variables, road density is significantly higher than rail density, with the variation in rail density being minimal. Looking at the controls, it can also be noted that there is significant variation in both road imports and exports. Lastly, the correlation matrix can be found in Appendix C.

Table 1: Descriptive statistics

Variables		N	Mean	St. Dev.	Min	Max
Dependent variables	GDP	640	6.48e+10	6.89e+10	1.09e+09	3.67e+11
	GDP per capita	638	24,470.45	6,130.57	12,003.43	42,540.47
	GDP hours	630	1.68e+09	1.81e+09	2.84e+07	9.78e+09
Independent variables	**Rail density**	**994**	**0.04**	**0.02**	**0**	**0.09**
	Road density	**943**	**0.57**	**0.36**	**0**	**2.31**
Control variables	Population density	1,006	385.52	987.01	20.88	6,505.39
	Unemployment rate	656	12.40	7.34	1.80	37.00
	Human capital rate	630	30.24	10.51	11.40	51.60
	Road imports	637	10,331.54	11,248.52	8.00	63,147.00
	Road exports	626	10,830.83	11,648.32	2.00	63,413.00
	Financial crisis	1,040	0.308	0.462	0	1.00

[14] A histogram was performed for each variable and they were all strongly skewed to the right.

3.6 Methodology

In order to empirically test the theoretical aspects previously discussed, the relationship between GDP, GDP per capita, GDP per hours worked and the density of the transportation infrastructure at a regional level in Italy and Spain will be investigated. Thus, the estimation equations are given by:

Baseline model (H1)

$$Productivity_{yit} = \alpha_i + Density_{xit-1} + Popdens_{it-1} + Unemployment_{it-1} + HumanCap_{it-1} + Imp_{it-1} + Exp_{it-1} + Crisis_{it-1} + Italy_t + \varepsilon_{it}$$

With the inclusion of time dummies to control for macroeconomic changes (H2):

$$Productivity_{yit} = \alpha_i + Density_{xit-1} + Popdens_{it-1} + Unemployment_{it-1} + HumanCap_{it-1} + Imp_{it-1} + Exp_{it-1} + Crisis_{it-1} + Italy_t + X_i + \varepsilon_{it}$$

With the inclusion of interaction terms, to assess whether the effect is different depending on the country (H3):

$$Productivity_{yit} = \alpha_i + Density_{xit-1} + Popdens_{it-1} + Unemployment_{it-1} + HumanCap_{it-1} + Imp_{it-1} + Exp_{it-1} + Crisis_{it-1} + Italy_t + (Density_{xit-1} * Italy_t) + \varepsilon_{it}$$

Where the subscript *i* stands for regions, *t* stands for time, *x* in *Density* can be either road or rail, and *y* in *Productivity* stands for be either GDP, GDP per capita and GDP per hours worked. In addition, X_i is the matrix of time dummies and ε_{it} is the stochastic error term.

The estimation technique selected is OLS panel data with fixed effects. For completeness, also an OLS panel data with random effects estimation has been performed. However, as the Hausman test concludes that the fixed effects model is preferred, only the results from this model are reported. To alleviate the problem of reverse causality, all independent variables are calculated with a one-year lag. With respect to heteroscedasticity in the panel, robust standard errors have been used in all three models.

4. Results

4.1 Baseline model

Table 2: Baseline model

VARIABLES	(1) Ln GDP	(2) Ln GDP per capita	(3) Ln GDP hours
Ln rail density	0.0507*	0.0488*	0.0649**
	(0.0278)	(0.0270)	(0.0272)
Ln road density	-0.0371	-0.0555*	-0.0211
	(0.0297)	(0.0309)	(0.0287)
Ln population density	1.627***	0.663***	1.594***
	(0.132)	(0.128)	(0.138)
Unemployment	-0.00922***	-0.00840***	-0.00886***
	(0.000802)	(0.000698)	(0.000855)
Human capital	0.0139***	0.0134***	0.0158***
	(0.00208)	(0.00202)	(0.00241)
Ln road imports	0.0126	0.0142	0.0170
	(0.0212)	(0.0216)	(0.0226)
Ln road exports	0.0928***	0.0899***	0.111***
	(0.0305)	(0.0302)	(0.0333)
Financial crisis	-0.0380***	-0.0349***	-0.0209**
	(0.00916)	(0.00888)	(0.00978)
Constant	15.63***	5.797***	11.92***
	(0.553)	(0.532)	(0.579)
Observations	499	499	499
R-squared	0.779	0.627	0.808
Number of NUTS2Region	36	36	36

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

It should be noted that to control for country fixed effects, a country dummy *Italy* had been added to the regression. However, due it not changing through time, it has been omitted from the fixed effects output. *Ln rail density* has a positive and significant effect on all three productivity measures. A 1% increase in rail density increases GDP by 0.0507% c.p., GDP per capita by 0.0488% c.p. and GDP per hours worked by 0.0649% c.p. *Ln road density* instead is negative and significant only for GDP per capita: a 1% increase in road density decreases GDP per capita by 0.0555% c.p.

Regarding the controls, all of them with the exception of *Ln road imports* are statistically significant for all productivity measures. Furthermore, they also all the expected signs. A 1% increase in population density increases GDP by 1.627% c.p., GDP per capita by 0.663% c.p. and GDP per hours worked by 1.549% c.p. A 1% increase in the unemployment rate decreases GDP by 0.922% c.p., GDP per capita by 0.840% c.p. and GDP per hour worked by 0.886% c.p. Human capital has a positive effect on productivity: a 1% increase in it increases GDP by 1.39% c.p., GDP per capita by 1.34% c.p. and GDP per hours worked by 1.58% c.p. Likewise, road exports also have a positive effect: a 1% increase in road exports increases GDP, GDP per capita and GDP per hours worked by 0.0928% c.p., 0.0889% c.p. and 0.111% c.p. respectively. Lastly, the *Financial crisis* dummy has a negative effect: the presence of the financial crisis and its aftermath negatively affects productivity, causing a decrease of 0.0380% c.p. in GDP, 0.0349% c.p. in GDP per capita and 0.0209% in GDP per hours worked.

4.2 Macroeconomic considerations

To test for macroeconomic considerations, time dummies were added to the baseline model. Compared to the baseline model, *Ln rail density* became insignificant for all productivity specifications, whereas *Ln road density* is negative and statistically significant at a 5% level only when considering GDP per capita: a 1% increase in road density decreases GDP per capita by 0.0476% c.p.

Regarding the controls, and comparing to the baseline model, *Human capital* became insignificant throughout, while *Ln road imports* became significant at a 5% level throughout. All signs are, again, as expected. A 1% increase in *Ln population density* leads to a raise in GDP of 0.902% c.p. and in GDP per hours worked of 0.839% c.p. Interestingly, its effect on GDP per capita is negative, however it is not statistically significant. *Unemployment* has a negative effect: a 1% increase decreases GDP, GDP per capita and GDP per hours worked by 3.92% c.p., 3.29% c.p. and 3.43% c.p. respectively. Road imports and exports both have a positive effect: imports increase GDP by 0.0808% c.p., GDP per capita by 0.0785% c.p. and GDP per hours worked by 0.0789% c.p.; while exports increase GD GDP by 0.0775% c.p., GDP per capita by 0.0758% c.p. and GDP per hours worked by 0.0815% c.p. Lastly, the *Financial crisis* dummy has a negative effect: the presence of the financial crisis and its aftermath negatively affects productivity, causing a decrease of 5.50% c.p. in GDP, 4.50% c.p. in GDP per capita, while no statistical significance is found for GDP per hours worked.

Table 3: Macroeconomic considerations

VARIABLES	(1) Ln GDP	(2) Ln GDP per capita	(3) Ln GDP hours
Ln rail density	0.00696	0.00591	0.0177
	(0.0157)	(0.0152)	(0.0144)
Ln road density	-0.0273	-0.0476**	-0.0207
	(0.0205)	(0.0217)	(0.0194)
Ln population density	0.902***	-0.0448	0.839***
	(0.144)	(0.141)	(0.148)
Unemployment	-0.00392***	-0.00329**	-0.00343**
	(0.00137)	(0.00122)	(0.00141)
Human capital	0.00249	0.00207	0.00233
	(0.00213)	(0.00208)	(0.00212)
Ln road imports	0.0808**	0.0785**	0.0789**
	(0.0314)	(0.0309)	(0.0327)
Ln road exports	0.0775**	0.0758**	0.0815**
	(0.0291)	(0.0280)	(0.0321)
Financial crisis	-0.0550***	-0.0450***	-0.0275
	(0.0167)	(0.0161)	(0.0166)
Constant	18.84***	8.957***	15.51***
	(0.566)	(0.553)	(0.584)
Time fixed effects	YES	YES	YES
Observations	499	499	499
R-squared	0.918	0.865	0.932
Number of NUTS2Region	36	36	36

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

4.3 Regional differences

To test whether the effects of investment in road and rail infrastructure are different depending on the country analyzed, two interaction terms *Ln rail density X Italy* and *Ln road density X Italy* have been added to the baseline model. Furthermore, this model was tested a second time, with the inclusion of the time dummies.

4.3.1 Baseline

While in Spain a 1% increase in road density increases GDP in Spain by 0.647% c.p., in Italy that same increase in road density leads to a decrease in GDP of 0.037% c.p. This same pattern can be observed with GDP per capita: while a 1% increase in road density increases GDP per capita in Spain by 0.617% c.p., in Italy it decreases it by 0.054% c.p. With respect to rail density, it has a positive and significant effect for all indicators, and there is no statistically significant differences between the two countries. A 1% increase in rail density increases GDP by 0.0533% c.p. and GDP per capita by 0.0514% c.p, and GDP per hours worked by 0.0678% c.p.

Considering the controls, with the exception of *Ln road imports*, they are all statistically significant at a 1% level for all specifications (except for *Financial Crisis* on GDP per hours worked, whose significance decreases to 5%). Furthermore, they all have the expected signs. A 1% increase in population density increases GDP by 1.593% c.p., GDP per capita by 0.632% c.p. and GDP per hours worked by 1.564% c.p. A 1% increase in the unemployment rate decreases GDP by 0.899% c.p., GDP per capita by 0.820% c.p. and GDP per hour worked by 0.868% c.p. Human capital has a positive effect on productivity: a 1% increase in it increases GDP by 1.33% c.p., GDP per capita by 1.29% c.p. and GDP per hours worked by 1.52% c.p. Likewise, road exports also have a positive effect: a 1% increase in road exports increases GDP, GDP per capita and GDP per hours worked by 0.0920% c.p., 0.0893% c.p. and 0.110% c.p. respectively. In addition, the presence of the financial crisis and its aftermath decrease GDP by 3.43% c.p., GDP per capita by 3.14% c.p. and GDP per hours worked by 1.75% c.p.

Table 4: Regional differences

	Baseline			With macroeconomic considerations		
	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Ln GDP	Ln GDP per capita	Ln GDP hours	Ln GDP	Ln GDP per capita	Ln GDP hours
Ln rail density	0.0533**	0.0514*	0.0678**	0.0111	0.0101	0.0228*
	(0.0262)	(0.0257)	(0.0250)	(0.0155)	(0.0152)	(0.0132)
Ln road density	0.647*	0.584	0.602	0.414**	0.370*	0.405*
	(0.369)	(0.356)	(0.400)	(0.196)	(0.184)	(0.204)
Ln population density	1.593***	0.632***	1.564***	0.923***	-0.0240	0.863***
	(0.136)	(0.132)	(0.146)	(0.132)	(0.130)	(0.138)
Unemployment	-0.00899***	-0.00820***	-0.00868***	-0.00427***	-0.00364***	-0.00382***
	(0.000887)	(0.000784)	(0.000949)	(0.00132)	(0.00117)	(0.00137)
Human capital	0.0133***	0.0129***	0.0152***	0.00182	0.00143	0.00167
	(0.00204)	(0.00198)	(0.00240)	(0.00212)	(0.00207)	(0.00211)
Ln road imports	0.00811	0.00991	0.0125	0.0705**	0.0685**	0.0682**
	(0.0213)	(0.0217)	(0.0227)	(0.0298)	(0.0293)	(0.0308)
Ln road exports	0.0920***	0.0893***	0.110***	0.0727**	0.0714**	0.0774**
	(0.0285)	(0.0284)	(0.0311)	(0.0275)	(0.0264)	(0.0302)
Financial crisis	-0.0343***	-0.0314***	-0.0175*	-0.0415**	-0.0322**	-0.0141
	(0.00908)	(0.00886)	(0.00988)	(0.0161)	(0.0156)	(0.0154)
Ln rail density X Italy	-0.0317	-0.0342	-0.0405	-0.0459	-0.0485	-0.0628
	(0.0788)	(0.0738)	(0.0838)	(0.0557)	(0.0509)	(0.0620)
Ln road density X Italy	-0.684*	-0.640*	-0.623	-0.450**	-0.425**	-0.434**
	(0.371)	(0.359)	(0.403)	(0.196)	(0.184)	(0.205)
Constant	16.13***	6.261***	12.36***	19.05***	9.138***	15.67***
	(0.711)	(0.677)	(0.754)	(0.572)	(0.548)	(0.608)
Time fixed effects	NO	NO	NO	YES	YES	YES
Observations	499	499	499	499	499	499
R-squared	0.787	0.639	0.813	0.921	0.871	0.935
Number of NUTS2Region	36	36	36	36	36	36

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

4.3.2 Inclusion of macroeconomic considerations

When time fixed effects are introduced, *Ln rail density* retains its positive sign, though it is statistically significant only for GDP per hours worked and its magnitude is smaller compared to the baseline model. Furthermore, the interaction term *Ln rail density X Italy* keeps being insignificant, thus highlighting how there is no discernable country difference in the effect of rail infrastructure on productivity.

Considering road infrastructure, it has now a positive and significant effect for all specifications. However, when looking at the interaction term *Ln road density X Italy*, it is negative and significant at a 5% level throughout: while in Spain, a 1% increase in road density increases GDP by 0.414% c.p., GDP per capita by 0.370% c.p., and GDP per hours worked by 0.405% c.p.; in Italy it decreases those same productivity measures by 0.036% c.p, 0.055% c.p., and 0.029% c.p. respectively.

Comparing the controls to the ones in the baseline model, all of them retain their signs, and *Unemployment* also retains its level of statistical significance. *Human capital* becomes insignificant while *Ln road imports* becomes significant at a 5% level: 1% increase in road imports increases GDP, GDP per capita and GDP per hours worked by 0.0705% c.p., 0.0685% c.p. and 0.0682% c.p. respectively. Lastly, both *Ln road exports* and *Financial crisis* lose a level of significance, going from 1% to 5%, with the magnitudes of *Financial crisis* being higher, and the ones for road exports being lower.

4.4 Discussion and limitations

Following, there will be discussion on the extent that the results support or reject the hypotheses formulated in Section 2.5, and an overview of the main limitations of this paper.

4.4.1 Discussion

H1: *At a regional level, investment in road and rail infrastructure has a positive impact on economic performance*.

Hypothesis 1 refers to the baseline model. Looking at the results, one sees that depending on the type of investment, the effect on productivity changes. Regarding rail, one fails to reject H1 as the coefficients are positive and significant for all specifications. On the other hand, when considering road, one rejects Hypothesis 1 as it has a negative sign throughout all specifications, though being statistically significant only for GDP per capita. Thus, at a regional level, the effect of investment in transport infrastructure on economic performance cannot be generalized, but rather varies depending on the type of transport infrastructure analyzed.

H2: *The effect of investment in road and rail infrastructure on regional productivity was affected by EU macroeconomic conditions*

When controlling for the EU macro conditions, the effect of investment in the railways becomes insignificant for all specifications. With regards to road investment, it retains its negative effect (being significant at a 5% level for GDP per capita), though the magnitudes for all productivity measures have decreased compared to the baseline. Thus one fails to reject Hypothesis 2, as the macroeconomic conditions of the EU render the effect of investment in railways on productivity insignificant, and they also lead to a decrease in the magnitude of investment in the road network.

H3: *At a regional level, the investment in rail and road infrastructures has a different effect in the two countries under analysis*

Similarly to Hypothesis 1, results are mixed for Hypothesis 3: if one considers only rail infrastructure, Hypothesis 3 fails to be rejected. However, if one considers only road infrastructure, then Hypothesis 3 is rejected.

With the introduction of interaction terms, rail density is positive and statistically significant for all performance indicators, and no statistically significant difference exists between Spain and Italy (i.e. the interaction term *Ln rail density X Italy* is statistically insignificant). This lack of a difference between the two countries persists also when time fixed effects are added, however in this case railway density becomes insignificant.

On the other hand, road density is positive, and when time fixed effects are introduced, it becomes significant for all specifications. The difference between Spain and Italy in this case is significant however: while in Spain road density has a positive effect, in Italy it has a negative effect on productivity. This significant difference in the economic effect of investment on road in Spain versus Italy could be due to the fact that the road network in Italy developed at an earlier time than in Spain, thus its positive impact on the economy has already been absorbed. Alternatively, it could also be due to the relatively recent focus of the Italian government on the development and improvement of the railway infrastructure.

4.4.2. Limitations and recommendations

A prominent weakness is the use of road and rail density (a physical measure) instead of the investment in the infrastructure (a monetary measure) that made it impossible to take into account the state of deterioration, and it also inhibits the analysis of the interaction between public and private capital. Furthermore, a discussion on the negative environmental externalities attached to transport infrastructure is omitted from this paper. Its inclusion could potentially alter the results, especially if one considers the increasing public attention to pollution and its effects on health, the environment and climate.

Similarly, the time span under analysis was limited due to data unavailability of the regional productivity measures. Furthermore, it should be taken into account that during that time period, in both countries there was a strong focus on the development and improvements of the railway system, and also in encouraging firms to use railways as the transportation mode for freight.

Furthermore, another major weakness of this analysis is that instrumental variables, which would have attenuated the issue of simultaneity bias in the model, have not been used. Their application is, however, beyond the scope of this thesis. Nonetheless, it should be noted that given the fact that an instrumental variable has to fulfill two requirements: (1) it has to be uncorrelated with the error term, and (2) it has to be correlated with the dependent variable (Wooldridge, 2015), it becomes significantly challenging to find a suitable instrumental that fulfills these requirements at the regional level.

5. Conclusion and policy recommendations

Ever since the 1990s, renewed interest of academics and policymakers has been placed on the provision of transport infrastructure and its effect on productivity. Using a fixed effects panel for the years 2000 to 2015, this paper empirically examined the relationship between rail and road infrastructure, and the economic performance of Italy and Spain In addition, it also analyzed whether the effect of transport infrastructure on productivity was affected the macroeconomic conditions of the EU, and whether the infrastructure affected the two countries differently.

In line with the majority of the existing literature (e.g. Chandra and Thompson, 2000; Aschauer, 1989a and 1989b; Holl, 2004a and 2004b; Anderson and Lakshmanan, 2007), results are mixed. Depending on the type of transportation infrastructure used, the effects on output could be the complete opposite of each other. Thus, given the fact that the positive effects of transport infrastructure are not clear-cut, governments should not overestimate the impact that infrastructure can have on the economy. Rather, governments should not focus on infrastructure investment in isolation, because as shown from Hypothesis 2, external macroeconomic phenomena can change the impact of infrastructure investment on productivity, and even make it become insignificant. Thus, investment in transport should be complemented with other policies targeting the labor market, the enhancement of a location's attractiveness for investments, and strengthening the government's investment in human capital.

Finally, there are certain areas for further research. For instance, this paper focused on the physical infrastructure and its impact on productivity, but perhaps attention should also be given to the efficiency of the service provision. This could be done by complementing the findings of this paper with an analysis on the state of privatization of service provision in the various countries. Connected to this first point, this same research could be re-conducted not on an aggregate level, but looking at specific industries inside a country and observing the extent that road and rail infrastructure affect a specific industry output. Furthermore, in this paper attention was only given to land transport infrastructure, thus excluding ports and airports. An inclusion of these two other modes of transportation would give a more complete image of the extent that transportation interacts with the economy. Lastly, as most of the T-ENT projects are still ongoing and should be completed by the early 2020s. It would then be interesting to investigate the extent of their impact and whether that would bring a change in the economic composition of the regions involved.

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Appendix

A. Regional codes

Reference Code	Region Name	Reference Code	Region Name
211	Piemonte	**401**	Galicia
212	Valle D'Aosta	**402**	Principado de Asturias
213	Liguria	**403**	Cantabria
214	Lombardia	**411**	País Vasco
221	Provincia Autonoma di Bolzano	**412**	Comunidad Foral de Navarra
222	Provincia Autonoma di Trento	**413**	La Rioja
223	Veneto	**414**	Aragón
224	Friuli-Venezia Giulia	**420**	Comunidad de Madrid
225	Emilia-Romagna	**431**	Castilla y León
231	Toscana	**432**	Castilla-La Mancha
232	Umbria	**433**	Extremadura
233	Marche	**441**	Cataluña
234	Lazio	**442**	Comunidad Valenciana
241	Abruzzo	**443**	Illes Balears
242	Molise	**451**	Andalucía
243	Campania	**452**	Región de Murcia
244	Puglia	**453**	Ciudad Autónoma de Ceuta
245	Basilicata	**454**	Ciudad Autónoma de Melilla
246	Calabria	**460**	Canarias
251	Sicilia		
252	Sardegna		

B. Variable definitions and sources

Variable	Description	Source
Ln GDP in PPS	Measured in current market prices	Eurostat: Regional Economic Accounts
Ln GDP per capita in PPS	Measured as ratio of GDP/total population	Own calculations
Ln GDP per hours worked in PPS	Measured as ratio of GDP/average number of weekly hours of work	Eurostat: Regional Labor Market Statistics and own calculations
Ln Rail density	Measured as ratio of rail length/area of NUTS2 region	Eurostat: Regional Transport Statistics and own calculations
Ln Road density	Measured as road length/area of NUTS2 region	Eurostat: Regional Transport Statistics and own calculations
Ln Population density	Measured as total population/area of NUTS2 region	Eurostat: Regional Demographic Statistics and own calculations
Unemployment rate	Measured as percentage of the total active population (15-74 years)	Eurostat: Regional Unemployment Statistics
Human capital	Measured as percentage of population aged 25 to 64 years with an educational attainment of at least upper secondary and post-secondary, but non-tertiary	Eurostat: Regional Educational Statistics
Ln Road imports	Measured in Million Tonne-Kilometer	Eurostat: Regional Transport Statistics and own calculations
Ln Road exports	Measured in Million Tonne-Kilometer	Eurostat: Regional Transport Statistics and own calculations
Presence of a crisis	Dummy variable, takes value 1 if there is a crisis, 0 otherwise	Own calculations
Italy	Dummy variable, takes value 1 if the region is in Italy, 0 otherwise	Own calculations
*Ln Rail density * DummyITA*	Interaction term between the log of rail density and the dummy *DummyITA*	Own calculations
*Ln Road density * DummyITA*	Interaction term between the log of road density and the dummy *DummyITA*	Own calculations

C. Correlation matrix of the main variables

	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*
(1) Ln GDP	1.00										
(2) Ln GDP per capita	0.23	1.00									
(3) Ln GDP per hours worked	1.00	0.24	1.00								
(4) Ln Rail density	0.49	0.35	0.50	1.00							
(5) Ln Road density	0.19	0.13	0.20	0.70	1.00						
(6) Ln Population density	0.66	0.29	0.66	0.77	0.57	1.00					
(7) Unemployment	0.01	-0.58	0.02	-0.23	-0.23	-0.11	1.00				
(8) Human capital	0.09	0.41	0.10	0.61	0.69	0.35	-0.41	1.00			
(9) Ln road imports	0.88	0.15	0.88	0.27	-0.02	0.39	0.14	-0.14	1.00		
(10) Ln road exports	0.83	0.14	0.83	0.22	-0.04	0.35	0.12	-0.16	0.99	1.00	
(11) Financial crisis	0.05	0.20	0.06	0.13	0.13	0.04	0.33	0.22	0.11	0.10	1.00