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TRANSPORT INFRASTRUCTURE AND TRADE: A SURVEY OF THE EMPIRICAL LITERATURE

ABSTRACT

In this study we survey the empirical literature on the effects of transport infrastructures on trade. In particular, we group studies into those that have estimated gravity equations of trade and those that belong to the Counterfactual Impact Evaluation tradition. Our understanding of the empirical literature is that denser and high quality transportation networks generally lead to more international and inter-regional trade. However, for some modes of transport (e.g. maritime trade), more research is needed, as it is perhaps the case for the debate on the net effect versus spatial reorganization of economic activity of transportation networks.

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RIASSUNTO

Infrastrutture di trasporto e commercio: una panoramica della letteratura empirica

In questo studio esaminiamo la letteratura empirica sugli effetti delle infrastrutture di trasporto sul commercio. In particolare, raggruppiamo gli studi tra quelli che hanno stimato le equazioni di gravità del commercio e quelli che invece appartengono alla tradizione della valutazione d'impatto controfattuale. La nostra interpretazione della letteratura empirica è che reti di trasporto più dense e di alta qualità contribuiscono in genere a un incremento nel commercio internazionale e interregionale. Tuttavia, per alcune modalità di trasporto (ad es. il commercio marittimo), sono necessarie ulteriori ricerche, come nel caso del dibattito esistente in merito al fatto che le reti di trasporto generino effetti economici netti o contribuiscano invece semplicemente ad una riorganizzazione dell'attività economica nello spazio.

1. Introduction

The immediate impact of an expansion in transport network capacity (or an improvement in its quality) is to lower transport costs by reducing distance, congestion and travel times. As a result, production costs drop, total factor productivity increases and output grows (provided that private capital investments are not crowded out). Moreover, the improvement in transport infrastructure, by reducing travel time and costs, increases markets accessibility and favors trade, thus enlarging relevant markets for firms and allowing the exploitation of comparative advantages and scale economies. Inter-regional and cross-country trade expansion generate output growth and induce productivity enhancing competitive pressure that affects firm dynamics, economy restructuring and improvement in the quality of production factors. Furthermore, higher intra-industry trade supports the diffusion of technology and knowledge, thus promoting innovation and growth. Hence, understanding the impact of infrastructure investments on trade becomes highly relevant, because it is perhaps the main channel through which transport infrastructures affect the level of economic activity, the birth (or relocation) of new firms and even the growth of productivity. Unfortunately, while there are many empirical works on the effects of transport infrastructure on GDP, value added, productivity or employment and a few literature reviews have already attempted to systematize that body of work (see, for a recent survey Ferrari *et al.*, 2018), in our opinion the empirical literature on the effects of transport infrastructure on trade has been still developing and, at this stage, a literature review might be helpful to understand what we (do not) know on the subject. First, it is important to acknowledge that several studies have empirically analyzed this issue following different approaches. Indeed, studies differ according to the type of infrastructure analysed, i.e. roads, ports, airports, railways, but also there are substantial differences in terms of the identification strategy and econometric methodology, i.e. panel fixed effects, GMM, spatial econometrics and counterfactual impact evaluation methods. Furthermore, there are also important differences in the samples considered: the data may be more or less disaggregated (e.g. country, region, or province level) and also may refer to the total economy or even to individual firms (in this case they may even refer to a specific sector). Finally, empirical studies have focused on both international trade flows and intra-national flows, i.e. inter-regional trade.

In this survey we distinguish studies according to the methodological approach that have been used and we group them in two classes, namely those based on estimation of a gravity model of trade and those adopting an identification strategy based on counterfactual impact evaluation methods. We also discuss some contributions that have followed a spatial econometrics approach.

2. Gravity model studies

The gravity model for international trade is a model that links bilateral trade between two countries directly with their economic size and inversely with trade costs that depend on geographical distance and on other variables[1]. The most popular empirical gravity equation can be expressed as follows[2]:

$$lnX_{ij,t} = lnY_{i,t} + lnE_{j,t} + (1-\sigma)lnt_{ij,t} - (1-\sigma)ln\Pi_{i,t} - (1-\sigma)P_{j,t} + \epsilon_{ij,t}$$

where $X_{ij,t}$ represents bilateral trade between country *i* (origin) and country *j* (destination), $Y_{i,}$ is the GDP on the origin country, $E_{j,}$ is the expenditure in the destination country, σ is the elasticity of substitution, and $t_{ij,t}$ represents trade costs. Importantly, two other terms are introduced in the model: $\Pi_{i,t}$ and $P_{j,t}$ that account for the outward and inward multilateral resistance, respectively (Anderson and Van Wincoop, 2003). The former captures the fact that exports from the origin country to the destination country depend on trade costs across all possible export markets (exporter *i*'s ease of market access), while the latter captures the dependence of imports into origin on trade costs across all possible suppliers (importer *j*'s ease of market access). The empirical estimation of the gravity equations raises several challenges that need to be dealt with. First, the multilateral resistances components are not observable. Different approaches to address this problem have been proposed in the literature, the most common being to approximate the multilateral resistance components with "remoteness indexes" (see among others Baier and Bergstrand, 2009), or to include exporter and importer fixed effects in the model (Feenstra, 2015). In particular, in a panel setting, the inclusion of exporter-time and importer-time fixed effects, not only would control for multilateral resistances, but also for $E_{j,t}$ and $Y_{i,t}$, as well as all other country-specific characteristics, as noted

[1] Initially, the basic gravity of international trade model considered two explanatory variables, namely GDP and distances between two countries. Subsequently, the model was modified to take into account some fundamental dimensions to explain international trade patterns (Sheperd, 2016), such as GDP *per capita*, exchange rate, trade-to-GDP ratio, inflation and taxes (Kubendran, 2020). As a way of example, Mosikari (2016) augmented gravity model by using consumer's prices and exchange rate effect on exports of agriculture, forestry, and fishing.
[2] In what follows, we largely follow Yotov *et al.* (2016).

by, among others, Olivero and Yotov (2012). Another important issue is related to the way trade costs are estimated. Usually, researchers approximate bilateral trade costs by using a set of observable variables like geographical distance, common borders, common language, common colonial history, and trade policy variables. It is worth noting that in panel settings the inclusion of pair fixed effects can account for all time-invariant bilateral trade costs (Agnosteva *et al.*, 2014; Egger and Nigai, 2015).

Among the earliest studies that analyze the role of domestic infrastructure on trade by estimating a gravity model is the work by Nicolini (2003). However, the author does not consider bilateral trade, but the regional industry export flows of six European regions. Since flows are let to depend on geographical factors and home market size (proxied by GDP per sq. km), in some specifications the author inserts a measure of the degree of organisation of the transport system, i.e. the density of the transport network (railways, roads, motorways, etc.) in each region[3].

Portugal-Perez and Wilson (2012) investigate the impact of “hard” and “soft” infrastructure on the bilateral trade of 101 countries in the period between 2004 and 2007. Specifically, the authors adapt the international trade model proposed by Helpman *et al.* (2008) to incorporate some infrastructure indicators into the gravity model and use a two-stage Heckman selection model[4]. Specifically, through factorial analysis, four infrastructure indicators are calculated at country level, two belonging to the “hard” dimension and two relating to the “soft” dimension of infrastructures. In particular, the hard dimension is made up by the physical infrastructure index that takes into account the level of development and quality of ports, airports, roads and railways. The results of the analysis show that improvements in infrastructure quality benefit export growth and that the physical infrastructure index seems to have the greatest impact.

Francois and Manchin (2013) also use a gravity model to estimate the impact of infrastructure and institutions on trade. Specifically, the authors rely on principal component analysis to construct two infrastructure indices and two institutional indices to be included in the model. Concerning the former, they identify a communication infrastructure index and a physical

[3] This framework is then adopted by Matthee and Naudé (2008), who, using data on 354 magisterial districts in South Africa, instead of the density of the transport system, enters into the model the distance from each magisterial district to its nearest export hub and the surface area of each magisterial district.
[4] In order to take multilateral resistance terms into account and be able to estimate the impact of the infrastructure indices, calculated at country level, the authors follow the strategy proposed by Baier and Bergstrand (2009).

infrastructure index, which also includes the road endowment of each country. The study analyses panel data on international trade between several high- and low-income countries and shows that exports depend, among other factors, on well-developed transport infrastructures as well as on institutional quality[5].

In a more recent paper, Bottasso *et al.* (2018) use a gravitational fixed-effects model to estimate the effect of port infrastructure on trade, considering both export and import values of Brazilian states observed over the period 2009-2012. The results of the study confirm the relationship between international trade, GDP, population and distance and find evidence of a significant role of port endowment (as measured by the total quay or pier extension in ports in each state divided by that state's total area) to foster international trade flows. The authors include in the model a set of fixed effects, like importer-exporter, importer-by-year, and exported-by-year fixed effects; moreover, to handle with possible remaining endogeneity issues, they also estimate a model where all main variables are lagged one period and they perform the test for strong exogeneity for fixed effects models proposed by Wooldridge (2010)[6].

In Donaubauer *et al.* (2018) authors use a two-step approach in a gravity model framework using data on 150 countries (both developed and emerging economies) observed over the period 1992-2011, which is indeed a quite long time span if compared with previous studies. First, authors estimate an augmented gravity model and investigate the impact of infrastructures on bilateral trade. The authors rely on an index of infrastructure for both the exporting and the importing country, plus an index of similarities in the countries' endowment of infrastructure. In particular, infrastructure quantity and quality is proxied by a composite index that consists of four sub-indices of infrastructure in transport, communication, energy, and finance[7]. Results from this analysis suggest that bilateral trade increases with better infrastructure endowments and that trade relations are stronger between countries with more similar infrastructure capacity. Furthermore, to disentangle the impact of infrastructure on trade and trade costs, authors follow a two-step approach as proposed by Head and Mayer (2014). In the first stage of

[5] Also in this case the authors follow Baier and Bergstrand (2009) and do not include country fixed effects dummies. Concerning endogeneity issues, authors rely on a lagged value of both infrastructure and institutional indexes.
[6] On port efficiency and trade see also Clark *et al.* (2004), where authors construct an index of country-specific maritime transport costs that is included in a standard trade gravity model and show that an increase in country-specific transport costs is associated with a reduction in bilateral trade. Building on Clark *et al.* (2004), Blonigen and Wilson (2008) estimate an equation for import charges for a panel covering the period 1991-2003. For a critical review of these two works see Ferrari *et al.* (2018).
[7] Authors rely on the infrastructural index constructed by Donaubauer *et al.* (2016).

the analysis authors estimate a standard gravity model where they let the bilateral exports between two countries to depend on trade costs and on infrastructure endowments of both exporter and importer, i.e. their index of similarities, accounting for a complete set of country-pair fixed effects as well as exporter-time and importer-time fixed effects. In the second step they regress the estimated exporter-time and importer-time fixed effects on the infrastructure capacity of the country, a set of country-specific covariates, and on trade costs determinants. Furthermore, they assess the effect of infrastructure on trade costs, both using as dependent variable calibrated trade costs and estimated trade costs from the first-stage of the analysis. In both analysis the significant impact of infrastructure is confirmed: in particular, a denser and higher quality infrastructure decreases trade costs.

In Wessel (2019), the author uses trade flows from 20 EU reporting countries to 28 EU partners, differentiating between five transport modes (road, railroad, sea, inland waterways, and air). In this case, the author does not use an aggregate indicator as in Donaubauer *et al.* (2016); Francois and Manchin (2013); Portugal-Perez and Wilson (2012), and uses infrastructure indicators at the level of each transport mode and also distinguishes between quality and quantity of infrastructure[8]. Using traditional gravity model variables together with infrastructure indices, and accounting for a complete set of control variable as well as multilateral resistance term calculated following Baier and Bergstrand (2009), the author find that quality of infrastructure is an important determinant for air and rail trade, while only improvement in road density seems to positively affect road trade. Moreover, the author confirms previous finding of Francois and Manchin (2013) and Bottasso *et al.* (2018) by observing that infrastructure improvements have a greater impact on exports than on imports.

More recently, Karymshakov and Sulaimanova (2021) have investigated the impact of transport infrastructure for Central Asian countries. In particular, authors consider bilateral trade of Kazakhstan, Kyrgyzstan, and Tajikistan with their main trading partners, for the period 2010-2018. They focus on air transport and railway infrastructure, and following Wessel (2019), they distinguish between quality and quantity of infrastructure. In particular, they consider as quantitative measures the total route of rail lines in kilometers, and for air transportation, the number of registered carried departures worldwide; while as qualitative measures they refer to

[8] For quality of infrastructures the author uses data from the Global Competitiveness Report of the World Economic Forum, while for the quantity of infrastructure he relies to different physical indicators from EUROSTAT, i.e., for example, length in km of roads and rails.

the above mentioned Global Competitiveness Report. Interestingly, in their empirical model specification of the augmented gravity model they also account for non-linearity of the infrastructure impact, by including the square values of the infrastructure variables. Results from the analysis show that both the quality and quantity of infrastructure in Central Asia have positive impacts on trade flows, while the positive effect of infrastructure development investment decreases over time.

Finally, it is important to mention the work by Donaldson (2018) where the author develops a model to assess the historical impact of colonial railways in India (the "Raj") on price differentials across regions, trade flows and incomes. The author constructs a panel database on 235 Indian district from 1870 to 1930, the period in which British India's current railroad lines were opened. The author performs different analysis, and after demonstrating that India's railroad network reduced trade costs, in a second step analysis he estimates a fixed-effects gravity equation to investigate the extent to which this reduction in trade costs affected bilateral trade volumes (data on bilateral trade refer to physical quantities of internal trade among 47 trade blocks for agricultural commodities, plus salt). The main explanatory variable of the model is the effective distance between origin and destination along lowest-cost route that is negatively correlated with bilateral exports. Results from the first and the second step of the analysis strongly support the hypothesis that railroads improved the trading environment in India.

3. COUNTERFACTUAL IMPACT EVALUATION STUDIES

Many of the studies analysed so far have sidelined the discussion of the identification assumptions on which the hypothesis of exogeneity of transport capital is based. In recent years, however, the literature on the economic effects of transport infrastructure capital has brought causality and identification issues to the forefront of empirical work. Counterfactual impact evaluation (CIE) methods are empirical methods that place great emphasis on the concept of the counterfactual, which, broadly speaking, can be defined as what would have happened to the treated units (such as states, regions, or individuals) had they not been treated[9]. The purpose of these methods is precisely to credibly define the counterfactual. In scientific experimentation that randomly assigns units to a treatment group the causal effect can be measured as an average difference in outcomes between the treatment group and the control group, the latter acting as a

[9] Refer to Angrist and Pischke (2009) and Imbens and Wooldridge (2009) for an in depth discussion.

counterfactual, but in most areas of economics scientific experimentation is very problematic. This is certainly true in the case of transportation infrastructure, which cannot be randomly assigned. Then, when analyzing observed data, the control group that did not receive the treatment (such as the construction of a new airport, or the construction of the high-speed rail line) is far from the ideal characteristics of the control group in scientific experiments. Empirical researchers have identified ways to identify the effect of a policy or spending program as the average difference in outcomes between the treated (or most intensively treated) units and the (valid) counterfactual. In this study, we focus primarily on two methods that have gained popularity in the literature on the economic effects of transportation infrastructure, namely differences in differences and instrumental variable (IV) strategies. Differences-in-differences methods aim to establish causality by combining information of a "before-after" study with that of a treatment and a control group. If we suppose that the government invests in the construction of a new highway and that at time T the new road is opened up, certainly there are municipalities affected by the new highway that are considered treated, and municipalities not crossed by the new highways that form the control group. In this approach, the impact of the new highway on a specific economic outcome, such as the value of exports, is measured as the average difference in value of exports at time T – 1 (before) and at time T + 1 (after) for municipalities belonging to the treated group, minus the average difference in value of exports at time T – 1 and at time T + 1 for municipalities belonging to the control group. Turning to IV methods, this approach aims to tackle the endogeneity problem by using only the exogenous variation in the explanatory variable in order to identify its impact on the outcome variable. In this approach it is necessary to have at least one variable, called "instrument", that should be correlated with the endogenous regressor; moreover, the instrument needs to be valid, i.e. it should affect the outcome variable only by affecting the endogenous right- hand side variable. In particular, the validity of the instruments needs to be justified case-by-case although it is often justified on the basis of economic theory or historical reasons. Importantly, studies in this literature do not use internal instruments (i.e. lagged values); indeed, they rely on "external instruments" which are found using a combination of economic reasoning, knowledge of history, past policy decisions and geography. In transport infrastructure context, three main approaches can be identified: the planned route approach[10], the historical route approach[11] the incidental beneficiaries approach[12].

[10] Pioneered by Baum-Snow *et al.* (2017). The author uses the plan for the US highways network in 1947 as a source of

Several studies have applied counterfactual impact evaluation methods to analyse the role of transport infrastructure on trade. A seminal work in this literature is Duranton *et al.* (2014), where the authors developed a theory of roads and trade to derive a characterization of the equilibrium relationship between them[13]. Their work considers bilateral exports of the Metropolitan Statistical Areas (MSAs) in the US and the analysis is based on a two-stage identification strategy very similar to that used in Redding and Venables (2004): the first stage uses a gravitational model (Anderson and Van Wincoop, 2003), while the second stage involves estimating the impact of road endowment on the export propensity of US cities. Specifically, the authors use data on bilateral trade of MSAs expressed in both weight and monetary value to estimate a gravity model to obtain estimates of export and import fixed effects, which are considered proxies for export and import propensity, respectively. The estimated fixed effects become the dependent variable of the second stage model where among the explanatory variables, such as labour, population, and manufacturing, the road endowment of each MSA is used. The authors use a "historical route" instrumental variable approach together with the "planned route" instrumental variable approach to overcome endogeneity problems. In particular, the authors use three instruments for the current road endowment: the routes of the major exploratory expeditions between 1528 and 1850, the 1898 railway routes, and the 1947 plan for the interstate highway system. The main result of the analysis is a strong impact of highway endowments within cities on the weight of their exports: the authors estimate an elasticity of about 0.5. A much smaller impact is estimated for export value, although when short-distance trade is analysed, a positive and significant impact on export value is found.

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quasi-random variation for the way the interstate highways network actually developed in the successive decades.

[11] Pioneered by Duranton and Turner (2012). The authors use a map of the US railroads network at the end of the 19th century as a source of quasi-random variation for the actual development of the US interstate highways system. Other examples include Garcia-Lopez *et al.* (2015) who estimates the effect of highways on suburbanization of Spanish cities using Roman roads and the 1760 Bourbon roads as instruments for actual highways; Holl (2016) who instrumented distance to highways with information on Roman roads and Spanish postal routes in 1760, and Percoco (2016) who used the network of Roman roads in Italy as a proxy for an highway's exit, among the others.

[12] This approach grounds on the fact that transport networks are usually built in order to connect a few major cities and some cities that are along the network might have been connected just because they were located near the shortest and least cost line between any two major nodes of the network. In this case, by excluding the terminal nodes of the network, the effect of the network on economic outcomes can be estimated with OLS-based methods. For an example see Jedwab and Moradi (2016).

[13] A previous related work is Michaels (2008). In his analysis, the author, using the advent of the US Interstate Highway System as a natural experiment, estimates the impact of reducing trade barriers on skill demand. The analysis in based on the famous Heckscher-Ohlin model and uses highways that were mostly built between 1959 and 1975 to connect cities and border crossings and to serve national defence. However, as a result, the new motorways network crossed many rural counties and, using as a valid instrument the original plan of routes proposed in 1944 to follow an IV approach, the author finds that these counties increased trade-related activities, such as trucking and retail sales.

Furthermore, the authors also estimate a set of auxiliary regression for railways endowment and they find that a denser railways network within a Commodity Flow Survey area increases the weight but not the value of that MSA's exports (with a magnitude that is even larger than in the motorways case). Finally, it is worth highlighting that the fact that more motorways (and railways) lead to an increase in the weight of exports and not in its value (except for short distance trade) suggests that the first order effect of road investment is to induce a reorganization effect, with cities with higher motorway endowment specializing in the production of heavier goods, with not much effect on the global value of trade.

The external validity of results obtained in Duranton *et al.* (2014) is investigated in Duranton (2015), where the author replicates the two-step methodology in Columbia. The author uses an "historical route" instrumental variable approach using two type of instruments: the routes from the era of colonization and the road network in 1938. In this analysis, data on trade refer both to weight and value of exports and several sources are used to construct the "road index": the number of principal roads, the mileage of these roads and the number of exits from the municipality by principal roads. Results from the IV estimates reveal that both trade in value and in weight is affected by the road capacity of each Columbian city. In particular, the estimated elasticity of trade with respect to within city roads is approximately 0.20 for OLS estimates and up to 0.50 for IV ones. Interestingly, the impact is stronger for value of exports than for the weight of exports. When comparing these results with those in Duranton *et al.* (2014) one should consider that trade in Columbia is typically a short-distance trade (at most about 1000 km): results for exports in values are very similar to results obtained in Duranton *et al.* (2014) when authors restrict the sample to trade taking place over less than 1000 km.

Volpe Martincus and Blyde (2013) use a natural experiment to assess the impact of transport infrastructure endowment on firm's export: they exploit the exogenous variation in transport capacity associated with the earthquake that took place in Chile in 2010. As a result of this natural disaster, some firms had to face a significant downgrade in both the quality and capacity of their transport networks[14]. After collecting disaggregated firm-level data (transaction-level data for all manufacturing firms[15]) they perform a difference-in-difference analysis, where the

[14] Roughly 9% of the total paved road network was affected by the earthquake.
[15] For each firm, the authors collect data on the geographical origin of exports, the quantity of goods shipped, the number of shipments, and the exit customs for each product-destination, before and after the earthquake (one year before and one year after).

main explanatory variable is a binary indicator that indicates whether the domestic routes that exporting firm originally used to ship a specific product to a specific country were damaged by the earthquake. Their sample period covers two years, from February 2009 to February 2010, so that the estimated impact of the reduction of the transport endowment can be considered only over a short-run period. Results from this analysis suggest that the decrease in available infrastructure had a negative effect on the quantity of shipped goods. Moreover, this effect is not associated to larger exports of Chilean unaffected firms, suggesting that spatial reorganization of economic activity did not play a key role in their data.

In a more recent work, Volpe Martincus *et al.* (2017) combine the difference-in-difference strategy with an IV approach[16], to study the impact of an asymmetric expansion of the road network that affected Peru between 2003 and 2010 (the country's main road endowment roughly increased of 10%). This expansion reduced the time to reach the nearest port for some firms but not for others, so that firms in locations that were not affected by the improvement in roads capacity can be considered as the control group. The authors collect highly disaggregated data on exports for 1999, 2002, 2003, and 2005-2010 from the Peruvian firms and were able to construct a dichotomous variable that take value 1 if the exporting firm experienced a reduction in the distance to ship the product to the nearest port, and 0 otherwise. The results suggest in a very robust way that the increase in road endowment made it possible for firms to increase their exports.

Another important example in this literature is Coşar and Demir (2016), where the authors analyse the impact of a huge public infrastructure investment that affected Turkey in the 2000s, whose aim was to improve the road network by expanding individual carriageways into dual carriageways. The authors collect data on international trade flows from each province and the Turkish gateway port, and by relying on a gravity model framework, they regress the change in foreign trade of the Turkish provinces between 2003 and 2012 on distances between provinces and gateway provinces and on the increase in road capacity, plus a set of gateways and provinces fixed effect. Moreover, in some specifications, they rely on an instrumental variable approach and they instrument the change in road capacity with the initial share of expressways at the

[16] Authors use the pre-Columbian Inca road network as an instrument for the modern road network.

beginning of the period. Results from this analysis suggest that the increase in road capacity is associated to a large and significant increase in trade flows[17].

Finally, for what concerns the impact of airports on trade a seminal work is that of Alderighi and Gaggero (2017) where authors use a panel database on exports of Italian regions with 24 European countries over 25 semesters (from 1998 to 2010) and use as a measure of air accessibility the number of non-stop flights. They estimate a gravity equation and control for a complete set of fixed effects. To overcome possible endogeneity issues, the authors instrument the number of non-stop flights with its own 3 to 5 semester lags and also with an external instrument. The results from the analysis suggest that an increase in scheduled flights is associated to a positive and statistically significant increase in exports[18].

A separate discussion is devoted to the works that have studied the impact of transport infrastructure on trade using a spatial econometric approach. A key issue in this literature is that related to the measurement of spillover effects associated to transport infrastructure investments.

Márquez-Ramos (2016) has analysed bilateral exports from 19 Spanish regions to 45 countries by estimating a spatial auto-regressive version of a gravity model. In particular, the author focuses on port facilities as proxied by the percentage of sea traffic over total traffic in Spain; moreover, she also uses a variable based on the Global Competitiveness Report to measure the quality of the destination port infrastructure. First, a spatial matrix is constructed by considering the geographical contiguity, the relative importance of port facilities in exporting regions, and the quality of ports in the importing countries. Then, a set of cross-section regressions (for the years from 2001 to 2008) is estimated including, among the traditional gravity variables, the interaction between the spatial matrix (W) and the lagged dependent

[17] In a more recent work, Coşar *et al.* (2022) rely on the same investment program analysed in Coşar and Demir (2016) to investigate its impact on district-to-district trade in Turkey, that captures a larger fraction of total economic activity. As a proxy for transportation costs they used GIS-based district-to-district travel times, and they have digitized the maps of road system before and after the investment program. The authors use as dependent variable of their main model the 10-years change in the logarithm of the value of bilateral trade between each exporting and importing district-pair and they demonstrate that the decrease in bilateral travel times resulted in a positive impact on trade flows at district level (as well as local manufacturing employment and wages).

[18] For an in-depth critical analysis of Duranton *et al.* (2014); Duranton (2015); Volpe Martincus *et al.* (2017); Alderighi and Gaggero (2017) see Ferrari *et al.* (2018).

variable ($X_{ij,t-1}$)[19]. Finally, the author estimates a dynamic panel model using the second and the third lag of the interacted term, i.e. $(W_t)X_{i\,j,t-2}$ and $(W_t)X_{i\,j,t-3}$. Results from this analysis suggest that spatial spillovers play a larger role than regional port facilities[20].

Another paper where a spatial econometric approach is used is Tsekeris (2017), where a dynamic Spatial Durbin model is estimated to assess how changes in the transport conditions of one region can affect its and neighbouring regions' foreign trade performance. In particular, the authors use data on exports of 51 prefectures of Greece over the period 2004-2012 and refer to four different dependent variables: agricultural goods exports by ship, agricultural goods export by truck, manufactured goods exports by ship, and manufactured goods exports by truck. Among the set of covariates, they include an accessibility index as well as several spatially structured dummy variables accounting, for example, for the presence in a specific prefecture of a major highways corridor or of a main international gateway to Western Europe. Results from this analysis suggest that several spatially lagged effects are significant for the regional export trades.

4. Conclusion

The literature that has analysed the relationship between infrastructure and bilateral trade within the gravity model framework strongly supports a positive impact of transport infrastructure on bilateral trade. Such results are based on the use of composite indices of infrastructure (e.g. Portugal-Perez and Wilson, 2012; Francois and Manchin, 2013; Donaubauer *et al.*, 2016), with the notable exception of Bottasso *et al.* (2018), which studied the impact of port infrastructure.

The empirical literature that has analyzed the impact of transport infrastructure investments on trade with CIE methods suggest that roads matter for international trade. This result does not depend on the type of country, as positive effects are found for Turkey, Chile, Colombia, and Peru, neither on the research design. Moreover, the effects that are uncovered in the various empirical estimates seem to be consistent with a "trade creation" effect, rather than a spatial

[19] The author also estimates a series of cross-section gravity regressions from 2000 to 2008 including among the explanatory variables port facilities of both exporter and importer and results suggest a positive effect on international trade.
[20] It is worth noting that spatial spillover effects are also analysed in Bottasso *et al.* (2018), since the authors include the so-called "spatial lag" of port infrastructure, where the matrix of weights is a contiguity matrix. The coefficient of the spatial lag is positive but not statistically significant.

reorganization of economic activity story, although two important studies. i.e. Duranton *et al.* (2014) and Volpe Martincus and Blyde (2013), suggest that the local economic effects of highways might be the result of non-negligible spatial reorganization. However, as far as the other modes of transport are concerned, it seems fair to say that there are fewer studies in the literature and that their research design raises some concerns, as there is a lack both of convincing instruments and of quasi-natural experiments. In the case of ports, there are robust correlations between port infrastructures and port efficiency and international trade in the case of the US, Brazil and Spain, while, in the case of airports, one single study explores the relationship between the airport sector, proxied by traffic flows, and international trade, finding a positive effect. Similarly, the evidence on railroads is even sparser: Duranton *et al.* (2014) report some evidence for the US which is consistent with railways fostering trade in weight but not in value, while Donaldson (2018) report evidence for 19th century India which is consistent with railways leading to more trade.

Finally, the literature that studied the relationship between transport infrastructure and trade seems to support the thesis that spatial spillover effects play an important role in determining regional trade.

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