The spatial effects of transportation on industrial employment

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Abstract: This paper examines the direct and indirect impacts of transport infrastructure on industrial employment. We estimate regressions with spatial econometric methods using data from the Spanish regions for the period 1995-2008. We find that the density of motorways and the amount of port traffic (particularly general non-containerized and container traffic) are significant determinants of industrial employment in the region, while the effects of railway density and the amount of airport traffic are unclear. Our empirical analysis shows the existence of significant negative spatial spillovers for the density of motorways and levels of container port traffic while the impact of general non-containerized port traffic seems to be mainly local.

Keywords: transportation, industrial employment, spatial econometrics, motorways, ports, railways, airports.

JEL Codes: L92, O18, R4

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1. INTRODUCTION

Transport infrastructure is crucial for the development of countries, regions and cities. Indeed, better infrastructure implies a greater outlay of public capital and, hence, higher productivity of private factors, fewer transport costs for firms and greater accessibility to territories. For this reason, a number of empirical studies have used production or cost functions to examine the impact of infrastructure on economic growth, and while most focus on aggregate amounts of public capital some distinguish between roads and other types of infrastructure. The geographical unit of analysis varies across these studies, from the national to the regional or local level.

Early examples of studies using production functions include Aschauer (1989), Munell (1990), Garcia-Milà and McGuire (1992) and Holtz-Eakin (1994), while example of studies using cost functions include Morrison and Schwartz (1996) and Nadiri and Mamuneas (1994).[1] While it is generally accepted that public capital may have positive direct effects, the magnitude of this impact is still a matter for debate.

Advances in spatial econometric techniques have allowed researchers to address other research questions in this field, most notably the quantification of spatial spillovers between neighboring regions from better infrastructure (Cohen, 2010). Thus, it has been possible to examine whether territories benefit not only from their own infrastructure but also from the endowment of their neighbors. In the case of transport infrastructure, both positive and negative regional spillovers have been found.

We generally expect improvements to the transport infrastructure of one region to have an influence on other regions because of their network nature. This is particularly true in the case of roads and railways but less so in that of airports and ports, whose networks are built by firms (i.e., airlines and shippers) that produce transport services without having to make any sunk cost investments. Moreover, maritime and air transport services are more competitive on medium- and long-haul routes, while road transport services may be better suited to short-haul routes.

Several studies of the impact of roads and highways on the output of states or counties in the US find evidence of non-significant or negative spillovers (Boarnet, 1998; Holtz-Eakin and Schwartz, 1995; Kelejian and Robinson, 1997; Ozbay et al., 2007). Moreno and López-Bazo (2007) also find evidence of negative spillovers when

[1]Melo et al. (2013) provide a meta-analysis of the impact of transport infrastructure on economic activity.

considering investments in transport infrastructure in Spain, while Delgado and Álvarez (2007) and Baños et al. (2013) are inconclusive regarding the direction of the spillovers in their analyses for Spain. Bronzini and Piselli (2009) report positive spillover effects of public capital for Italian regions using the regional stocks of roads and motorways, railways, water and electricity.

Negative spillovers are typically explained as the result of the migration of mobile production factors (labor and mobile capital). Where regions compete to attract economic activities, investments in transport infrastructure in one region may negatively affect other regions if the improved infrastructure allows for higher returns on the production factors.

Chen and Haynes (2013), in contrast, find positive spillover effects of highways estimating a production function for the Northeast US corridor. Cohen and Morrison Paul (2003, 2004) also find evidence of positive spillovers across US states. They estimate cost functions for the manufacturing industry by focusing on the role of airports and highways. Relieving air congestion in one node may benefit other nodes located in other states, while the network nature of highways means that better highways in one state may reduce travel costs for that state and its neighbors. In more general terms, transport infrastructure may lead to positive spatial spillovers when it improves the connectivity of geographically linked regions.

Although there is a vast literature on the link between public capital and output (and, to a lesser extent, costs), few studies examine the impact of different modes of transport infrastructure on regional employment. Those that do, generally, focus on one specific mode. In an analysis for the US state of North Carolina, Jiwattanakulpaisarn et al. (2009) find that investment in motorways does not have a notable effect on private sector employment. Clark and Murphy (1996) found a positive and significant role of highways on employment growth in US for less densely populated areas, what disappears in more congested regions. Duranton and Turner (2012) estimate a structural model to investigate the effects of interstate highways on the growth of employment in US metropolitan areas and they find a robust statistically significant impact.

Studies of European and Italian regions (Bottasso et al., 2013, and Ferrari et al., 2010, respectively) show that port throughput positively affects employment. In US urban areas, Brueckner (2003) found a significant causal link between air traffic and employment in service-related industries but not in goods-related industries, while

Bloningen and Cristea (2012) bring evidence of a direct relevant effect of air passenger traffic on employment in US urban areas (particularly employment in wholesale and retail industries). Finally, Percoco (2010) obtained evidence of positive spatial spillovers for Italian airports. To the best of our knowledge, no multivariate empirical study has been undertaken of the impact of railways on regional employment.

This paper estimates the determinants of industrial employment in Spanish regions using data for the period 1995-2008. Controlling for various regional attributes, we examine the direct and indirect impacts of different modes of transportation, including the direct effects on the areas in which the infrastructure is located and the indirect effects on neighboring regions.

As in previous studies (Hulten and Schwab, 1991; Cohen and Morrison Paul, 2003, 2004; Morrison and Schwartz, 1996; Moreno and López-Bazo, 2007), we focus our attention on the industrial sector. Cohen and Morrison Paul (2004) argue that the focus on a particular sector offers more plausible and interpretable results than a macroeconomic approach, while Holtz-Eakin and Lovely (1996) show that manufacturing activity benefits more from improved transport infrastructure than is the case of other productive sectors. In any case, the industrial sector is clearly very important for regional economies. A high proportion of exports and R&D expenditure are associated with manufacturing activities. Note also that industrial establishments can occupy a variety of locations, while service industries tend to be located in the central business districts of major urban areas. In this regard, rather than addressing transport infrastructure that improves intra-urban mobility, we focus on infrastructure that influences intra- and inter-regional mobility.

Our paper contributes to the literature by examining the impact on industrial employment of various modes of transportation, including roads, railways, air traffic and different types of port traffic. We also identify spillover effects from different types of transport infrastructure. While previous studies have examined spillovers from network modes (e.g., roads and railways) this paper also considers spatial spillovers from non-network modes (i.e., ports and airports).

The impact on employment of a better endowment of transport infrastructure in one region on its neighbors is not clear a priori. Indeed, improved infrastructure may give rise to a competition effect associated with the agglomeration of activities in the region with better infrastructure and a complementary effect associated with improved access to other regions or international markets. Port traffic is such a heterogeneous mode that it is particularly difficult to predict the direction of spatial spillovers without differentiating traffic types (container, general non-containerized, bulk).

Previous studies of the spatial spillovers of transport infrastructure generally use the monetary gross domestic product (or costs) and the value of the public capital stock. In this paper the dependent variable refers to employment in a particular sector and we use physical indicators of transport infrastructure (number of kilometers of highways and railways, and port and airport traffic measured in tones of goods). Note that the use of physical measures may capture the services provided by the infrastructure more appropriately, while the stock of capital is essentially an indicator of construction costs.

In this regard, investment in transport infrastructure has two effects (Vickerman, 1987). In the short run, the investment itself reactivates the construction sector while, in the long run, the investment has an external effect on the region's production costs by reducing accessibility costs. Our use of physical indicators as opposed to monetary indicators may help isolate this long-run effect, provided that the employment data focus on manufacturing activities.[2]

The rest of the paper is organized as follows: Section 2 describes the data sources and justifies the explanatory variables selected; Section 3 describes the econometric techniques used; Section 4 gives the details of our empirical model; and Section 5 presents our main findings. The last section summarizes those findings and discusses policy implications.

2. DATA AND VARIABLES

In this section we describe the data and variables used to estimate the determinants of industrial employment across Spanish regions. We consider all the Spanish regions except for the Islands (Balearic and Canary) and the two territories located in the North of Africa (Ceuta and Melilla) as we would be unable to assess the indirect impact of transportation in these regions. Our data cover the period 1995-2008.

[2] Our data are based on Spain's National Institute of Statistics sector classification, which disaggregates employment statistics as follows: 1) Agriculture, livestock and fisheries; 2) Energy; 3) Industry; 4) Construction; 5) Market services; and 6) Non-market services.

The dependent variable in our empirical analysis is the total number of employees in the industrial sector in the Spanish provinces (*industrial_employment*). The information for this variable was obtained from Spain's *Instituto Nacional de Estadística* (National Institute of Statistics, INE) and is made available at the NUTS-3 level.[3] We consider the following explanatory variables:

1) *Motorway_density*. This variable measures motorway infrastructure in kilometers per square meter. The data were obtained from the European Commission's Eurostat agency and are made available at the NUTS-2 level (in Spain, autonomous communities, or first-level political and administrative divisions). Unfortunately, the data for this variable are not available at the NUTS-3 level (in Spain, provinces).

2) *Railway_density*. This variable measures railway infrastructure in kilometers of track per square meter. The data were also obtained from Eurostat at the NUTS-2 level and are unavailable at the NUTS-3 level.

3) *Port_traffic*. This variable measures the total amount of traffic of each Port Authority aggregated by province (NUTS-3) and in tones.[4] Given the heterogeneity of port traffic, we not only consider the aggregate amount but also the magnitude of different traffic types. Specifically, we consider general non-containerized, container, solid bulk and liquid bulk traffic. The data on port traffic were taken from the historical series provided by the Spanish Ministry of Transport.

4) *Airport_traffic*. This variable measures the total amount of freight in tones moved in the airports of each province (NUTS-3). These data were obtained from the annual report of the Spanish airports operator (Aena).

5) *Market_potential*. Our study considers the population variable available at the NUTS-3 level as provided by the INE (Spanish statistics institute). Using data on population and distance, this variable is measured through the weighted sum of the population of all provinces, including the border regions of Portugal and France.[5]

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[3] Eurostat's NUTS classification (Nomenclature of Territorial Units for Statistics) is the European Commission's hierarchical statistics system for referencing the economic territory of the EU. A NUTS-2 area should have a population between 800,000 and 3,000,000 inhabitants, while that of a NUTS-3 area should range between 150,000 and 800,000 inhabitants. In practice, the statistical territorial units are defined in terms of the existing administrative units in the Member States and do not necessarily fulfill these population limits. In Spain, NUTS 2 are *Comunidades Autónomas* (autonomous communities, or first-level political and administrative divisions) and NUTS 3 are provinces.

[4] The ports of Almeria (province of Almeria) and Motril (province of Granada) were managed by a joint port authority until 2002. To assign traffic to each province when they were managed by a joint port authority, we calculated the relative weight of traffic in each port when they were managed separately.

[5] The following Portuguese subregions are considered: Minho-Lima; Cávado; Douro; Alto Trasos Montes; Beira Interior Norte; Beira Interior Sul; Alto Alentejo; Alentejo Central; Baixo Alentejo; Algarve. In the

Weights are based on the distance from the capital of each province to the capitals of the other provinces. The distance data for provincial capitals are collected from Google Maps and measured in kilometers.

6) *Education*. This variable describes the percentage of people with secondary education studies within the total working age population, and is used to examine the influence of the availability of skilled labor. The data for this variable were taken from the *Instituto Valenciano de Investigaciones Económicas* (the Valencian Institute of Economic Research, IVIE).

Table 1 shows the descriptive statistics of the variables used in our analysis, while Figure 1 depicts the regional allocation of employment in manufacturing industry.[6] The data in Table 1 show the coefficient of variation of each explanatory variable as the ratio of the standard deviation to the mean. The coefficient of variation shows that the variability of data for *Industrial employment*, *Port traffic*, and *Market potential*, and to a lesser extent, *Motorway density* is high, while it is relatively low for *Railway density* and *Education*.

INSERT TABLE 1

An examination of the geographical distribution of employment in the manufacturing sector reveals a marked difference between coastal areas and the interior. Of the twelve Spanish provinces presenting the highest manufacturing employment figures (accounting for more than half the country's total figure), nine are located on the coast and three in the interior. These twelve provinces can be grouped in three geographical areas: the Mediterranean coast (including Barcelona and Valencia), the Ebro Valley (including Bilbao and Zaragoza), and Madrid. On the other hand, with the exception of Madrid, the provinces with the lowest employment values are located in the interior.

INSERT FIGURE 1

An examination of the infrastructure variables reveals the geographical distribution of network modes (railways and motorways) to be quite similar. As one of Spain's transport objectives has been to improve connections between the political capital and the provincial capitals (Albalate et al., 2012), the region of Madrid has the highest

case of France, the following departments are considered: Pyrénées-Atlantiques; Hautes-Pyrénées; Haute-Garonne; Ariège; Pyrénées-Orientales.

[6]The Stata software provides us with the map of the distribution of employment in the manufacturing industry by quantile measures grouped in four different intervals of values.

density of motorways and railways in Spain — more than twice as high as the other regions with the next largest endowments, namely Catalonia, Valencia and the Basque Country. The density figures are quite similar in the case of railways.[7] Note also that in the period under study, many of the motorways linking cities in the Mediterranean Coast and the Ebro Valley were tolled, while all motorways in the region of Madrid were toll-free (Bel and Fageda, 2005). In network modes, the mismatch between the demand and supply of infrastructure has become a significant characteristic of the policy aimed at connecting the political capital with all provincial capitals (Albalate et al., 2013).

In contrast, the main ports are generally located on the Mediterranean coast. The Spanish port system comprises 28 port authorities managing 44 ports of general interest. The three largest, Algeciras, Barcelona and Valencia, are amongst Europe's top ten ports in volume of container traffic. Their privileged location in the Mediterranean Sea corridor allows them to channel the traffic from Asia to the South of Europe. Other ports with significant volumes of traffic are Bilbao, Tarragona and Cartagena. Tarragona and Cartagena are also located in the Mediterranean corridor.

Finally, the Spanish airport system comprises 47 airports of general interest. The two largest, Madrid and Barcelona, concentrate about 75% of the system's total air traffic of goods. Other airports with significant volumes of freight traffic are Zaragoza and Vitoria and, to a lesser extent, Valencia and Seville. Airport freight traffic is therefore mainly concentrated in the most populous cities and in the two specialized facilities in Zaragoza and Vitoria.

3. THE EMPIRICAL STRATEGY

In this section we outline the methodology used for estimating the determinants of employment in the manufacturing sector. Given that the spatial spillovers between provinces may be especially relevant to our study, the regressions are conducted using spatial econometric techniques.[8]

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[7] Since 2000, one of Spain's main transport objectives has been to provide a high-speed rail link between the political capital and all provincial capitals. The specific objective is that Madrid should be reached from all provincial capitals in a journey time of less than four hours.

[8] We also estimated dynamic regressions with the GMM estimator. The results are disappointing because the only significant variable is the lag of the endogenous variable and the variable *Motorway density*. One explanation might be that the sample does not have enough time variability to identify the relevant effects of the growth rates. Note also that GMM estimator does not capture the heterogeneity between regions

The spatial econometrics literature usually distinguishes between the effects of three types of interaction: endogenous interaction effects involving the dependent variable, exogenous interaction effects among the explanatory variables, and interaction effects among the error terms. The spatial Durbin model includes a spatially lagged dependent variable and spatially lagged explanatory variables, i.e., endogenous and exogenous interaction effects. Elhorst (2010a, 2010b) and LeSage and Pace (2009) consider this to be the most suitable specification for modeling spatial effects. In the spatial Durbin regressions, the equation to estimate for the corresponding province *i* in year *t* is as follows:

$$\begin{aligned}\text{Industrial\_employment}_{it} &= \alpha_0 + \alpha_1 W^*\text{Industrial\_employment}_{it} \\ &+ \alpha_2\text{Motorway\_density}_{it} + \alpha_3\text{Railway\_density}_{it} + \alpha_4\text{Port\_traffic}_{it} + \alpha_5\text{Airport\_traffic}_{it} + \\ &\alpha_6\text{Market \_Potential}_{it} + \alpha_7\text{Education}_{it} + \alpha_8 W^*\text{Motorway\_density}_{it} + \\ &\alpha_9 W^*\text{Railway\_density}_{it} + \alpha_{10} W^*\text{Port\_traffic}_{it} + \alpha_{11} W^*\text{Airport\_traffic}_{it} \\ &+ \alpha_{12} W^*\text{Market\_Potential}_{it} + \alpha_{13} W^*\text{Education}_{it} + \; + \mu' D^{year}_{t} + \varepsilon_{it} \qquad (1)\end{aligned}$$

In this equation we include the spatial lag of the dependent variable and the spatial lag of the explanatory variables where W (N x N) is a spatial weight matrix that defines dependence across N regions.[9] The spatial Durbin model takes into account the way in which the variation in the explanatory variable for a single region can affect the dependent variable in all other regions, through the introduction of these additional spatial variables.

To calculate the spatial interaction effects, we estimate equation (1) using the maximum likelihood method. First, we estimate spatial and time-period fixed effects in order to test whether the spatial Durbin model can be simplified to the spatial error model or to the spatial lag model. To this end, we consider the results from the Wald and the Likelihood ratio tests. Second, we estimate fixed and random spatial effects models and calculate the Hausman test to determine which of the two is most suitable. The results all confirm that the most suitable model is the spatial Durbin model with spatial and time-period fixed effects (Elhorst, 2012a, 2012b).

A central element in our analysis is the specification of the spatial weight matrix (W). The W is a positive (NxN) matrix that describes the structure of dependence

and, more importantly, it does not allow researchers to identify the spatial effects (one of this paper's main concerns).

[9]According to Hughes (2011), when the number of time periods is larger than ten, it is reasonable to estimate a model with a spatially lagged dependent variable. In our case, the number of time periods is fourteen.

between units in the sample, where the weight (w_{ij}) reflects the link between units i and j (Elhorst and Halleck-Vega, unpublished results). To this point, it is possible to apply different specifications of the weight matrix. The most common approach is to apply a spatial weight matrix based on physical contiguity (i.e., when regions share borders) and a spatial weight matrix based on geographic distance between regions. Other spatial weight matrixes are based on the similarity between regions' economic characteristics (for example, income levels) or on their trade relations.

Anselin (1988) considers that the elements in the weight matrix should be non-stochastic and exogenous to the model. Thus, an advantage of specifying the matrix W based on location is that the elements are exogenous (Elhorst and Halleck-Vega, unpublished results).

We estimate a spatial Durbin model with two different specifications according to the spatial weight matrix used: 1) a binary contiguity weight matrix; and 2) an inverse distance weight matrix. First, we consider a binary contiguity matrix (W_1) with elements w_{ij}=1 when two units share a common border and w_{ij}=0 in all other cases. Second, we construct an inverse distance (d) matrix based on the geographical distance between Spain's provincial capitals in which $w_{2ij} = 1/d_{ij}$. The first weight matrix assumes that spillovers only take place between bordering regions, while the second assumes that all the regions contribute to the geographical spillovers proportionally to the distance so that the weights penalize the most distant regions more heavily.

When interpreting the coefficients, therefore, the direct effects are the coefficient estimates of the non-spatial variables and the spillover effects are those associated with the spatially lagged variables. As such, a change in a single observation associated with any given explanatory variable affects the region itself (direct impact) and may affect all the other regions indirectly (an indirect impact).

Overall, we expect a positive sign in the coefficient associated with the non-spatial variables: in other words, all direct effects should be positive. A better endowment of transport infrastructure is expected to lead to lower transportation costs so that local producers can buy cheaper inputs, specialize in those activities for which the region has a comparative advantage or find new markets and products.[10]

[10] Interestingly, some theoretical models suggest that improvements to transport infrastructure lead to the opening up of markets and increase the degree of competition to which local producers are exposed

Within a given province, a better endowment of network infrastructure (motorways and railways) may lead to a reduction in transportation costs for firms and increase accessibility to territories. Both factors may attract new manufacturing firms and promote the expansion of established firms. Note we assume that when better surface transportation modes improve mobility within the region, this will lead to improved mobility between neighboring regions. Likewise, we assume that an increase in provincial port and airport freight traffic will improve national and international accessibility so that both exports and imports become cheaper for local firms.

Employment in manufacturing activities should also be higher in provinces with higher market potential, above all if the exploitation of scale economies is easier and transportation costs decrease. As our empirical analysis exploits differences between provinces, we do not expect to find a centrifugal effect attributable to congestion as such an effect would only be of relevance when analyzing the location of manufacturing firms within a given province. Finally, the availability of skilled workers may also have a positive effect on the employment level in the manufacturing sector in a given province.

The expected sign of the coefficient associated with the spatially lagged dependent variable is not, a priori, clear. A high level of employment in the manufacturing sector in one province may positively affect nearby provinces because the closest locations will benefit from easier access to suppliers and specialized employees. However, provinces with high employment levels in this sector may benefit from the exploitation of agglomeration economies and draw employees from less productive regions.

The expected direction of the indirect effect of network modes is likewise, a priori, unclear. On the one hand, it may be positive because the increased connectivity of improved highways and railways extends beyond the region in which the infrastructure is located. However, it may be negative because the region with better infrastructure attracts employees from other regions. Similarly, provinces that are close to others endowed with large ports and/or airports may take advantage of easier access to goods produced in distant markets, while those provinces with large ports and/or airports may also attract employees from provinces with no significant port or airport activity.

(Ferrari et al., 2012). If local producers are not efficient, improvements to transport infrastructure may spur the import of cheaper goods so that local employment actually decreases.

Note that the geographical unit of analysis may condition our results for the network variables. The level of aggregation of the geographical units employed is usually conditioned by the availability of data. Here, one limitation of our data is that the dependent variable is available at the NUTS-3 level, while the network mode variables are available at the NUTS-2 level.

The indirect effect of the *Market potential* variable is expected to be positive as transport costs should be lower due to proximity to dense markets, while the indirect effect of *Education* is expected to be negative because more productive provinces, thanks to their greater endowment of skilled employees, may draw resources from other nearby provinces.

Some of the explanatory variables are potentially endogenous. In particular, the manufacturing employment and transport infrastructure variables may be simultaneously determined.

Endogeneity problem should not be a concern in the case of network modes because they have a strong inertia with data being included in terms of number of kilometers per square meter. Note also that investments in network modes in Spain have prioritized passenger rather than freight transport and have not been guided by demand criteria (Albalate et al., 2012, 2013). More generally, it would be reasonable to argue that the activity in the manufacturing sector is unlikely to drive policy decisions across regions (Cohen and Morrison, 2003).

However, non-network transport modes and employment may be simultaneously determined. In order to deal with this endogeneity, we estimate the model with one year lag of *Port traffic* and *Airport traffic* variables but our analysis has been limited by not having better instruments for these potentially endogenous variables. On the other hand, we expect any potential bias to influence only the magnitude of the direct effect but not its statistical significance. Note also that we focus on the geographical spillovers across regions that should be less affected by this endogeneity bias. Indeed, some uncontrolled factors could simultaneously affect employment and port (or airport) traffic in one region, even though it is difficult to make a case for the correlation between lagged spatial variables and current unobserved shocks.

4. RESULTS

Table 2 shows the results of the regressions. The first column shows the results when using the contiguity weight matrix while the second column shows the results when using the inverse distance weight matrix. In both columns, the first six rows report the direct effect of the explanatory variable in question and the seventh to thirteenth rows report the indirect spatial effects. The Wald test and Likelihood ratio test reject the spatial lag and spatial error models, respectively. Hence, the spatial Durbin model is considered to be the one that provides the best description of the data (Elhorst, 2012). Note also that the Hausman test recommends the fixed effects model be used instead of the random effects model.

INSERT TABLE 2

We draw the following conclusions. First, there is evidence that motorway density has a substantial impact on industrial employment in the manufacturing sector. Indeed, the coefficient associated with this variable is positive and statistically significant at the 1% level. In contrast, there is no clear evidence that railway density positively influences employment. The coefficient associated with this variable is positive but not statistically significant in any of the regressions estimated.

This result for the railways variable may be explained by Spain's transport policies since the 1990s, when the country began investing in a high-speed rail network that is not designed to be truly compatible with freight. Spain's freight rail transport has one of the lowest shares in Europe (Albalate et al., 2013). It may also be explained by the fact that the variability of data for this variable is particularly low.

Our analysis shows that the level of employment in the manufacturing sector is higher in regions with larger ports. The coefficient associated with the *Port traffic* variable is positive and statistically significant at the 5% level. In contrast, the coefficient associated with *Airport traffic* is positive but not statistically significant. The results for the airport traffic variable may be explained by the very high concentration in Madrid and Barcelona of goods moved by Spanish airports. Industrial employment in these provinces may be better explained by the *Market potential*, *Motorway density* (Madrid) or *Port traffic* (Barcelona) variables. In fact, the coefficient associated with *Market potential* is positive and statistically significant at the 10% level.

This result is somewhat unusual because we would expect greater statistical significance for this variable. Regressions excluding *Airport traffic* increase the statistical significance of the market potential variable up to the 1% level.

The effect of the *Education* variable is also positive but not statistically significant. This may be because the differences in educational level across the different Spanish regions were not high enough to have statistically significant effects. This need not mean that the availability of skilled employees does not influence manufacturing employment levels but it could modestly affect the distribution of such levels across regions.

Overall, we find that employment in the manufacturing sector in a given region is positively affected by the availability of good infrastructure (motorways and ports) and by proximity to large markets. The results of our analysis concerning ports are in line with Bottasso et al. (2013) and Ferrari et al. (2010) and they are in line of those obtained by Duranton and Turner (2012) for motorways. Otherwise, we find stronger positive effects for motorways than those reported by Jiwattanakulpaisarn et al. (2009) or Clark and Murphy (1996).

In contrast to previous studies using employment equations, our focus is on the spatial effects of infrastructure across nearby regions. An examination of the spatially lagged variables shows that all the variables that have no direct statistically significant effect likewise have no indirect statistically significant effect. Indeed, the coefficients associated with the spatially lagged variables of *Railway density*, *Airport traffic* and *Education* are not statistically significant, regardless of the weight matrix used.

On the other hand, we find that the coefficient associated with the spatially lagged variable of *Market potential* is positive and statistically significant at the 5% level, regardless of the weight matrix used. This appears to confirm that a province takes advantage of being located close to other populated provinces to gain cheap access to large markets.

The coefficient associated with the spatially lagged dependent variable is negative although it is only statistically significant at the 10% level when we use the spatial weight matrix with distances. This result provides weak support for the fact that industrial activities are concentrated in some regions because they exploit agglomeration economies. Indeed, agglomeration economies may exert some effect on the location of industrial employment across nearby regions. However, note that the geographical level of the analysis would have to be further disaggregated to capture the effect of such economies on industrial employment with greater precision.

Importantly, the coefficient associated with the spatially lagged *Motorway density* variable is negative and statistically significant at the 1% level, regardless of the spatial weight matrix used. Hence, a good endowment of motorways in one region negatively affects employment in the manufacturing sector in other nearby regions. The magnitude of the indirect effect is much clearer than the magnitude of the direct effect, particularly in the regression that uses the inverse distance matrix. Note here that our analysis may be limited by the fact that the dependent variable is provided at the NUTS-3 level (in Spain, that of the provinces), while the network transportation variables are at the NUTS-2 level (in Spain, that of the regions). This may distort the magnitude of the indirect effect obtained for network modes but we do not expect this data limitation to affect the direction and statistical significance of the spillover effects.

Overall, we find evidence that the negative effect associated with the migration of employees to more productive regions is stronger than the positive effect associated with the improved connectivity of less productive regions. This is in line with Holl (2004), who analyzes the impact of road transport infrastructure on the location of manufacturing establishments using micro-level data for Spain. The author finds that the benefits from road improvements are concentrated near the new infrastructure.

Note also that several studies on spatial spillovers have focused on road transport infrastructure. This may be because the literature usually examines the relationship between output and investments, and because the investment in roads accounts for a large share of the sector's total investment in transportation. In this regard, our results are in line with Boarnet (1998), Chandra and Thomson (2000) and Ozbay et al. (2007), who find clear evidence of negative spatial spillovers from investments in motorways, and with Holtz-Eakin and Schwartz (1995), who also reject the existence of positive spillovers in motorways.

The coefficient associated with the spatially lagged *Port traffic* variable is negative and statistically significant at the 1% level when we use the contiguity weight matrix, while it is negative but not statistically significant when we use the distance weight matrix. In both cases, the magnitude of the indirect effect is much greater than the direct effect. From our results, it seems that the positive effects of port activities in terms of employment tend to be concentrated in the region in which the port is located while the negative spatial spillovers are only statistically relevant for bordering regions. Our results are in contrast with those obtained by Márquez-Ramos (in press) who finds positive spatial spillovers of ports in an analysis that focuses on exports rather than on industrial employment.

Ports may also specialize in different categories of traffic. Liquid and solid bulk traffic may have a limited impact on regional employment, while the impact of general non-containerized and container traffic may be higher. Note here that an increasing proportion of port traffic is transported in containers that are easily transferred to surface transportation modes such as road and rail. Hence, the magnitude and sign of the spatial spillover effects for container traffic could differ from those of other types of port traffic.

Table 3 shows the results of the regressions with port traffic disaggregated by category. This table only reports the results of the spatial regressions for the port traffic variables. The first two columns show the regressions with a weight matrix for contiguity regions, and the third and fourth show the regressions with a weight matrix for distance between regions.

The results for the direct effects remain similar regardless of the spatial weight matrix used. The coefficient associated with general non-containerized traffic and container traffic is positive and statistically significant at the 1% level in both regressions. In contrast, and unlike Bottasso et al. (2013), we do not find a positive direct effect of bulk traffic.

An examination of the indirect effect shows that the coefficient associated with the spatially lagged general non-containerized traffic variable is negative but not statistically significant in either regression. The coefficient associated with the spatially lagged container traffic variable is negative and statistically significant at the 5% level in the regression that uses the binary contiguity spatial matrix and negative but not significant in the regression that uses the distance weight matrix.

Note that an important characteristic of container traffic is that it can be easily moved by trucks and trains. Given the good intermodal transportation options that containers provide to shippers, the final destination of this type of traffic is not necessarily the region in which the port is located. In contrast, the final destination of the general (non-containerized) traffic is more frequently the region where the port is located. Hence, the impact of the general traffic on employment may be concentrated in the province in which the port is located, while the impact on employment of container traffic may also (negatively) affect adjacent regions.

5. CONCLUSIONS

This paper shows that some types of transport infrastructure significantly influence employment in the manufacturing sector. Motorway density and the level of port traffic (particularly general and container traffic) have a positive and statistically significant impact, while the density of railways and the amount of airport traffic have no clearly observable effects. Proximity to large markets (measured by population) is also a major determinant.

Our empirical analysis shows that there are significant negative spatial spillovers for motorways and container port traffic, although in the latter case the spatial effects are only noted in bordering regions. The impact of general non-containerized port traffic seems to be mainly local.

Our analysis finds evidence of negative spillovers from modes with network characteristics. Indeed, better network infrastructures in a given region do not seem to represent an advantage for neighboring locations. Overall, therefore, our findings suggest that industrial activities tend to be concentrated in regions that are more attractive for manufacturing firms. Such regions are typically characterized by being close to large cities and waterways and they have a high-density motorway network.

When goods are transported in containers, a large proportion of their total trip length can be made using surface modes of transportation. To some extent, this means that the spatial effects of container traffic will be similar to those of road transport. In contrast, the effects of general non-containerized traffic will tend to be local, similar in this respect to what might be expected of a point infrastructure. This suggests that spatial spillovers will tend to be greater in the case of network transport infrastructures.

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TABLES AND FIGURES

Table 1. Descriptive statistics of variables

Variable	Mean	Std. Dev.	Variation Coefficient	Min	Max
Industrial_Employment (thousands of employees)	60.63	95.69	1.57	4.8	626.7
Motorways_density (kilometers per square meter)	0.023	0.015	0.65	0	0.09
Railways_density (kilometers per square meter)	0.028	0.012	0.43	0.02	0.09
Port_Traffic (ten per millions of tones)	0.588	1.155	1.96	0	7.6
Airport_traffic (tones)	0.935	4.287	4.59	0	33.7
Market_Potential (million inhabitants)	0.911	1.001	1.09	0	6.3
Education (percentage of people with secondary education)	4.165	1.992	0.48	0	11.5

Figure 1. Distribution of manufacturing employment (NUTS-3)

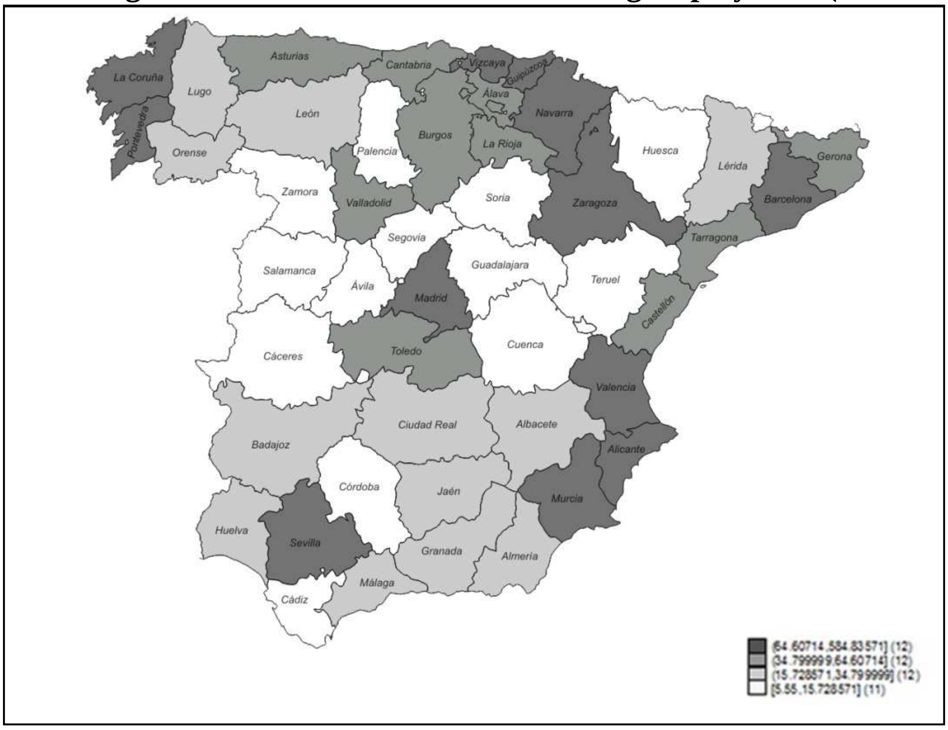

Table 2. Results of estimates of the employment equation (Spatial Durbin model)

EXPLANATORY VARIABLES	W-contiguity	W-distance
Motorways_density	900.537*** (8.588)	840.321*** (8.814)
Railways_density	141.409 (1.462)	112.735 (1.315)
Port_traffic	2.362** (2.416)	2.563** (2.533)
Airport_traffic	0.159 (0.253)	0.433 (0.659)
Market_Potential	10.621* (1.788)	9.907* (1.718)
Education	0.295 (1.502)	0.305 (1.551)
W*Industrial_Employment	-0.033 (-0.567)	-0.314* (-1.807)
W*Motorways_density	-707.293*** (-4.216)	-2047.819*** (-3.589)
W*Railways_density	76.956 (0.481)	722.288 (1.579)
W*Port_Traffic	-6.053*** (-2.759)	-10.502 (-1.055)
W*Airport_Traffic	-1.236 (-0.800)	-1.773 (-0.355)
W*Market_Potential	28.115** (2.306)	75.741** (2.045)
W*Education	-0.049 (-0.118)	-0.811 (-0.497)
Time specific effects Spatial specific effects	Yes Yes	Yes Yes
Wald Test Spatial Lag	25.83***	20.20***
LR test spatial Lag	25.75***	19.89***
Wald Test Spatial Error	27.56***	21.14***
LR test spatial Error	27.12***	21.10***
Hausman test- statistic	39.53***	31.95***
Observations R-squared Log-likelihood	658 0.994 -2197.527	658 0.994 -2199.604

Note 1: t-statistics in brackets.
Note 2: Statistical significance at 1 %(***), 5 %(**), 10% (*)

Table 3. Results of estimates of the employment equations (with different categories of port traffic)

	Spatial Durbin Model (Contiguity)		Spatial Durbin Model (Distance)	
Explanatory variables (port traffic)	**Direct Effect**	**Indirect Effect**	**Direct Effect**	**Indirect Effect**
Total	2.362** (2.416)	-6.053*** (-2.759)	2.563** (2.533)	-10.502 (-1.055)
General	45.452*** (6.092)	-20.674 (-1.313)	45.065*** (6.035)	-7.652 (-0.137)
Container	3.850*** (2.662)	-7.344** (-2.165)	4.266*** (2.729)	-7.641 (-0.439)
Solid Bulk	-3.868 (-0.998)	9.982 (1.056)	-3.630 (-0.918)	72.279* (1.714)
Liquid Bulk	2.078 (0.849)	-19.083*** (-3.781)	-0.257 (-0.096)	-78.484*** (-2.994)

Note 1: t-statistics in brackets.
Note 2: Statistical significance at 1 %(***), 5 %(**), 10% (*)