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THE EFFECT OF ACCESSIBILITY ON PRODUCTIVITY IN SPANISH MANUFACTURING FIRMS*

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ABSTRACT. This paper evaluates the impact of accessibility on the productivity of Spanish manufacturing firms. We suggest the use of accessibility indicators of workers and commodities, integrating transport, land use, and individual components, computing real distances or traveling times using the Spanish full road network. Estimated firms' total factor productivity is explained as a function of the accessibility indicators and additional control variables. Results evidence the crucial role on firms' productivity to the accessibility of commodities and to a slightly lesser extent the workers.

1. INTRODUCTION

The positive effects of transport infrastructures on economic growth have been well documented since the 1990s, although some controversy still exists with regards to the magnitude of these effects (Melo, Graham, and Brage-Ardao, 2013). The consequences, directly derived from these effects, can result in a firm changing location, motivated by a reduction in logistic costs, as well as considering new forms of production within a firm, such as the "just in time" method (Gillen, 2001). Furthermore, the increase and improvement of connections between territories broadens firms' markets and thus the rising of specialization and economies of scale is more likely to occur, which in turn provokes increases in competition pressure and technological diffusion. Additionally, the improvements in infrastructures generate on one hand a reduction in firms' costs and hence productivity gains, and on the other, a change in location attractiveness which lead to more geographic concentration and thus reinforce the productivity effects

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associated with the economics of agglomeration (Graham, 2007a; Venables, 2007; and Le Néchet, Melo, and Graham, 2012).

Consequently, the analysis of the effects of transport infrastructures should be carried out using modern measures of accessibility, which incorporate both, the agglomeration of economic activity and the infrastructure networks. Geurs and Ritsema van Eck (2001) define accessibility as the measure that allows evaluation of the use of a transport system that permits economic agents and commodities to attain different destinations and activities. As opposed to agglomeration and classical potential market measures, the accessibility notion incorporates an individual component that captures the actual use each agent makes of the infrastructure network as well as the true connection with remaining and relevant economic agents. Thus the concept of accessibility takes into account the position which each agent has in urban hierarchy, due to the inclusion of their specific requirements in the productive system. These requirements are obtained in specific nodes or locations of existing urban hierarchies, depending mainly on their size (i.e., larger cities produce more complex and heterogeneous goods and services). As a result, and according to the suggestions in Partridge et al. (2009), our accessibility measures, in contrast to market potential measures, are able to distinguish between territories with different urban structures.

Previous literature from the macro perspective has shown the positive effect of agglomeration on productivity, using the density of economic activity measures and different geographical areas, as units of analysis (refer to Melo et al., 2009 for detailed literature review on urban agglomeration economies). In some cases, the potential market is introduced as a proxy for economic agglomeration, as Combes et al. (2010) do for French employment areas. In some other cases, the effect of accessibility on territories is studied, as Forslund and Johansson (1995) for Swedish municipalities, and Weisbrod and Treyz (1998) for Michigan districts.

Firm or plant level studies are only recent. Andersson and Lööf (2011) analyze the effect of agglomeration on Swedish firms' productivity. Studies analyzing the effect on productivity of different market potential measures are more usual, as Graham (2007a, 2007b) and Graham and Kim (2008) do for British firms, Holl (2012) for Spain, Le Néchet et al. (2012) for France, and Lall, Shalizi, and Deichmann (2004) for Indian firms. In fact, market potential is a measure standing between classical agglomeration variables and the ones associated with accessibility.

A special mention needs to be made to the papers of Partridge et al. (2009, 2010). They analyze American counties and obtain evidence in favor of the implementation of hierarchical distances, rather than market potential measures, when identifying the determinants of the differences in wage levels and wage increases. They argue that the largest cities have a more complex production and thus generate different economic linkages with the firms located within them.

The available empirical evidence is nonetheless scarce with regards to firm level accessibility measures and the effect on firms' productivity of derived accessibility scores. The present paper evaluates the effect of accessibility on firms' productivity, using a large sample of firm level data from the SABI database (The Iberian branch of European AMADEUS databases). Accessibility is measured on two factors, workers and commodities. To the best of our knowledge, this is the first time that both accessibility measures are considered jointly and computed for each firm, using their specific locations. Furthermore, when estimating the loss in utility associated with traveling (impedance function), the specific features of economic agents (workers and firms) are taken into account. Moreover, when measuring accessibility we consider the effective times and distances of traveling across the complete Spanish road infrastructure network (urban and intercity), and not just along the high capacity network as it is often the case. This in turn constitutes a radical and important contribution to this paper.

Our results confirm a statistically significant and crucial effect of accessibility on the productivity of Spanish manufacturing firms, the effect being stronger in the case of commodities than in the case of workers. Estimated elasticities are in fact larger than those available in the previous literature, possibly due to a more precise measurement and identification of the infrastructures actually available to firms, as well as their actual use.

The paper is organized as follows. The following section presents and examines employed accessibility indicators for workers and commodities. Section 3 is dedicated to the formulation of estimated empirical models. We then describe the measurement procedures followed for productivity, accessibility and the remaining control variables. Section 5 offers and discusses the results which were obtained. Concluding remarks and policy recommendations are presented in Section 6.

2. ACCESSIBILITY INDICATORS

The economic literature offers a wide variety of accessibility measures (Geurs and Van Eck, 2001; and Baradaran and Ramjerdi, 2002; amongst others). These indicators should include four components: transport, land use, individual and temporal accessibility. The first component considers the availability and configuration of transport infrastructure networks, as well as the loss in utility associated with traveling. The land use factor reflects the distribution of opportunities along the geographical territory, which also considers urban hierarchy and thus, the geographic concentration of economic activities. The individual component identifies economic agent characteristics, in order to take advantages of available opportunities and make use of transport infrastructures. Lastly, the temporal factor analyses changes in opportunities and in capacity or use of transport infrastructures along different points of the time line (e.g., morning, afternoon, night, summer, winter, etc.).

The simplest measures of accessibility only partially consider the first mentioned component (for instance, contemplating the distance from the firm to the nearest transport infrastructure—Lutter, Pütz, and Spangenberg, 1992). The validity of these indicators has been improved by the inclusion of the land use factor. This is also true for the market potential indicators. Often, with regards to the transport component, these measures contemplate a disutility function based on the inverse of the geodesic distance (Graham, 2007a; Graham and Kim, 2008; amongst others) or real travel distances or times along main road networks (Graham, 2007b; Holl, 2012; Le Néchet et al., 2012; Melo, Graham, Levinson, and Aarabi, 2013; amongst others). Lall et al. (2004) when analyzing Indian firms, they go a step further by introducing a more complex function (negative exponential) in order to adjust for the observed utility loss. Finally, the papers of Partridge et al. (2009, 2010) consider the different distances to the different kind of nodes—cities—following the theory of urban hierarchy, which relates production complexity with city size.

Only a few examples incorporate the individual components (for instance, workers' accessibility to jobs as a function of worker's qualification—Van Ham, Hooimeijer, and Mulder, 2001; and Korsu and Wenglenski, 2010). With the exception of very specific applications (Kwan, 1998), the temporal component is usually omitted or substituted by the average accessibility, across time.

The present paper thus measures manufacturing firms' accessibility to the most relevant factors determining their costs and hence their productivity, (i) the accessibility to workers, and (ii) the accessibility to commodities.

Accessibility measures for the labor markets, are often based on the labor supply side, focusing attention on limited geographical areas such as municipalities, functional areas, industrial districts, local labor markets, etc. (Kawabata, 2003 from the perspective of demand and Gibbons et al., 2010; Melo, Graham, Levinson, and Aarabi, 2013 from supply; amongst others). However, these explicit geographical limits are unnecessary.

The inclusion of individual characteristics derived from firms and workers, captures the idea, that to some extent, labor markets are segmented (e.g., in terms of qualification), and workers/firms are restricted by certain geographical boundaries. Thus it is in fact possible that across these smaller (segmented) labor markets, workers compete for jobs and firms vie for those most suitable workers. For this reason, we select an accessibility measure from the competition typology, based on Shen's (1998) proposal, which takes the form of expression (1).

$$(1)\qquad ACC_i^w = \sum_J \frac{\mathrm{W_J} f_{\mathrm{ij}}^{\mathrm{w}}(\mathrm{d_{IJ}}, \mathrm{Z_I}, \mathrm{Z_J}, \mathrm{w_j}, \mathrm{k_i})}{\sum_{\mathrm{p}} \mathrm{E_p} f_{\mathrm{pj}}^{\mathrm{w}}(\mathrm{d_{PJ}}, \mathrm{Z_P}, \mathrm{Z_J}, \mathrm{w_j}, \mathrm{k_p})}.$$

Where ACC_i^w is the accessibility indicator to workers of firm i located in municipality I. In the numerator, W_J registers the number of potential workers (labor supply) living in a generic municipality J located in the neighborhood of municipality I (also including municipality I). $f_{\mathrm{ij}}^{\mathrm{w}}(\ldots)$ is the impedance function for workers and accounts for the disutility associated to traveling from I to J.[1] It also depends on the traveling time or distance between I and J (d_{IJ}), the characteristics of both municipalities ($\mathrm{Z_I}$ and $\mathrm{Z_J}$), the features of the potential workers living in J ($\mathrm{w_j}$), and firm's i characteristics ($\mathrm{k_i}$). The point realization of this impedance function can be interpreted as the probability of a potential worker living in a municipality J having to work in firm i located in I, conditionally based on the specific characteristics of both, the worker and the firm (as well as corresponding municipalities). Therefore, the numerator of (1) shows firm's i expectations on hiring workers from the municipality where it is located and the associated neighborhood (opportunities).

The denominator expresses firms' labor demand over workers residing in municipality J (competition for the opportunities). Its construction is identical to that of the numerator. Competition for workers is measured by addition of the crossed product of labor demand originated in municipalities—denoted here by P—located across the attraction radius of workers living in J ($\mathrm{E_P}$) and the probability of firms located in these municipalities choosing an available workforce in J.

With regards to the accessibility of commodities, the indicator is based on potential economic activity and considers three different types of commodity, flows to/from the firm, intermediate consumption of goods by firms, and final production, differentiating between that sold to other firms (intermediate uses) and that distributed to consumers' markets (final uses).

Firm's accessibility to each of the three different types of commodities is defined as the ease with which the firm has access to potential markets (origin or destination) in other municipalities. The indicator takes the form of expression (2),

$$(2)\qquad ACC_i^g = \frac{\sum_J SC_{Jg} f_{\mathrm{ijg}}^{\mathrm{m}}(\mathrm{d_{IJ}}, \mathrm{Z_I}, \mathrm{Z_J}, \mathrm{C_{ig}}) SI_{igJ}}{\sum_J SC_{Jg}}.$$

Where ACC_i^g is firm's i (located in I) accessibility indicator to a commodity type g. J denotes each one of all possible municipalities where production is either originated (intermediate consumption) or destined (final production of the firm). SC is the quantity of the symmetric flow to/from the firm of a given commodity available or demanded in

[1]If municipality J is far enough from municipality I, then, $f_{\mathrm{ij}}^{\mathrm{w}} = 0$, implying that municipality J is beyond the attraction or influence radius of firm i.

J. In the case of intermediate consumption we consider the manufacturing production available, for intermediate use, in each municipality. When we compute the accessibility indicator of a firm's production, which is destined for intermediate consumption of remaining firms, we include the intermediate consumption demanded by firms located in each municipality. In the case of the accessibility indicator for the final uses of firm's production destined to final consumers, we assume homogeneity in tastes across final markets, so accessibility depends on markets' size measured by the income of the municipalities. $f^{m}_{ijg}(\ldots)$ represents the impedance function, which in this case also depends on the characteristics of a firm's i corresponding commodity type g (C_{ig}). Once again, the interpretation of this function has a direct relationship with the probability that a firm i is provided with commodities that have been produced by the firms located in J, or alternatively that a firm i sells its production to these firms. *SI* is a similarity index between commodities produced (or consumed by firms) in J and the intermediate consumption required (or obtained final production) by a firm i. Thus this similarity index reflects the potential intensity of flows between municipality J and firm i.[2] This index is omitted in the case of the accessibility indicator to final uses of firm's production destined to final consumers. All possible manufacturing locations are considered as potential commodity origins or destinations, including the municipality where the firm is located.

Each one of the accessibility indicators to commodities is normalized according to country total. The global accessibility indicator is finally defined as the firm-level weighted average of the accessibility indicators to each type of commodity flow.

3. THE EMPIRICAL MODEL

In order to analyze the effect of accessibility on manufacturing firms' productivity, we assume that technology can be described by a Cobb-Douglas production function, with two factor inputs of the form described by expression (3).

$$Y_{it} = A_{it} L_{it}^{\beta_l} K_{it}^{\beta_k}. \quad (3)$$

Where Y_{it} is firm's i value added in period t, L and K are labor and capital, respectively, and A is the efficiency level or total factor productivity (TFP) of the firm. Taking logarithms in expression (3) we have the linear function in (4).

$$y_{it} = \alpha_{it} + \beta_l l_{it} + \beta_k k_{it}. \quad (4)$$

Where α and lower case letters denote the logarithms of the variables registered in (3). α_{it} is an efficiency measure specific to each firm and year which can be decomposed in (i) the average level of firms' efficiency in corresponding industry (β_0), and (ii) an individual component of firm i (υ_i) capturing efficiency differences between each firm and sector averages. Lastly, ε_{it} registers efficiency differences by year with respect to industry and firm averages.

$$\alpha_{it} = y_{it} - \beta_l l_{it} - \beta_k k_{it} = \beta_0 + \upsilon_i + \varepsilon_{it}. \quad (5)$$

This is followed by a two-step approach, in order to evaluate the impact of accessibility on firms' productivity. In the first step we estimate the production function (4), and in the

[2]The specific definition of this similarity index is given by $SI_{igJ} = 1 - 0,5 \sum_r |S_{igr} - S_{Jgr}| = \sum_r Min(S_{igr}; S_{Jgr})$, where S_{igr} is the share of commodity r in firm's i commodity g flow (intermediate consumption or final production), and S_{Jgr} is the share of commodity r in municipality's J commodity g flow (final production or intermediate consumption). The index is zero when both flows differ substantially, and increases as similarities arise.

second, we explain derived firms' TFP as a function of specific firms' accessibility as well as associated characteristics.

The two-step estimation has some practical advantages, mainly due to the availability of data. Whilst firms' panel data is available for a large time horizon, the information on full transport infrastructure endowments (including urban road networks) is only recent.[3] Consequently, the TFP function derived from (5) is specified as described by expression (6).

$$\alpha_i = \ln(A_i) = \beta_0 + \sum_k \gamma_k lnACC_i^k + \eta_Z X_i + \varepsilon_i. \quad (6)$$

Where ACC_i^k refers to each of the used accessibility measures and X_i is a vector of control variables identifying those firms' characteristics and strategies affecting their productivity levels.

The first group of control variables recognizes firms' internationalization strategies. International trade strategies (exports and/or imports) have been shown to be related to higher productivity levels (Fariñas and Martín-Marcos, 2007; Aw, Roberts, and Xu, 2011; amongst others). The same occurs with foreign investment (Tomiura, 2007; Yeaple, 2009; to mention some recent ones) and foreign capital participation on firms' social capital, which positively affect productive efficiency (Harris and Robinson, 2003). Additionally, the inclusion of a variable indicating the presence of domestic subsidiaries in the country, may capture a positive relation with productivity, as it may identify internal reorganization of production in relation to domestic outsourcing strategies affecting firms' productivity.

A second group of control variables identifies firms' specific features. Firm age captures knowledge accumulation and learning by doing processes (Huergo and Jaumandreu, 2004). In order to detect the relationship indicated by Jovanovic (1982) and Hopenhayn (1992), by which exiting firms exhibit lower productivity levels just before abandoning activity, we introduce a variable to reveal market exit. Lastly, the inclusion of employees' qualification, enables a recognition of the fact that higher human capital endowments are usually associated to higher levels of innovations in management, processes and product, and hence productivity (Bartelsman and Doms, 2000).

Estimation of expression (6) is not trivial due to the possible incidence of endogeneity between firms' productivity and the degree of accessibility they face. If workers' propensity to change place of residence depends on wage differentials, and these wage differentials are linked to productivity, as expected in competitive markets, a simultaneity problem arises between workers' accessibility and productivity.

Furthermore, Holl (2012) claims that positive productivity shocks, attract new firms and workers that derive from firms' accessibility improvements, thus generating causality between accessibility and market growth, and in turn productivity (Graham et al., 2010). A documented simultaneity source is due to location, as shown by Baldwin and Okubo (2006) amongst others, which influences productivity through market size and qualified human capital endowments. The way in which policy oriented towards construction of new infrastructures is executed, also constitutes an important source of simultaneity, as infrastructure plans aim to anticipate future infrastructure demand through expected economic and productivity growth as well as higher labor concentration. Consequently, expression (6) must be estimated consistently by means of instrumental variables procedures.

[3]The complete road network, and in particular the urban one, is necessary to precisely measure the accessibility of firms to workers. In the case of Spain, the complete road network is only available from year 2006.

4. DATA

In order to fulfill the defined two-step estimation strategy, we must estimate first the production function using a firm's panel data from 1999 to 2009 in order to ensure consistency and thus compute TFP appropriately. Then by exploiting estimated TFP and accessibility data, we assess the effect of the latter on the former in the year 2009 cross-section. Table A.1 presents the summary statistics for all the variables used in the analysis.

TFP Calculation

The literature covering the estimation of production functions, recommends semi-parametric procedures to achieve consistency (Van Beveren, 2012). The procedure that fits best with our data availability is the one proposed by Levinsohn and Petrin (2003), which takes into account the classical simultaneity problems and includes intermediate inputs (raw materials) as a proxy for unobservable productivity shocks.[4]

The information required to estimate the production functions: production, employment, net tangible fixed assets (as a proxy for capital), raw materials and the main activity of the firm at four digits (NACE rev. 1.1), is obtained from *SABI* database, elaborated by Informa and Bureau Van Dijk, and integrated in AMADEUS Database (refer to Table A.2 in the Appendix for a detailed description of used data sources). An unbalanced panel within the period covering 1999–2009 is available, with a total of 155,937 mainland Spanish manufacturing firms.[5]

Production, intermediate consumption and capital are deflated using the Index for Industrial Prices (IIP) available at the Spanish National Institute of Statistics (INE).[6] Consequently, the value added is deflated by applying a double deflation criterion. As the panel is unbalanced, upward biases in TFP estimations associated with the exclusion of firms exiting the market, are attenuated. In order to estimate the production functions by type of productive activity, each firm is assigned to its sector of main activity defined at four digits, covering a total of 93 different manufacturing activities.[7]

Accessibility

To compute accessibility indicators, we approximate impedance functions from a collection of probability functions. In the case of workers, we obtain one function for each

[4]The pioneer procedure is the one proposed by Olley and Pakes (1996), and requires information on firms' investment in order to account for unobservable productivity shocks. Investment is nonetheless not available in SABI.

[5]SABI coverage for the manufacturing sector amounts to 30 percent in terms of firms and 66.7 percent in terms of employment. The average number of manufacturing firms by year is 67,542, oscillating between 52,037 in 2009 and 72,801 in 2006. On average, firms continue active in the sample for six years, although 53 percent of them remain for more than five years, and 22 percent attain 10 years.

[6]This IIP is available to three digits NACE rev. 1.1. Intermediate consumption and capital are deflated according to the different intermediate goods and capital goods components, respectively, of the IIP.

[7]On average, estimated elasticity for capital is 0.180 (standard deviation equals 0.053), with a maximum value of 0.300 (Manufacture of grain mill products) and a minimum 0.075 (Manufacture of pharmaceutical preparations). The elasticity for labour averages 0.879 (standard deviation equals 0.093), with a maximum value of 1.059 (Manufacture of pharmaceutical preparations) and a minimum 0.607 (Manufacture of other wearing apparel and accessories). 69 industries show increasing returns to scale, and remaining ones show constant and decreasing returns evenly. Production functions estimates are available under request to authors.

of the available commuting time intervals. This procedure allows for easy consideration of the individual characteristics of involved agents (i.e., workers and firms), as the specific features of commutes are known, independently of the origin or destination of commutes.[8]

$$f_{ij}^{w} = \begin{cases} PW_{ij}^{0} = 1 \quad \text{if} \quad 0 \le d_{IJ} \le d_0 \\ PW_{ij}^{1} = \alpha_0^1 + \alpha_1^1 x_j + \alpha_2^1 x_J + \alpha_3^1 x_i + \alpha_4^1 x_I \quad \text{if} \quad d_0 < d_{IJ} \le d_1 \\ \vdots \\ PW_{ij}^{n} = \alpha_0^n + \alpha_1^n x_j + \alpha_2^n x_J + \alpha_3^n x_i + \alpha_4^n x_I \quad \text{if} \quad d_{n-1} < d_{IJ} \le d_n \end{cases} \tag{7}$$

Where PW_{ij}^{n} refers to the commutation probability of a worker j (living in municipality J) to a firm i (located in municipality I) over the distance or time interval n (between distances d_{n-1} and d_n). x_j incorporates worker's subjective characteristics, x_J refers to the features of the municipality where the worker resides, x_i includes the attributes of the hiring firm, and x_I describes the municipality where the firm is located.

The information needed to estimate the probability functions for each time interval of commuting in mainland Spain comes from a 5 percent sample extracted from the microdata of the Spanish Population Census (SPC) for year 2001 and published by INE.

Commuting information is grouped into seven different time intervals, (i) less than 10 minutes, (ii) between 10 and 20 minutes, (iii) 20–30 minutes, (iv) 30–45 minutes, (v) 45–60 minutes, (vi) 60–90 minutes, and (vii) more than 90 minutes. For municipalities up to 100,000 inhabitants, we consider commutes with a maximum of 45 minutes. Whilst for those larger municipalities, we include different maximum commutation times (45, 60, or 90 minutes, depending on the selected measure). These maximum commutation times are well above the average values for Spain (20–25 minutes in the SPC 5 percent sample[9]). The final sample covers about 600,000 commuting observations.

The initial probabilities (PW_{ij}^{n}) required to estimate the equations of expression (7) are computed assuming that commuting times reveal agents' propensity to commute. This implies the following. (i) All individuals are able to travel along the minimum time interval (up to 10 minutes), i.e., the probability here is degenerated. (ii) Individuals prepared to commute along a given time interval would also do it along the previous ones. (iii) The probability of commuting over the maximum considered time (45, 60, or 90 minutes) is zero. (iv) Estimations include all individuals commuting; though assigned probabilities vary according to the estimated probability function.[10]

[8]Conversely, the estimation of commuting models through gravity functions, factor compensation models or spatial interaction models (LeSage and Thomas-Agman, 2015) requires precise knowledge of agents' location as well as the intensity of flows between them. Furthermore, these types of procedures do not permit the inclusion of the individual characteristics of involved economic agents

[9]The 2003 *INE* survey on the Use of Time offers an average commuting time of 29 minutes. For 2006, the survey *Movilia* (Ministry of Infrastructures) offers similar results, and only on those municipalities over 100,000 inhabitants average commuting times attain 32 minutes, and just in largest cities (Madrid and Barcelona) average commuting times achieve between 35 and 40 minutes. Commuting times in Spain are thus much lower than European averages, even in the case of largest cities. According to European Commission (2010) average commuting time in London is 43 minutes, 15 percent of individuals traveling for more than 60 minutes. The equivalent information for Madrid and Barcelona is 31 and 28 minutes, and only 5.1 percent and 4.8 percent of commutes take more than an hour, respectively.

[10]For instance, a worker commuting over the 20 to 30 minutes time interval would have a degenerated probability along this time interval and the previous one (i.e. 10 to 20 minutes), and a zero probability for the interval 30 to 45 minutes. This does not imply that commutes do not take place over that time interval, but for that given worker we set these 0/1 values when estimating the probability function, as that is what available data reveals.

Information on the characteristics of firms, municipalities and individuals is also obtained from the available SPC microdata. In relation to workers, subjective characteristics include: sex, age and education level. With respect to the municipality where the worker inhabits and the municipality where the firm is located, we consider the province of location (47 in mainland Spain), the size of the municipality measured in intervals, and the municipality's unemployment rate. In terms of a firm hiring a worker, we reflect the sector of economic activity, the size-class, and the average qualification level of the jobs. We estimate five probit functions, one for each of the commuting time intervals: 10–20 minutes, 20–30 minutes, 30–45 minutes, 45–60 minutes, and 60–90 minutes.

Distances and minimum commuting times between the Spanish municipalities (7,954 municipalities in mainland Spain) across the urban and intercity road networks have been computed from Google Maps enquiries, hence accessibility data is only available for year 2009.[11] Firms and workers are thus assumed to be located in municipalities' centroids, obtained from The Spanish National Geographical Institute (SNGI).[12]

Once the probability function parameters[13] and minimum commuting times between municipalities are known, we can calculate the accessibility indicators of workers for each firm by entering the observed values of workers' individual characteristics, as well as those of hiring firms, into the estimated equations. In order to achieve this, we need additional information for the year 2009, being, municipal unemployment rates from the National Public Service for Employment (NPSE), population figures and some of the associated characteristics from the Municipal Population Register (MPR), the affiliation statistics of the National Social Security Service (NSSS) and the qualification of workers from IVIE.

In the case of commodities, the impedance functions take a similar form to those of workers, i.e., a collection of probability functions. In this case, the range of considered attributes is far less due to the scarcity of available information. Every probability function adopts the form of expression (8).

$$PC_{ij}^{n} = \alpha_0^n + \alpha_1^n OR_I + \alpha_2^n DR_J + \sum_k \delta_k^n M_k \quad \text{if} \quad d_{n-1} < d_{IJ} \leq d_n. \tag{8}$$

Where PC_{ij}^{n} is the probability that firm i, located in I, transports its production to municipality J, located at a distance within the range $(d_{n-1}, d_n]$. OR_I refers to Origin Region (i.e., the one where municipality I is located), DR_J is the Destination Region (i.e., the one where municipality J is located), and M contains several qualitative variables describing the type of transported commodity.[14]

These probability probit functions are estimated using microdata on journeys from the Permanent Survey on Road Commodity Transport (PSRCT) of the Ministry of

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[11]Commuting times using public transport are not considered, as the information is only partially available. Commutes in public transport are longer than those carried out by private means (63 percent longer according to 2003 *INE* survey on the Use of Time). This would in fact augment the upper bound in accessibilities' calculations. The bias is however induced in both, numerator and denominator, and thus cancels out. Possible biases associated to relatively more intense use of public transport in larger cities are taken into account through municipality size dummies.

[12]Núñez-Serrano (2012) shows the estimation results of these impedance functions.

[13]We assume that the estimated parameters of the probability functions are stable between 2001 (year of the census) and 2009 (year of infrastructure data). This assumption implies that commuting preferences of workers and firms are invariant over time. Anas (2015) provides evidence and support on the stability of commutes, at least in the urban context.

[14]Year dummies are also included.

Infrastructures along the time horizon 2002–2009. The sample amounts to 1,241,495 observations.[15]

Expression (8) is estimated for nine different distance intervals: 20–40 km, 40–70 km, 70–100 km, 100–150 km, 150–200 km, 200–250 km, 250–350 km, 350–500 km, and more than 500 km. The initial assignation of probabilities (0 or 1) is carried out in a similar way to that applied for workers' commutes. Finally, once these functions are known we can estimate corresponding probabilities between each firm and municipality, identifying corresponding distances from the real road network through Google Maps enquiries and plugging in specific characteristics of each firm and municipality.

Furthermore, accessibility indicators need additional information to be computed. Firms' intermediate consumption and production for the year 2009 are obtained from *SABI* database. The composition and distribution of commodities in each firm's intermediate consumption is assumed to be equal to the one revealed by the corresponding sector of economic activity, registered in the Use Table of the Spanish Input-Output Table (IOT) of year 2007. With respect to commodities' structure of final production, the procedure is identical; nonetheless, the distribution is computed according to the Supply Table in the year 2007. In order to quantify the proportion of each commodity dedicated to intermediate use (intermediate demand) or final use (final demand), we calculate the average of the shares in each of the producing sectors observed in the year 2005's Symmetric Input-Output Table.[16]

The intermediate consumption, the production, and associated commodities' distributions in each municipality, are obtained by aggregation of the firms located in them, and applying the corresponding elevation coefficients. Municipalities' income is calculated multiplying the number of inhabitants in MPR (year 2009) by the Province per capita income derived from *INE*'s Regional Accounts (RA) of the same year. Figure 1 shows maps for the average accessibility to workers and commodities at the municipality level in the year 2009, as well as the corresponding average TFP.

Control Variables in Productivity Function

The remaining variables included in the productivity functions are obtained from SABI database. In the case of firm foreign trade activity, where only qualitative variables are available, the possibilities are four, (i) no foreign trade activity, (ii) firm exports, (iii) firm imports, and (iv) firm exports and imports. If the firm is associated with foreign owners controlling more than 50 percent of social capital (OECD control criterion), the firm is assumed to have foreign capital. If a firm participates in more than 50 percent of social capital of other Spanish or foreign firms, the firm is assumed to have Spanish and/or foreign affiliates, respectively. The age of the firm is calculated by subtracting the year when the firm was first incorporated, from 2009. The firm exit variable is obtained from SABI's State variable (different to active and related to an exit scenario). Lastly, the qualification level of the firm's workers is derived through a complex mechanism which compares the firm's mean wage, obtained from SABI, with that observed in the Province, in which the firm is located, in the corresponding sector of economic activity,

[15]This survey only considers commodity transport in the domestic market (80 percent of transported commodities in Spain) and only those made using the road network (94 percent of the total).

[16]The classification of manufacturing products in the Use and Supply Tables, has been aggregated to 11 groups of homogenous commodities between the Revised Nomenclature for Transport Statistics (NST/R) used by the PSRCT, and the National Classification of Products by Activity (*CNPA*-96) of National Accounts.

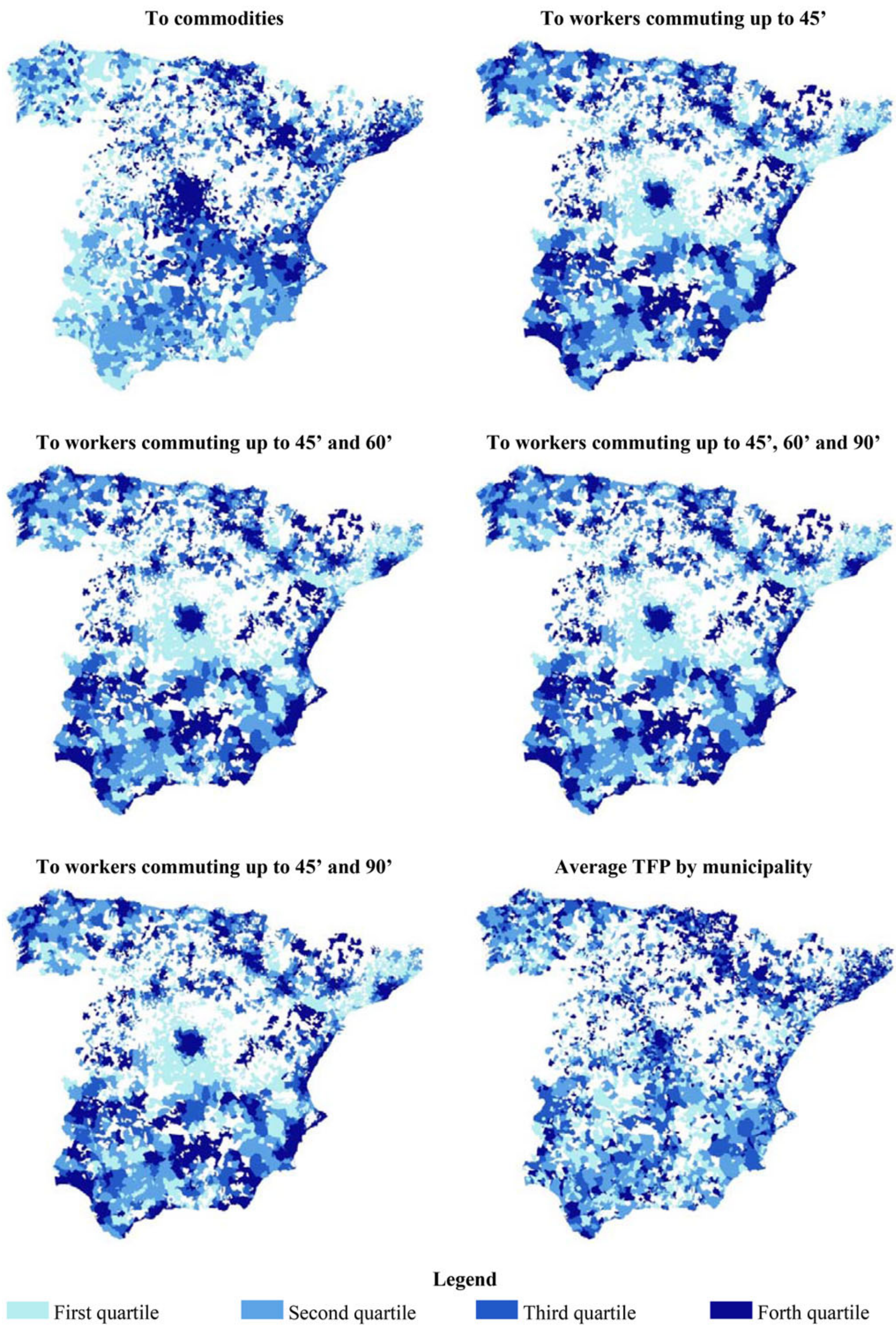


FIGURE 1: Average accessibility and TFP of manufacturing firms by municipality in 2009.

also considering workers qualification calculated at this same level of aggregation from SPC and IVIE data (the complete procedure is described in the Appendix).

Instruments

Choosing appropriate external instruments is a complex task. Combes et al. (2010) argue that in the context of agglomeration and thereby accessibility, these exogenous variables can come from the geographical-geological and historical fields.

We start by considering mean municipal altitude and ruggedness computed in Goerlich and Cantarino (2010). They calculate these variables from the NASA SRTM data. The ruggedness index corresponds to that proposed by Riley, DeGloria, and Elliot (1999), and basically measures differences in elevation through neighboring areas.

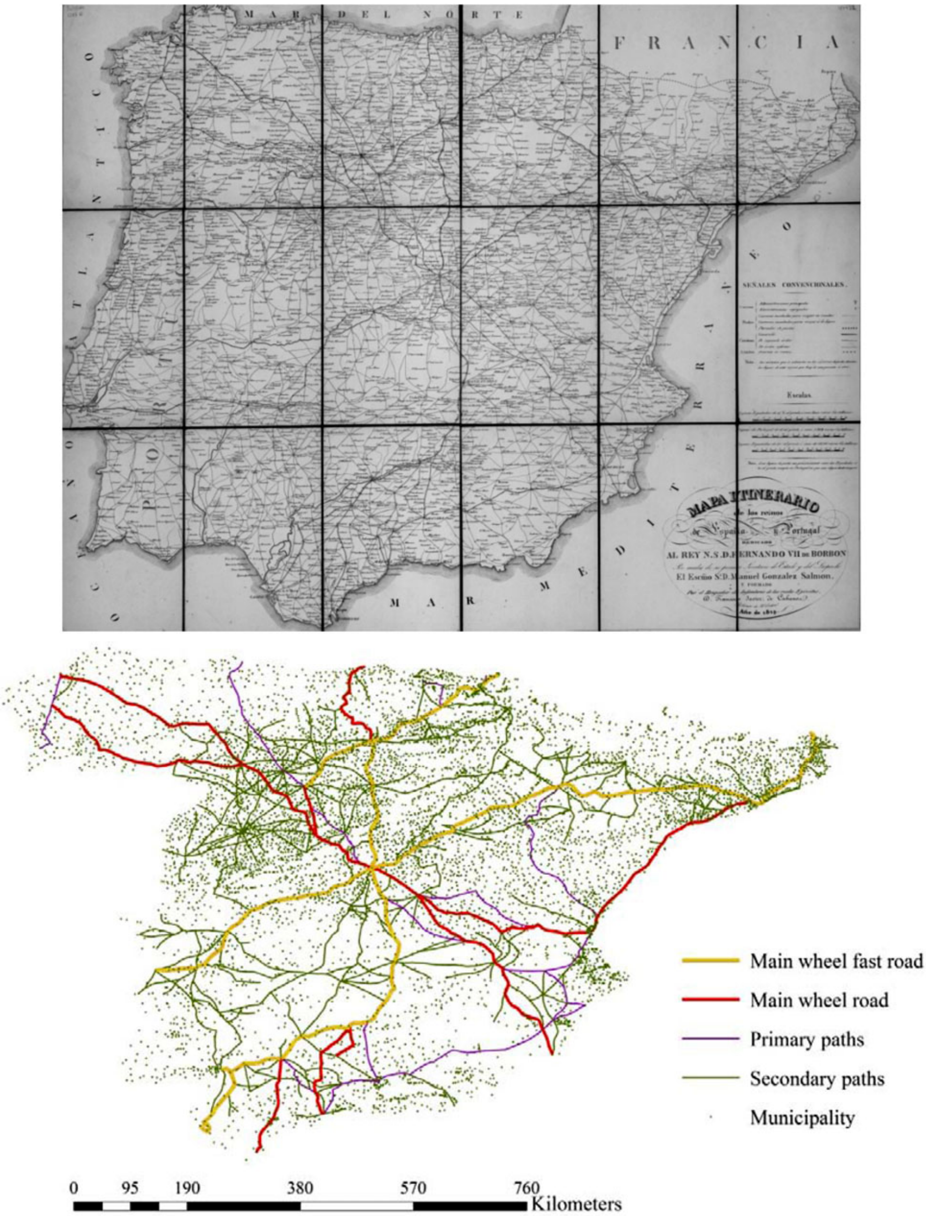
With regards to the historical dimension, we have constructed two instruments: the year 1900 population density and the accessibility to final markets in 1857.[17] Allowing for wide time gaps between years 1857, 1900, and 2009, we intend to avoid possible collinearities amongst considered instruments and also remove weak instruments behavior often associated with the use of closer lagged values in persistent variables.

The year 1857 accessibility measure is based on the accessibility to final markets, defined in expression (2). Municipal income is nonetheless substituted by population from the first proper Spanish Population Census taken in 1857, implementing 2009 municipal definition. With regards to the road and path infrastructure, we draw the map provided by Cabanes (1830) and build a geodatabase (see Figure 2) that allows network analysis using GIS. This road network represents the original basis of the present Spanish road network, and contrary to the one used by Holl (2012), it further includes not just the postal routes, but the remaining main roads and pathways in Spain. We consider up to four different road categories, two main roads where carriage transit was possible, and two more path categories denoted as primary and second order. A different velocity is assigned to each of these four categories,[18] thus allowing determination of the distance associated to the fastest route between two points. These distances, when introduced in expression (8), permit calculation of the probability of commodity transportation conditional on past infrastructure network.

Table 1 shows the pairwise correlations between chosen instruments and the endogenous variables, as well as some of the results derived from the univariate regressions between them. Although R^2 values are in some cases relatively low, taking into account the complete set of instruments and the statistical significance of correlations, it seems that chosen instruments have certain explanatory power over endogenous variables. Specifically, we can expect that commodities' accessibility will be better explained by the accessibility indicator to final markets in 1857, followed by population density and to a lesser extent, municipal ruggedness. In the case of workers' accessibility, population density and municipal altitude should show better results.

[17]In the way Duranton and Turner (2012) do when considering the planned high capacity network of year 1947 and the 1898 railway network to instrument 1983 infrastructure stock. Similarly, Combes et al. (2010) calculate French market potential indicators for year 1831 to instrument contemporary values, and Holl (2012) does the same for Spain with data on 1760 postal roads and 1900 population.

[18]Specifically, the Treaty on Postal and Custom Network of 1826 establishes speed at 32 Castilian *leguas* (1 Castilian *legua* = 5,572.7 meters) per day. This is equivalent to 7.5 km per hour if taking into account horse resting and time dedicated to horse switching. In computed network geodatabase, we establish a velocity range from 7.5 km per hour to 4.0 km per hour, depending on the quality of considered roads and paths.



Source: Cabanes (1830) and own elaboration.

FIGURE 2: Road and Pathway map of Spanish and Portuguese Kingdoms and computed network geodatabase map for network analysis.

5. THE EFFECT OF ACCESSIBILITY ON PRODUCTIVITY

Table 2 presents OLS results of the estimation of (6), which relates firms' productivity with the different accessibility indicators and mentioned control variables. Additionally, all estimations include sector of economic activity (two-digit NACE) indicators. The dependent variable corresponds to the logarithm of TFP. The accessibility variables, as well

TABLE 1: Pairwise Correlations, Coefficients and R^2 of Univariate Regressions of External Instruments

	Ln (accessibility to workers)				Ln (accessibility to commodities)
	45’	45’ & 60’	45’, 60’ & 90’	45’ & 90’	
Ln (altitude)	−0.2571***	−0.2585***	−0.2618***	−0.2565***	0.0274***
	−0.1831***	−0.1905***	−0.1973***	−0.2011***	0.0130***
	0.0642	0.0650	0.0668	0.0643	0.0008
Ln (ruggedness)	−0.1065***	−0.1117***	−0.1107***	−0.1166***	−0.1128***
	−0.1279***	−0.1387***	−0.1404***	−0.1538***	−0.0888***
	0.0113	0.0125	0.0122	0.0136	0.0127
Ln (Accessibility to final markets in 1857)	0.1149***	0.1174***	0.1178***	0.1182***	0.8166***
	0.1888***	0.1994***	0.2042***	0.2130***	0.8784***
	0.0132	0.0138	0.0139	0.0140	0.6669
Ln (population density)	0.3965***	0.4119***	0.4347***	0.4339***	0.1640***
	0.2313***	0.2483***	0.2680***	0.2778***	0.0628***
	0.1594	0.1720	0.1918	0.1909	0.0269

Note: First row is the pairwise correlation, second row presents the coefficient of the univariate regression, and third row accounts for the R^2.

as firm age and employees’ qualification level, are also evaluated in logarithms. The first five columns of Table 2 refer to estimation results, when accessibility indicators are introduced in an isolated manner, i.e., one by one. The last four columns show estimation results when both accessibility indicators are considered, i.e., the aggregated accessibility indicator to commodities and the different versions of the accessibility to workers.

In terms of workers’ accessibility, we consider the four alternative measures mentioned in Section four, based on the maximum willingness to spend time commuting. (i) up to 45 minutes for all municipalities, (ii) 45 for all and up to 60 minutes for those municipalities with more than 100,000 inhabitants, (iii) same as in (ii) but adding up to 90 minutes commutes in municipalities larger than 500,000 inhabitants, and (iv) up to 45 minutes for all municipalities and up to 90 minutes for municipalities with more than 100,000 inhabitants.

All of the accessibility indicators, both to workers (except in the last column) and commodities show a positive and statistically significant effect over TFP, being substantially larger in the case of commodities. Additionally, the magnitude of these values varies only in the case of workers when both accessibility indicators are jointly introduced.

Resulting elasticities decrease as maximum commuting times increase, and oscillate between 0.023 and 0.010 when introduced in an isolated manner, and between 0.015 and 0.008 in joint estimations. The values for the TFP elasticity of commodities’ accessibility are much more stable across different specifications (0.194–0.198).

In order to assess robustness of these results and amend possible endogeneity problems, expression (6) is estimated consistently using the two-step least squares estimator (2SLS). Table 3 records results when the specifications consider both indicators simultaneously.

To ensure instrument validity, a wide range of test statistics are computed and reported (cf., Table 3). Endogeneity of accessibility indicators is confirmed by means of a control-function approach, testing for statistical significance of predicted residuals from first-stage OLS regressions when included as additional explanatory variables in the OLS estimation of expression (6). Considered instruments are jointly significant at the 99.9 per cent significance level thoroughly in first-stage regressions, as reported by first-stage regression F-tests’ statistics. The Sargan-Hansen test for the null hypothesis that the

TABLE 2: Accessibility effects on the productivity of Spanish manufacturing firms

Dependent variable	TFP 2009								
Accessibility to workers 45’	0.023***					0.015***			
	(0.003)					(0.003)			
Accessibility to workers 45’ and 60’		0.017***					0.009***		
		(0.003)					(0.003)		
Accessibility to workers 45’, 60’, and 90’			0.016***					0.008***	
			(0.003)					(0.003)	
Accessibility to workers 45’ and 90’				0.010***					0.002
				(0.003)					(0.003)
Accessibility to commodities					0.194***	0.194***	0.196***	0.196***	0.198***
					(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
Control Variables									
Only exports	0.340***	0.340***	0.340***	0.340***	0.338***	0.338***	0.338***	0.338***	0.338***
	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)
Only imports	0.307***	0.307***	0.307***	0.307***	0.308***	0.307***	0.307***	0.307***	0.308***
	(0.012)	(0.012)	(0.012)	(0.012)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
Exports and imports	0.431***	0.431***	0.431***	0.431***	0.431***	0.430***	0.431***	0.431***	0.431***
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
Has Spanish affiliates	0.335***	0.336***	0.336***	0.337***	0.336***	0.335***	0.335***	0.335***	0.336***
	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
Has foreign affiliates	0.345***	0.346***	0.346***	0.347***	0.340***	0.338***	0.339***	0.339***	0.340***
	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)
Foreign social capital	0.320***	0.321***	0.321***	0.322***	0.294***	0.292***	0.292***	0.292***	0.293***
	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)
Firm exits	−0.167***	−0.167***	−0.166***	−0.166***	−0.171***	−0.173***	−0.172***	−0.172***	−0.172***
	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)
Firm age	0.102***	0.103***	0.103***	0.103***	0.096***	0.095***	0.095***	0.095***	0.095***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Employees qualification level	0.654***	0.655***	0.655***	0.656***	0.671***	0.668***	0.669***	0.670***	0.671***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
N	64034	64034	64034	64034	61443	61440	61440	61440	61440
R^2	0.333	0.333	0.333	0.333	0.343	0.343	0.343	0.343	0.343

Notes: All estimations are carried out by OLS. All variables, except qualitative ones, are evaluated in logarithms. All estimations include a sector of activity indicator, two digits NACE-93. Significance levels are denoted as follows: 99.9 percent (***), 99 percent (**), 95 percent (*), 90 percent (†).

TABLE 3: Accessibility effects on the productivity of Spanish manufacturing firms. Dependent variable is TFP 2009

	45'		45' & 60'		45', 60' & 90'		45' & 90'	
Accessibility to workers	0.0295***	0.0592***	0.0273***	0.0573***	0.0255***	0.0555***	0.0242***	0.0549***
	(0.008)	(0.011)	(0.008)	(0.011)	(0.007)	(0.011)	(0.007)	(0.011)
Accessibility to commodities	0.1452***	0.1393***	0.1458***	0.1397***	0.1465***	0.1405***	0.1470***	0.1409***
	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)
Implemented Instruments and Statistics for Instrument Evaluation								
Accessibility to final markets in 1857	Y	Y	Y	Y	Y	Y	Y	Y
Average municipal altitude	N	Y	N	Y	N	Y	N	Y
Average municipal ruggedness index	Y	N	Y	N	Y	N	Y	N
Municipal population density in year 1900	Y	N	Y	N	Y	N	Y	N
Endogeneity test. First-stage regression residuals, workers	−0.0147†	−0.0455***	−0.0188*	−0.0493***	−0.0194*	−0.0495***	−0.0241***	−0.0544***
	(0.009)	(0.012)	(0.008)	(0.011)	(0.008)	(0.011)	(0.007)	(0.011)
Endogeneity test. First-stage regression residuals, commodities	0.0725***	0.0650***	0.0689***	0.0646***	0.0664***	0.0624***	0.0632***	0.0624***
	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)
First-stage regression F-test (·) (workers)	3,272.95***	2,258.18***	3,612.51***	2,269.62***	4,081.42***	2,314.07***	4,110.51***	2,180.39***
First-stage regression F-test (·) (commodities)	17,802.55***	26,008.73***	17,802.55***	26,008.73***	17,802.55***	26,008.73***	17,802.55***	26,008.73***
Sargan-Hansen Overidentification $\chi^2(\cdot)$	5.08*	–	5.16*	–	4.90*	–	5.19*	–
Anderson Underidentification $\chi^2(2)$	7,901.68***	4,077.34***	8,655.48***	4,105.69***	9,709.46***	4,203.6***	9,786.09***	3,981.36***

Continued

TABLE 3: Continued

	45’		45’ & 60’		45’, 60’ & 90’		45’ & 90’	
Weak Identification Cragg-Donald Wald F	3,017	2,180	3,353	2,196	3,837	2,252	3,873	2,125
Anderson-Rubin Wald F(·)	67.06***	97.90***	67.06***	97.90***	67.06***	97.9***	67.06***	97.90***
Anderson-Rubin Wald $\chi^2(2)$	201.53***	196.13***	201.53***	196.13***	201.53***	196.13***	201.53***	196.13***
Stock-Wright LM $\chi^2(2)$	200.87***	195.5***	200.87***	195.50***	200.87***	195.50***	200.87***	195.50***
Control Variables								
Only exports	0.338***	0.339***	0.339***	0.339***	0.339***	0.339***	0.339***	0.340***
	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)
Only imports	0.307***	0.305***	0.307***	0.306***	0.307***	0.306***	0.307***	0.306***
	(0.011)	(0.012)	(0.011)	(0.012)	(0.011)	(0.012)	(0.011)	(0.012)
Exports and imports	0.431***	0.430***	0.431***	0.430***	0.431***	0.431***	0.431***	0.431***
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
Has Spanish affiliates	0.333***	00.330***	0.333***	0.331***	0.334***	0.331***	0.334***	0.331***
	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
Has foreign affiliates	0.337***	0.332***	0.337***	0.332***	0.337***	0.332***	0.338***	0.332***
	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)
Foreign social capital	0.294***	0.290***	0.294***	0.290***	0.294***	0.290***	0.294***	0.290***
	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)	(0.020)
Firm exits	−0.173***	−0.177***	−0.173***	−0.177***	−0.173***	−0.176***	−0.173***	−0.176***
	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)
Firm age	0.096***	0.095***	0.096***	0.095***	0.096***	0.095***	0.096***	0.095***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Employees qualification	0.662***	0.657***	0.662***	0.656***	0.663***	0.657***	0.663***	0.656***
	(0.006)	(0.007)	(0.006)	(0.007)	(0.006)	(0.007)	(0.006)	(0.007)
N	61,440	61,440	61,440	61,440	61,440	61,440	61,440	61,440

Notes: All estimations are carried out by 2SLS and include a sector of activity indicator, two digits NACE-93. All variables, except qualitative ones, are evaluated in logarithms. Significance levels are denoted as follows: 99.9 percent (***), 99 percent (**), 95 percent (*), 90 percent (†). Degrees of freedom for first-stage F-tests are $F(2, 61{,}336)$ and $F(3, 61{,}335)$ when the number of instruments is 2 and 3, respectively. Sargan-Hansen Overidentification is $\chi^2(1)$ statistic. Underidentification and Weak-Instrument-Robust inference are $\chi^2(1)$ and $\chi^2(2)$ statistics depending on the number of implemented instruments, 2 and 3, respectively.

over-identifying restrictions are valid can be rejected at the 5 percent level but not at the 1 percent level, suggesting caution should be used in interpreting the results. Furthermore, the Anderson LM statistic for the null hypothesis that the model is underidentified can be systematically rejected at the 0.1 percent level. Comparison of Cragg–Donald Wald *F* statistics with Stock and Yogo (2005) critical values, discards weak identification problems. Lastly, endogenous regressors in the structural equations are jointly significant in all considered specifications, as shown by the set of the three provided test statistics, robust to the presence of weak instruments.

The magnitude of consistently estimated elasticities is corrected in the expected direction, returning lower values in the case of commodities (around 14 percent) and significantly higher ones in the case of workers' accessibility (2.4–5.9 percent). Results in Table 3 correspond to the specifications generating the minimum and maximum values, in each version of the indicator, for TFP elasticities of the accessibility to workers, extracted from a set of six different specifications which combine available instruments. Again, 2SLS elasticities with regards to workers' accessibility decrease with commuting time, even to a larger extent than in OLS estimations. Further, they are now statistically significant in all cases.[19] The correction of the zero elasticity obtained in the OLS estimation of column 9 in Table 2 suggests that workers' accessibility considering up to 90 minutes journeys throughout medium size municipalities (100,000–500,000 inhabitants) may be measured with error. This therefore reinforces the implementation of 2SLS estimation procedures to additionally amend possible measurement errors in the variables of interest.

Comparison of workers' accessibility results with already existing ones, is not straightforward as they usually refer to more specific areas or they use agglomeration or market potential measurements in their analysis. Nonetheless they are much in line with previous findings, highlighting a moderate impact over TFP (Gibbons et al., 2010; Le Néchet et al., 2012; and Melo, Graham, Levinson, and Aarabi, 2013).

Our elasticities, in the case of commodities, at least double in magnitude those recently available results in the literature analyzing the effect of agglomeration or market potential on productivity (Melo, Graham, and Noland, 2009; Puga, 2010; Combes, Gilles Duranton, and Gobillon, 2011; Combes et al., 2012; Holl, 2012; amongst others), and they are only slightly higher than those provided by Brülhart and Mathys (2008). Specifically, the nature of the computed accessibility indicators can explain the differences in magnitude between provided and already available results. On one side, the inclusion of the individual component of accessibility implies that certain firm's characteristics, affect not just productivity but the accessibility indicator itself. In fact, within municipalities accessibility variance accounts for 46 percent of the total variance due to the individual component. Additionally, substantial disparities on the magnitude of the variances of delivered indicators and those market potential ones grounded on inverse distance formulations of the impedance functions (Holl, 2012), justify discrepancies in elasticity values. Consideration of probabilities, estimated from real traveling times or distances, makes the impedance function incorporate the highest propensity to supply larger markets even across those poorly communicated locations. This results in a relatively lower variance of our indicators and therefore higher elasticity levels.[20]

[19]To evaluate the p-value problem associated to large samples, following Lin, Lucas, and Shmueli (2013), we have carried out Monte Carlo simulations to generate 1,000 samples (conditioned on geographical distribution maintenance) for different sample sizes (5,000–60,000). The analysis of p-values from 2SLS estimations doesn't show evidence of this problem.

[20]Potential market indicators introduce the inverse of the distance as impedance functions, whilst the indicators proposed here use real traveling probabilities which imply lower impedance levels (i.e. higher probability). For instance, 100 km journey gives 0.01 impedance function in potential market indicators

TABLE 4: Percentage changes in productivity due to accessibility improvements expressed in percentiles

Percentile	**25**	**50**	**75**	**90**
	Accessibility to commodities			
10	8.6	17.8	25.4	33.7
25		5.8	10.5	15.7
50			3.4	7.1
75				3.0
	Accessibility to workers, 45' commuting time			
10	5.6	14.1	23.3	31.8
25		3.8	7.8	11.6
50			2.2	4.3
75				1.4
	Accessibility to workers, 45' & 60' commuting time			
10	5.6	14.5	24.4	34.6
25		3.8	8.0	12.4
50			2.2	4.5
75				1.5
	Accessibility to workers, 45' & 60' & 90' commuting time			
10	5.3	13.5	22.7	34.7
25		3.5	7.6	12.8
50			2.1	4.9
75				1.8
	Accessibility to workers, 45' & 90' commuting time			
10	5.0	13.0	24.3	35.3
25		3.5	8.5	13.3
50			2.7	5.2
75				1.5

Disparities on the results obtained for the two types of evaluated accessibility, are somehow surprising. They are possibly triggered by the degree of volatility of the accessibility indicators themselves. In order to objectively evaluate the impact of accessibility over TFP, Table 4, based on the average elasticities listed in Table 3, evaluates the increase in productivity associated to changes in firm's accessibility calculated according to the year 2009 real locations. Moving from percentile 10–90 in terms of commodities' accessibility causes a 33.7 percent increase in productivity, and a 10.5 percent increase if the accessibility improvement is equivalent to a shift from percentile 25 to percentile 75. In terms of workers' accessibility, the increases in productivity are 25–30 percent lower, depending on the evaluated accessibility measure.[21]

Dissimilarities in obtained results can also be interpreted in terms of the cross-sectional and temporal variation. Although only the former dimension is exploited in estimated regressions, it is important to notice that there has been a substantial improvement in Spanish urban and metropolitan infrastructure endowments along recent years, which

and 0.25 when using real traveling probabilities. Furthermore, the difference increases with distance, e.g. in the case of 500 km impedances become 0.002 and 0.072.

[21]Note that diminishing observed improvements in productivity associated to constant changes in accessibility across higher percentiles (see diagonals in Table 4) are due to lower accessibility gains, as elasticities are constant.

has reduced workers' commuting time. The efficiency gains associated to better infrastructures are already present in firms' productivity levels, and therefore, cross-sectional variation in workers' accessibility has been reduced. However, commodities' accessibility is more influenced by agents' location and thus the structure and quality of the full road network, where there may still be important connection problems in certain territories.

Additionally, high unemployment rates in Spanish labor markets erode workers' bargaining power, so labor commuting costs are often solely undertaken by workers and not shared by hiring firms. Conversely, commodities' transportation costs enter the costs function of the firm, directly affecting its productive efficiency.

Lastly, the productive structure of the Spanish economy may also help in understanding observed differences in estimated elasticities. Spanish manufacturing firms generally produce goods of medium-low technological content, and hence, the demand for qualified labor is relatively low. This provokes that firms' benefits associated with suitable matching between labor specialization and required level of qualifications are rather limited. Additionally, labor intensive manufacturing activities will tend on one hand to hire labor located nearby production locations, and on the other, to locate their plants in the neighborhood of large labor markets. This in turn reduces the impact of workers' accessibility on firm's productivity.

With respect to control variables, they are all statistically significant and show the expected signs. Foreign trade activities positively affect a firm's productivity, the effect being higher if firms engage jointly in both exports and imports. Having affiliates either in Spain or abroad is also associated to a better firm's performance, and estimated effects are as expected larger than those observed for foreign capital participation. Experienced firms and those hiring higher proportions of qualified labor, show a positive effect, whilst those firms exiting the market during the study year have a negative sign.

Obtained results, highlight the important role played by infrastructures on firms' productivity. It is little wonder firms prefer their locations across the best endowed territories in terms of road transport infrastructures. Furthermore, accessibility to commodities reveals, at least in the specific case of Spanish, it is more important to enhance firms' productivity improvements than the accessibility to workers.[22]

6. CONCLUSIONS

This paper measures the impact on firms' productivity against degrees of accessibility to labor markets and commodities. We consider two types of accessibility measures, one to workers and another to commodities.

An important contribution of this paper is the way in which accessibility is measured. First in terms of the impedance functions, approximated through the estimation of probability functions using microdata, to properly identify the individual features of both, workers and firms. Secondly, the measurement is at firm level, providing the indicators for more than 60,000 firms for the year 2009 and evaluating the distances and travel times between firms and workers or firms and territories using the full urban and intercity road network. The estimation of the TFP functions uses Levinsohn and Petrin methodology and is carried out for almost a hundred different manufacturing activities.

Our findings confirm that the impact of accessibility on firms' productivity is positive, elasticities ranging from 0.139 to 0.147 in the case of commodities, and from 0.024 to

[22]For robustness check of obtained results, firm size (in four different size classes) was included in regressions. Given that this particular variable is highly correlated with the rest of regressors, results, which did not show significant differences, have not been included in the paper.

0.059 in terms of labor markets. An accessibility improvement to commodities equivalent to a shift from percentile 10 to 90, increases productivity to almost 33.7 percent, and 10.5 percent if the accessibility correction is from percentile 25 to 75. The impact on productivity in terms of workers' accessibility is approximately 25–30 percent lower if compared to commodities' accessibility. This is due to the fact that on one hand, workers, rather than hiring firms, run in general with commuting costs. On the other hand, proper matching between labor demand and supply, plays a relatively less important role in Spanish labor markets, as a consequence of the manufacturing specialization of goods with a medium-low technological content.

Here delivered results should not be mistaken for policy recommendation purposes. Although the positive role of road infrastructure in firms' productivity is confirmed, this should not necessarily imply that any type of transport infrastructure investment would generate indicated effects on productive efficiency. For this to occur, new infrastructures should increase connection between firms, firms and final consumers, and between firms and workers. Productivity improvements are expected to be larger, the more oriented they are on the productive sector, the higher is the number of firms affected by them, and rather than concentrating in particular territories, they should transform the complete infrastructure network by means of increasing connectivity. Precisely, given provided results, infrastructure policy in Spain should concentrate further on the improvement of commodity transport infrastructures, which will definitely deliver efficiency gains to Spanish productive system.

APPENDIX

In order to obtain the level of qualification of firm employees, we carried out a rather complex measurement procedure following the income-based approach to measure human capital (see Oxley, Le, and Gibson, 2008 for details). For each firm in *SABI* we calculate the average wage for years 2001 and 2009 (w_i^{2001} and w_i^{2009}), as the ratio between labor expenditures and employees. We then obtain a weighted average for the wage by province (w_p^{2001} and w_p^{2009}) and by activity and province for both years (w_{sp}^{2001} and w_{sp}^{2009}). Additionally, from the microdata 5 percent sample of the Spanish Population Census (SPC), we calculate by province (h_{jp}^{2001}) and by province and sector (h_{jsp}^{2001}) the number of workers in each of the three available educational levels, primary ($j = 1$), secondary ($j = 2$), and tertiary ($j = 3$). Next we compute the average number of workers' years of schooling in each province (H_p^{2001}) and each activity and province (H_{sp}^{2001}) according to,

$$H_{\cdot}^{2001} = 6 \times h_{1\cdot}^{2001} + 12 \times h_{2\cdot}^{2001} + 17 \times h_{3\cdot}^{2001}. \tag{A.1}$$

Assuming that the differences in relative wages observed across activities within each province with respect to the provincial average are due to qualification differences, expression (A.2) can be estimated.

$$\frac{w_{sp}^{2001}}{w_p^{2001}} = \alpha + \beta \frac{H_{sp}^{2001}}{H_p^{2001}} + \varepsilon. \tag{A.2}$$

Rearranging expression (A.2) and assuming that the relationship holds in time, we obtain by expression (A.3) the average level of education (average number of schooling years) for workers in a given activity and province in year 2009; $\mathrm{w}_{\mathrm{sp}}^{2009}$ and $\mathrm{w}_{\mathrm{p}}^{2009}$ are known in expression (A.2) from *SABI*. $\mathrm{H}_{\mathrm{p}}^{2009}$ is obtained from human capital database of IVIE).

$$\widehat{H_{sp}^{2009}} = \left(\frac{w_{sp}^{2009}}{w_p^{2009}} - \hat{\alpha} \right) \frac{H_p^{2009}}{\hat{\beta}}. \tag{A.3}$$

TABLE A1: Summary Statistics[(a)]

Variables	Units	Mean	Median	STD	MIN	MAX	P10	P25	P75	P90
Total Factor Productivity (Levinsohn-Petrin)	Normalized[(b)]	1.12	0.90	1.29	0.00	139.71	0.37	0.59	1.32	1.94
Accessibility to workers 45’	Normalized	1.00	0.96	0.58	0.01	3.96	0.23	0.52	1.44	1.88
Accessibility to workers 45’ and 60’	Normalized	1.00	0.93	0.62	0.01	4.10	0.21	0.49	1.42	1.93
Accessibility to workers 45’, 60’, and 90’	Normalized	1.00	0.90	0.67	0.01	4.14	0.21	0.48	1.37	1.98
Accessibility to workers 45’ and 90’	Normalized	1.00	0.84	0.72	0.01	5.70	0.20	0.45	1.41	1.95
Accessibility to intermediate consumption	Normalized	1.00	0.98	0.40	0.03	2.35	0.50	0.70	1.24	1.59
Accessibility for intermediate uses	Normalized	1.00	1.06	0.62	0.02	2.92	0.16	0.40	1.52	1.80
Accessibility for final uses	Normalized	1.00	1.07	0.34	0.03	1.79	0.50	0.87	1.20	1.37
Accessibility to commodities	Normalized	1.00	1.01	0.41	0.07	2.29	0.45	0.72	1.25	1.51
Only exporting firms	0/1[(c)]	0.06	0	0.24	0	1	0	0	0	0
Only importing firms	0/1[(c)]	0.04	0	0.20	0	1	0	0	0	0
Exporting and Importing firms	0/1[(c)]	0.11	0	0.31	0	1	0	0	0	1
Firms with domestic subsidiaries	0/1[(c)]	0.07	0	0.26	0	1	0	0	0	0
Firms with foreign subsidiaries	0/1[(c)]	0.02	0	0.14	0	1	0	0	0	0
Firms with foreign capital (>=50 percent)	0/1[(c)]	0.01	0	0.12	0	1	0	0	0	0
Exiting firms	0/1[(c)]	0.03	0	0.16	0	1	0	0	0	0
Firm Age	Years	14.81	14.00	10.72	0.00	141.00	3.00	7.00	20.00	28.00
Employees qualification level	Years of schooling	9.29	6.93	4.10	6.00	17.00	6.00	6.00	12.27	17.00
Accessibility to final markets in 1857	Normalized	1.00	1.08	0.30	0.05	1.71	0.57	0.89	1.18	1.33
Average municipal altitude	Meters	367.48	294.37	286.88	0.00	2,439.53	50.04	114.16	618.07	746.82
Average municipal ruggedness index	Index	18.26	18.62	1.98	2.76	115.11	6.89	11.04	30.12	45.48
Municipal population density in 1900	Inhabitants/Km^2	402.31	88.30	1,016.77	0.05	5,625.29	22.46	43.82	257.78	950.32

Notes: [(a)]Statistics refer to year 2009 sample of firms. [(b)]The mean for all firms along 1999–2009 period is 1. For year 2009, this mean is larger due to technical progress. [(c)]The mean corresponds to the proportion of firms showing corresponding characteristic.

TABLE A2: Data and Information Sources

Database		Source	Type	Date	Availability	Variables
HSPC	**Historical Spanish Population Census**	INE and own elaboration	Spanish Municipalities	1857–2009	Free	• Population
		WEB: http://www.ine.es/intercensal/				
IIP	**Index for Industrial Price**	INE	Sector, type of good	1999–2009	Free	• Index for industrial price for final production, intermediate production and capital goods
		WEB: www.ine.es/en/inebmenu/mnu_industria_en.htm				
HCS	**Human Capital in Spain**	IVIE	Province	2001, 2009	Free	• Workers’ education
		WEB: http://www.ivie.es/en/banco/caphum/caphum.php				
MPR	**Municipal Population Register**	INE	Spanish Municipalities	2009	Free	• Population by sex and age
		WEB: www.ine.es/en/inebmenu/mnu_padron_en.htm				
NPSE	**National Public Service for Employment**	Ministry of Employment	Spanish Municipalities	2009	Free	• Unemployment rate
		WEB: www.sepe.es/contenido/estadisticas/datos_estadisticos/municipios/index.html				
NSSS	**National Social Security Service**	Ministry of Employment	Spanish Municipalities	2009	Free	• Jobs
		WEB: www.seg-social.es/Internet_1/Estadistica/Est/AfiliacionAltaTrabajadores/AfiliacionesAltaLaboral				

Continued

TABLE A2: Continued

Database		Source	Type	Date	Availability	Variables
HRNGS	**Historical Road Network Geodatabase for Spain**	Cabanes (1830) and own elaboration	Roads – Four categories	1829	Free and under request	• Main wheel fast road • Main wheel road • Primary paths • Secondary paths
IOT	**Input-Output Tables**	INE	Sector	2005, 2007	Free	• Use Table (2007) • Supply Table (2007) • Symmetric Table (2005)
		http://www.ine.es/daco/daco42/cne00/cneio2000.htm				
PSRCT	**Permanent Survey on Road Commodity Transport**	Ministry of Infrastructures	Microdata (journeys)	2002–2009	Under request	• Transported commodity • Region of origin of journey • Region of destination of journey • Distance
RA	**Regional Accounts**	INE	Province	2009	Free	• Per capita GDP
		http://www.ine.es/daco/daco42/cre00/b2008/dacocre_base2008.htm				
SABI	**Sistema de Analisis de Balances Ibéricos**	Bureau Van Dijk and Informa	Microdata (only manufacturing fims)	1999–2009	Under subscription	• Income • Employment • Net tangible fixed assets • Raw materials • Main activity • Subsidiaries • Shareholders • Foreign trade activity • Labour cost • Year of incorporation • Firm state
		Sabi.bvdinfo.com				

Continued

TABLE A2: Continued

Database		Source	Type	Date	Availability	Variables
SNGI	**Spanish National Geographical Institute**	Ministry of Infrastructures	Spanish Municipalities	2009	Under request	• Centroids
SPC	**Spanish Population Census (5 percent sample)**	INE	Microdata (inhabitans)	2001	Free	• Workers' sex • Workers' age • Workers' education • Workers' province • Workers' mun. size • Workers' mun. unemployment rate • Commuting time to work • Firms' province • Firms' mun. size • Firms' mun. unemployment rate • Firms' activity • Workers' job occupation • Firms' activity
		WEB: www.ine.es/en/prodyser/micro_censopv_en.htm				
		Goerlich and Cantarino (2010)	Spanish Municipalities	2010	Under request	• Municipal altitude • Riley's Ruggedness index
		Google Maps	Spanish Municipalities	2009–2010	Free	• Minimum commuting time on car between municipalities • Distance between municipalities (minimum commuting time)

Similarly, wage disparities amongst firms engaged in same activity and located in a province must be originated from differences in the employees' qualifications. Expression (A.2) can be rewritten to obtain expression (A.4) for year 2009.

$$\text{(A.4)} \qquad \frac{w_{spi}^{2009}}{w_{sp}^{2009}} = \hat{\alpha} + \hat{\beta}\frac{H_{spi}^{2009}}{\widehat{H_{sp}^{2009}}}.$$

Where w_{spi}^{2009} and H_{spi}^{2009} are respectively the wage and the average number of schooling years for firm's i employees working in province p and activity s. Rearranging expression (A.4), the qualification of firm's i employees can be estimated by (A.5); $\mathrm{w}_{\mathrm{spi}}^{2009}$ and $\mathrm{w}_{\mathrm{sp}}^{2009}$ are obtained from *SABI* database, whilst $\widehat{\mathrm{H}_{\mathrm{sp}}^{2009}}$ is estimated from expression (A.3)

$$\text{(A.5)} \qquad \widehat{H_{spi}^{2009}} = \left(\frac{w_{spi}^{2009}}{w_{sp}^{2009}} - \hat{\alpha}\right)\frac{\widehat{H_{sp}^{2009}}}{\hat{\beta}}.$$

REFERENCES

Anas, Alex. 2015. "Why are Urban Travel Times so Stable," *Journal of Regional Science*, 55(2), 230–261.

Andersson, Martin and H. Hans Lööf. 2011. "Agglomeration and Productivity: Evidence from firm-Level Data," *Annals of Regional Science*, 46(3), 601–620.

Aw, Bee Yan, Mark J. Roberts, and Daniel Yi Xu. 2011. "R&D Investment, Exporting, and Productivity Dynamics," *American Economic Review*, 101(4), 1312–1344.

Baldwin, Richard E. and Toshihiro Okubo. 2006. "Heterogeneous firms, Agglomeration and Economic Geography: Spatial Selection and Spatial Sorting," *Journal of Economic Geography*, 6(3), 232–346.

Baradaran, Siamak and Farideh Ramjerdi. 2002. "Performance of Accessibility Measures in Europe," *Journal of Transportation and Statistics*, 4(2/3), 31–48.

Bartelsman, Eric J. and Mark Doms. 2000. "Understanding Productivity: Lessons from Longitudinal Microdata," *Journal of Economic Literature*, 38(3), 569–594.

Brülhart, Marius and Nicole A. Mathys. 2008. "Sectoral Agglomeration Economies in a Panel of European Regions," *Regional Science and Urban Economics*, 38(4), 348–362.

Cabanes, Francisco J. 1830. *Guía general de correos, postas y caminos del reino de España*. Madrid, Imp. de Miguel de Burgos.

Combes, Pierre-Philippe, Gilles Duranton, and Laurent Gobillon. 2011. "The Identification of Agglomeration Economies," *Journal of Economic Geography*, 11(2), 253–266.

Combes, Pierre-Philippe, Gilles Duranton, Laurent Gobillon, and Sébastien Roux. 2010. "Estimating Agglomeration Economies with History, Geology, and Worker Effects," in E. L. Glaeser (ed.), *Agglomeration Economics*. University of Chicago Press, pp. 15–66.

Combes, Pierre-Philippe, Gilles Duranton, Laurent Gobillon, Diego Puga, and Sébastien Roux. 2012. "The Productivity Advantages of Large Cities: Distinguishing Agglomeration from firm Selection," *Econometrica*, 80(6), 2543–2594.

Duranton, Gilles and Matthew A. Turner. 2012. "Urban Growth and Transportation," *Review of Economic Studies*, 79(4), 1407–1440.

European Commission. 2010. "Perception Survey on Quality of Life in European Cities. Analytical Report," Eurobarometer 277, EC.

Fariñas, Jose C. and Ana Martín-Marcos. 2007. "Exporting and Economic Performance: Firm-level Evidence of Spanish Manufacturing," *The World Economy*, 30(4), 618–646.

Forslund, Ulla M. and Börje Johansson. 1995. "Assessing Road Investments: Accessibility Changes, Cost Benefit and Production Effects," *The Annals of Regional Science*, 29(2), 155–174.

Geurs, Karst T. and Jan R. Ritsema van Eck. 2001. "Accessibility Measures: Review and Applications," Rijksinstituut voor Volksgezondheid en Milieu (National Institute of Public Health and the Environment, RIVM) and Urban Research Centre, Utrecht University. Bilthoven/Utrecht, Netherlands

Gillen, David W. 2001. "Public Capital, Productivity, and the Linkages to the Economy: Transportation Infrastructure," Building the future: Issues in public infrastructure in Canada, *Policy Study*, 34, 36–72.

Goerlich, Francisco J. and Isidro Cantarino. 2010. "Un índice de rugosidad del terreno a escala municipal a partir de modelos de elevación digital de acceso público," Working Papers 20105, BBVA Foundation.

Graham, Daniel J. 2007a. "Agglomeration, Productivity and Transport Investment," *Journal of Transport Economics and Policy*, 41, 317–343.

——— 2007b. "Variable Returns to Agglomeration and the Effect Of Road Traffic Congestion," *Journal of Urban Economics*, 62, 103–120.

Graham, Daniel J. and H. Youn Kim. 2008. "An Empirical Analytical Framework for Agglomeration Economies," *Annals of Regional Science*, 42, 267–289.

Graham, Daniel J., Patricia C. Melo, Piyapong Jiwattanakulpaisarn, and Robert B. Noland. 2010. "Testing for Causality between Productivity and Agglomeration Economies," *Journal of Regional Science*, 50(5), 935–951.

Harris, Richard and Catherine Robinson. 2003. "Foreign Ownership and Productivity in the United Kingdom. Estimates for UK Manufacturing using the ARD," *Review of Industrial Organization*, 22(3), 207–223.

Holl, Adelheid. 2012. "Market Potential and firm-Level Productivity in Spain," *Journal of Economic Geography*, 12, 1191–1215.

Hopenhayn, Hugo A. 1992. "Entry, Exit and Firm Dynamics in Long Run Equilibrium," *Econometrica*, 60, 1127–1150.

Huergo, Elena and Jordi Jaumandreu. 2004. "Firms' Age, Process Innovation and Productivity Growth," *International Journal of Industrial Organization*, 22(4), 541–559.

Jovanovic, Boyan. 1982. "Selection and the Evolution of Industry," *Econometrica*, 50, 649–670.

Kawabata, Mizuki. 2003. "A GIS-Based analysis of jobs, workers, and job access in Tokyo," CSIS Discussion Paper No. 57.

Korsu, Emre and Sandrine Wenglenski. 2010. "Job Accessibility, Residential Segregation and Risk of Long-Term Unemployment in the Paris Region," *Urban Studies*, 47(11), 2279–2324.

Kwan, Mei-Po. 1998. "Space-Time and Integral Measures of Individual Accessibility: A Comparative Analysis using a Point-Based Framework," *Geographical Analysis*, 30(3), 191–216.

Lall, Somik V., Zmarak Shalizi, and Uwe Deichmann. 2004. "Agglomeration Economies and Productivity in Indian Industry," *Journal of Development Economics*, 73(2), 643–673.

Le Néchet, Florent, Patricia C. Melo, and Daniel J. Graham. 2012. "The Role of Transport Induced Agglomeration Effects on Firm Productivity in Mega-City regions: Evidence for Bassin Parisien," *Transportation Research Record: Journal of the Transportation Research Board*, 2307, 21–30.

LeSage, James P. and Christine Thomas-Agnan. 2015. "Interpreting Spatial Econometric Origin-Destination Flow Models," *Journal of Regional Studies*, 55(2), 188–208.

Levinsohn, James and Amil Petrin. 2003. "Estimating Production Functions Using Inputs to Control for Unobservables," *Review of Economic Studies*, 70(2), 317–341.

Lin, Mingfeng, Henry C. Lucas, and Galit Shmueli. 2013. "Too Big to Fail: Large Samples and the p-Value Problem," *Information Systems Research*, 24(4), 906–917.

Lutter, Horst, Thomas Pütz, and Martin Spangenberg. 1992. *Accesibility and peripherality of community regions: The role of road, long-distance railways and Airoport Networks*. Brussels: Commission of the European Communities.

Melo, Patricia C., Daniel J. Graham, and Robert B. Noland. 2009. "A meta-Analysis of Estimates of Urban Agglomeration Economies," *Regional Science and Urban Economics*, 39, 332–342.

Melo, Patricia C., Daniel J. Graham, and Ruben Brage-Ardao. 2013. "The Productivity of Transport Infrastructure Investment: A Meta-Analysis of Empirical Evidence," *Regional Science and Urban Economics*, 43(5), 695–706.

Melo, Patricia C., Daniel J. Graham, David Levinson, and Sarah Aarabi. 2013. "Agglomeration, accessibility, and productivity: Evidence for Urbanized Areas in the US," Paper submitted for the Transportation Research Board 92nd Annual Meeting.

Núñez-Serrano, Juan A. 2012. "El efecto de la accesibilidad a los mercados en la eficiencia empresarial. Una aproximación microeconómica," Ph.D Thesis, Universidad Complutense de Madrid, December 2012. Available at: http://eprints.ucm.es/21006/

Olley, G Steven and Ariel Pakes. 1996. "The Dynamics of Productivity in the Telecommunications Equipment Industry," *Econometrica*, 64(6), 1263–1297.

Oxley, Les, Trinh Le, and John Gibson. 2008. "Measuring human capital: Alternative methods and international evidence," *The Korean Economic Review*, 24(2), 283–344.

Partridge, Mark D., Dan S. Rickman, Kamar Ali, and M. Rose Olfert. 2009. "Agglomeration Spillovers and Wage and Housing Cost Gradients Across the Urban Hierarchy," *Journal of International Economics*, 78(1), 126–140.

———2010. "Recent Spatial Growth Dynamics in Wages and Housing Costs: Proximity to Urban Production Externalities and Consumer Amenities," *Regional Science and Urban Economics*, 40(6), 440–452.

Puga, Diego. 2010. "The Magnitude and Causes of Agglomeration Economies," *Journal of Regional Science*, 50, 203–219.

Riley, Shawn J., Stephen D. DeGloria, and Robert Elliot. 1999. "A Terrain Ruggedness Index that Quantifies Topographic Heterogeneity," *Intermountain Journal of Science*, 5, 23–27.

Shen, Qing. 1998. "Location Characteristics of Inner-City Neighbourhoods and Employment Accessibility of Low-Wage Workers," *Environment and Planning B*, 25, 345–365

Stock, James H. and Motohiro Yogo. 2005. "Testing for Weak Instruments in Linear IV Regression," in D. W. K. Andrews and J. H. Stock (eds.), *Identification and Inference for Econometric Models: Essays in Honor of Thomas Rothenberg*. Cambridge, U.K: Cambridge University Press, pp. 80–108.

Tomiura, Eiichi. 2007. "Foreign Outsourcing, Exporting, and FDI: A Productivity Comparison at the Firm Level," *Journal of International Economics*, 72(1), 113–127.

Van Beveren, Llke. 2012. "Total Factor Productivity Estimation: A Practical Review," *Journal of Economic Survey*, 26(1), 98–128.

Van Ham, Maarten, Pieter Hooimeijer, and Clara H. Mulder. 2001. "Urban form and Job Access: Disparate Realities in the Randstad," *Tijdschrift voor Economische en Sociales Geografie*, 92(2), 231–246.

Venables, Anthony J. 2007. "Evaluating Urban Transport Improvements: Cost-Benefit Analysis in the Presence of Agglomeration and Income Taxation," *Journal of Transport Economics and Policy*, 41, 173–188.

Weisbrod, Glen and Frederick Treyz. 1998. "Productivity and Accessibility: Bridging Project-Specific and Macroeconomic Analyses of Transportation Investments," *Journal of Transportation and Statistics*, 1(3), 65–79.

Yeaple, Stephen R. 2009. "Firm Heterogeneity and Structure of U.S. Multinational Activity," *Journal of International Economics*, 78, 206–215.