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**The impact of agglomeration effects and
accessibility on wages**

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1. Introduction

The benefits from improved accessibility to input and output markets has been given a theoretical basis thanks to the new economic geography literature (Fujita et al., 1999). One of the implications derived from this literature is the new insights provided to the evaluation of transport investment appraisal. In the presence of market failure, conventional user benefit measures give an incomplete picture of the benefits derived from the new infrastructure.

Venables (2007) develops a model of urban economics where additional benefits from transport investments derives from the fact that infrastructure increases the size of agglomeration by improving accessibility. The presence of increasing returns to the size of agglomeration in such scenario allows for additional benefits due to additional productivity gains that, it is claimed, should be included in the appraisal exercise. As Graham (2007) puts it, the estimation of the effects of agglomeration and accessibility to agglomeration on productivity should become an input for transport appraisal studies.

This paper contributes to the empirical literature on the effects of agglomeration and accessibility on productivity. Specifically, our purpose is to contribute to the debate about the way in which accessibility affects the performance of firms by looking at the case of Spain. In the last three decades, several ambitious road investment programs have been implemented in Spain. Our analysis starts in 1995 when the first motorway plan, started in 1985, was completed and Spain reached a good level of road infrastructures by European standards. Nonetheless, the investments in motorways continued over the following years at a similar rate, which maintained the pace of the previous years. Our aim is to assess whether the improvements in accessibility as a result of these road transport programmes have had any effect on the productivity of firms.

Additionally, we also look at the impact of agglomeration effects, measured by employment density, on productivity. Preliminary estimations showed that this impact was non linear and we explore this relationship in the paper.

We approach productivity indirectly by using individual wages allocated at the NUTS III level that correspond to provinces in Spain. Therefore, we estimate a wage equation with worker level data. We use a repeated cross-section of individual micro-data for the years 1995, 2002 and 2006. The availability of interprovincial travel time data for each

of the three years allows controlling for transport improvements over the period, by using a market potential variable. The fact that our spatial unit of analysis is the province provides a lower variability of market potential than in the case of using municipalities but, on the other hand, provinces approach much better than municipalities the boundaries of existing local labour markets.

This paper is organised in six sections. The next section reviews relevant literature and explains the strategy followed. In section three, the characteristics of the dataset used are explained as well as the changes in accessibility that take place during the study period. Sections four and five show the estimated equations and the derived results. A final section draws the main conclusions.

2. Related literature and selected strategy

The effect of economies of agglomeration on productivity has been the subject of a large empirical literature as reviewed in Rosenthal and Strange (2004). However, it was not until the last decade that a theoretical body was developed to explain the microfoundations of the economies of agglomeration beyond the Marshallian triad (Duranton and Puga, 2004). The classification of these microfoundations as “sharing”, “matching” and “learning” has become widely accepted. Additionally, the seminal work by Krugman (1991) that set the basis for the “new economic geography”, established the relation between economies of scale, transport costs and factor mobility that determines the concentration of activity. This line of work offers new insights into the relationship between accessibility and the location of activity.

A basic framework to establish the relationship between productivity and agglomeration economies is provided by Combes et al (2008). We consider a firm j producing in region r and sector s that uses labour l and a composite of other inputs k with a technology described by the following Cobb-Douglas production function. A_j is a Hicks-neutral factor augmenting technological level, and s_j is a labour efficiency index.

$$y_j = A_j (s_j l_j)^\mu k_j^{1-\mu} \quad (1)$$

The firm's profit is given by:

$$\pi_j = p_j y_j - w_j l_j - r_j k_j \quad (2)$$

where w_j is the wage and r_j the price of other inputs.

The following expression is obtained for the wage of worker j after applying first order conditions and substituting:

$$w_j = \mu(1-\mu)^{(1-\mu)/\mu} s_j \left(\frac{p_j A_j}{r_j^{1-\mu}} \right)^{1/\mu} \quad (3)$$

It is also possible to derive expressions (4) and (5) for average productivity of labour as well as total factor productivity.

$$\frac{p_j y_j}{l_j} = \mu(1-\mu)^{(1-\mu)/\mu} s_j \left(\frac{p_j^{1-\mu} A_j}{r_j^{1-\mu}} \right)^{1/\mu} \quad (4)$$

$$\frac{p_j y_j}{l_j^\mu r_j^{1-\mu}} = p_j A_j (s_j)^\mu \quad (5)$$

The last three expressions give us a guide to the channels through which productivity is affected by economies of agglomeration. Some of the effects may arise from pure externality effects as A_j and s_j capture. Technological and human capital externalities through learning may help to spill over knowledge and skills to enhance worker productivity. But improved matching effects may also be reflected in higher total factor productivity. Other effects show up in the prices of output p_j and inputs k_j . A higher price of output translates to higher wage which in turn contributes to a higher agglomeration. Regarding inputs, a large number of accessible suppliers may reduce r_j . Conversely, an inelastic supply of an input will induce input price increases as the agglomeration of the firms demanding the input grows.

The measurement of economies of agglomeration has followed several strategies. The most obvious is the estimation of production functions that directly establish a link between productivity and agglomeration effects. Most of the early work on agglomeration effects used this strategy. The available evidence makes it possible to establish an increase in range of productivity of between 3%-8% when doubling city size (Rosenthal and Strange, 2004). Most of this work used aggregated data and did not control for the two biases found in the estimation of agglomeration economies, simultaneity bias and unobserved heterogeneity. The first study to carefully deal with these endogeneity issues was Ciccone and Hall (1996), who used an instrumental

variables strategy. Instruments are long lagged agglomeration variables under the assumption that the location of agglomeration 100-150 years ago may explain current locations but not current productivity. More recent work with establishment micro data can approach much better the theoretical models and deal with the endogeneity issues. Henderson (2003) and Martin et al. (2011) are two of the best examples. Both studies show that the effect of the size of total nearby employment (urbanization economies) is less important than the size of employment of the own industry (localization economies)¹. An interesting point of the work of Martin et al. (2011) is that they find a non-linear effect of agglomeration in line with the work by Henderson and Au (2006) for Chinese cities.

Given the difficulties involved in estimating production functions, different estimation strategies have been followed to indirectly estimate the relation between productivity and agglomeration effects as reviewed by Rosenthal and Strange (2004). One of the most explored is based on equation (3). This implies the estimation of a wage equation as follows:

$$w_{js} = \alpha + \beta den_j + \varepsilon_{js} \quad (6)$$

where w_{js} is the wage in region j and industry s , den_j is the density of employment of region j (employees per unit of land area), and ε_{js} is a random disturbance term.

Estimating wage equations has the advantage that wages are measured more precisely than average labour productivity and total factor productivity. A number of papers have followed this strategy to test the hypothesis that wages are higher in denser areas due to the effects of agglomeration economies. Nonetheless, other explanations can be adduced for the higher productivity of workers in larger markets. The most obvious candidate is the existence of a sorting effect where non observable skill characteristics can be better rewarded in larger markets. In this case, the higher productivity of denser markets is the result of the concentration of highly skilled workers. From the supply side, a higher nominal wage should be needed to compensate workers for the higher living costs in denser areas. But firms will only be willing to offer a higher wage if productivity advantages due to agglomeration justify a higher reward.

¹ Henderson (2003) finds that the relevant agglomeration measure is the number of establishments rather than employees.

The available evidence shows a robust positive relation between wage and density². In the case of American studies, Glaeser and Mare (2001) find that controlling for observable worker characteristics, the urban wage premium using different data sets is about 25%. When introducing worker fixed effects the premium drops to 5%-10% depending on the dataset. Wheeler (2001) estimates an elasticity of 2.7% with respect to MSA population. Yankow (2006) finds a 19% premium for those workers residing in cities of over 1 million, but when unobserved heterogeneity is controlled for by using fixed effects, the large cities premium reduces to 6%. Both Glaeser and Mare (2001) and Yankow (2006) find that the sorting of skilled individuals partly explains the higher wage in large cities, but a premium still persists.

In the case of European countries, several recent studies have found evidence of a positive effect of density on wages. Most notably, Combes et al. (2008) use a large panel of French workers residing and working in 346 employment zones. Estimating with instruments and worker fixed effects to control for unobserved heterogeneity, they find an effect of density of 3%. Mion and Naticchioni (2009), for the case of Italian provinces, control for both workers and firm heterogeneity by using an employer-employee matched dataset. They find an elasticity of 2.2% when estimating with OLS, which is low in comparison with previous studies. The authors argue that the low elasticity is related to the centralized Italian wage bargaining system where sectors are subject to nationally binding conditions like minimum wages. When introducing workers fixed effects and firm size to control for firm heterogeneity, the wage elasticity drops to 0.56%. Controlling for endogeneity by using IV estimators, density falls to 0.2%. Finally, Melo and Graham (2009) do not find very different results for Britain using a panel and Travel-To-Work Areas. The elasticity of employment density when estimating by OLS amounts to 2.2%. When introducing workers fixed effects the estimated elasticity is 1% and the IV estimation reduces the elasticity to 0.8%.

The main focus of interest of the present paper is the effect of market potential as a way to capture the effects of accessibility to inputs and output markets on productivity and wages. As far as accessibility changes are related to transport improvements, the effect of market potential can provide a measure of the effects of transport improvements on productivity.

² Here we only refer to studies using microdata.

The effect of transport improvements on productivity have been approached from different perspectives in the existing literature. Since Aschauer's (1989) contribution, a large number of articles have been published that have sought to disentangle the effects of public capital on aggregate productivity both on a national and regional level. Nonetheless, over the last two decades a new focus has been given to transportation infrastructure effects with the development of the new economic geography (Krugman, 1991; Fujita et al., 1999).

While the former approach deals with infrastructure as a production factor, the new theories put the emphasis on the relation between transport costs and economies of scale. This implies that transportation infrastructure is an important ingredient to the extent that it affects transport costs and accessibility to output and input markets.

Better accessibility to inputs may reduce the price paid by firms if they cover part of the transport costs. This may have scale effects that have a positive effect on productivity if there are economies of scale.

Regarding output, better accessibility means widening the spatial scope of markets, which increases the effects of existing economies of scale. On the other hand, better accessibility exposes firms to more intense competition. In the long run, some firms will exit the market, which will increase market shares and economies of scale for the remaining firms. Despite the fact that the number of firms decreases, the more intense competition due to better accessibility will lead to lower mark-ups and prices.

Productivity may also increase due to a selection effect as a result of increased competition. Less productive producers are forced out of the market, giving rise to a selection effect in which only the more efficient firms remain in the market.

But changes in accessibility may also affect agglomeration economies. On the one hand, better accessibility may attract new and relocating firms, causing clustering of activities in places that are positively affected by accessibility changes. On the other hand, transport improvements may reduce the cost of benefitting from agglomeration economies generated by widening the spatial scope of agglomeration benefits. Consequently the effects of agglomeration on productivity/wages will be enhanced (Holl, 2006).

Graham (2007) uses a measure of “effective density” that measures accessibility to employment in the remaining areas, including firms’s own area in the estimation of production functions with a micro dataset of firms. He finds an elasticity of 0.129 for the whole economy, and 0.07 for manufacturing, while services are those that most benefited from agglomeration economies with an elasticity of 0.197. Combes et al. (2008) use density as a potential measure, which is weighted by the inverse of great circle distance between areas. They estimate a potential elasticity of 3.5% with fixed effects. The estimation using instrumental variables reduces elasticity by one percentage point. Mion and Naticchioni (2009) use the provincial disposable income weighted by the inverse of distance as a market potential measure. They obtain a market potential elasticity in their equation when controlling for fixed effects and firm size of 4.5% and after instrumenting slightly increases to 4.6%. In comparison with Combes et al. (2008), the market potential effect on wages is more significant and much larger than employment density. Finally, Melo and Graham (2009) market potential variable is total employment of the Travel-To-Work Areas weighted by the distance deducted from latitude and longitude of TTWA centroids. The elasticity from the OLS estimation is as high as 10%. However, the fixed effects estimation decreases the elasticity to 5.4% whereas instrumenting, as in Mion and Naticchioni (2009), increases the elasticity to 5.8%. Again, the effect of market potential is far higher than that of employment density.

In the case of Spain, some studies have estimated a positive albeit reduced effect of accessibility on productivity. Most of these studies follow the strategy of indirectly approaching productivity effects from firm births. Holl (2004), using data on new firms by municipality for the 1980-94 period, finds a significant effect of attraction of new firms for those municipalities which experience an increase in accessibility to the newly built motorway network. This effect is reduced with distance from the network. Other authors like Alañón and Arauzo (2008) and Arauzo (2005) find similar results. Albarrán et al. (2009) find that that the firm’s decision to become an exporter is positively affected by accessibility in terms of internal transport, measured as travel time to main export ports.

However, as far as we know there has been no study that has estimated the effect of agglomeration and accessibility on productivity using micro-data. Our paper seeks to fill this gap by estimating a wage equation with individual worker data. The choice of the wage equation strategy is selected given the quality of the wage data in comparison

with the data available on firm surveys. The advantages of wage data come from a higher number of control variables and, mainly, a more detailed spatial disaggregation.

In order to measure those effects we use an employment density variable in line with the literature reviewed and a market potential variable to approach accessibility. Additionally, a specialization index is introduced to control for intraindustry externalities and an aggregate index of education level is also included to control for possible human capital externalities.

3. Data

We use micro-data on individual wages from the Spanish Structure of Earnings Survey (SES). The SES is a four-yearly survey carried out in all Member States of the European Union using the same methodology with the objective of providing accurate and harmonised data on wage levels and their distribution. In the case of Spain, the survey is conducted by the National Institute of Statistics and data is available for the years 1995, 2002 and 2006. The main advantages of this database are its size, a large set of variables to control for workers and firm characteristics, information on the industrial sector at two-digit level and the possibility of allocating workplaces on an NUSTS-III level.

In order to guarantee data comparability among the three years, we considered workers in firms with at least 10 employees in the manufacturing and service sectors, excluding workers in the health and education sectors given that this information is available only for 2002 and 2006³. The final number of observations was 109,596 for 1995, 114,368 for 2002 and 86,456 for 2006.

Table 1 reports a summary of the statistics for the relevant individual variables in the dataset. Our variable of analysis is the gross monthly wage, which includes the base wage plus any additional fixed or variable wage payments, except overtime payments, before deducting income tax and worker's contributions to the public social insurance system⁴. Workplaces are allocated at NUTS-III level, the smallest geographic unit for which we can have information, which corresponds to the 47 Spanish mainland provinces. Table 1 shows that the mean gross monthly wage decreased in constant prices between 1995 and 2006. This reduction can be explained by the behaviour of some of the main determinants of wages: a decrease in the average value of years of tenure, an increase in the rate of female employment and a significant growth in part time labour. Wage data also reveals a large dispersion among provinces that is highly persistent over time. For instance, the coefficient of variation of the average wages per province is equal to 0.15 for 1995 and 0.14 for 2006.

³ Workers located in the Canary Islands, Balearic Islands, and in the North-African cities of Ceuta and Melilla have also been excluded.

⁴ Alternatively, we work with the gross hourly wage. The results proved to be very similar, however we selected monthly wages due to the lack of reliability in the number of working hours reported for some workers in the sample.

Table 1. Summary statistics for the main variables in the study
(average across all individuals in the sample)

	1995		2002		2006	
	Individual continuous variables					
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Gross monthly wage (Euros, 2006)	1620	1168	1616	1202	1561	1070
Age (years)	38.5	10.9	38.0	10.9	38.5	10.9
Tenure (years)	10.8	9.9	8.0	9.8	7.5	9.5
	Individual discrete variables (shares)					
Gender						
Male	74.7%		66.1%		61.1%	
Female	25.3%		33.9%		38.9%	
Working time						
Full time	96.0%		90.1%		85.0%	
Part time	4.0%		9.9%		15.0%	
Type of contract						
Indefinite	76.1%		78.6%		77.8%	
Fixed term	24.0%		21.4%		22.2%	
Level of education						
Primary or less	32.0%		27.0%		27.5%	
Compulsory secondary	31.1%		30.8%		28.1%	
Post-compulsory secondary	12.4%		11.2%		12.0%	
Vocational training	13.4%		16.3%		15.2%	
University Degree	11.0%		14.7%		17.3%	
Observations	109596		114368		86456	

The spatial variables used in the analysis are detailed in Table 2. All these variables are computed at the aggregate NUTS-III level. The use of provinces allows for a sufficient level of territorial disaggregation whereas at the same time providing a rich range of potential explanatory variables.

Accessibility is measured according to the traditional market potential based on Harris (1954) definition. The market potential for each province is defined as $\sum_j GDP_j / t_{ij}^\alpha$;

that is, the sum of GDP over all the provinces j , weighted by travel time between each origin and destination provinces. In line with common practice, after exploring different values for α , our final choice was the simple inverse cost weighting scheme, $\alpha = 1$.

This variable picks up both changes in GDP and changes in interurban travel times derived from improvements in the road network⁵.

Table 2. Summary statistics for the spatial variables in the study
(average across all individuals in the sample)

	1995	2002	2006	$\Delta 2002/$ 1995	$\Delta 2006/$ 2002	$\Delta 2006/$ 1995
Market potential						
Mean	3195	4205	4766	31.6%	13.4%	49.2%
Std. Dev.	1001	1300	1478			
Min	1630	2324	2581			
Max	4879	6405	7276			
Employment density						
Mean	91.3	121.8	147.5	33.4%	21.1%	61.6%
Std. Dev.	85.0	116.9	141.2			
Min	3.1	3.4	3.9			
Max	212.2	310.5	370.9			
Specialisation						
Mean	1.35	1.36	1.30	1.1%	-4.6%	-3.5%
Std. Dev.	1.28	1.39	1.26			
Min	0.05	0.10	0.12			
Max	13.19	14.84	14.73			
Human capital						
Mean	16.0	21.0	23.4	31.2%	11.4%	46.3%
Std. Dev.	4.5	4.9	4.8			
Min	8.0	13.0	14.1			
Max	24.8	30.2	31.5			

Secondly, agglomeration economies are measured through employment density, i.e., workers per square kilometre. Thirdly, we include an index of the degree of industrial specialization of each province computed as the employment share of sector r in the total employment of province j , sectors being defined at two-digit levels. So, this variable depends on both the province and the sector. Finally, we measure the level of human capital as the share of working population with a tertiary degree. Alternatively, similar results are obtained when the measure used is the average years of education⁶.

All the spatial variables analysed present a high level of variability among provinces. This is particularly true for the variables accounting for urbanisation and location economies. Moreover, dispersion is approximately constant over time, except for human capital, which shows a continuous reduction. According to this data, the different road programmes implemented have not led to a more homogeneous spatial

⁵ Travel time matrices have been computed for each year in the sample using a GIS based on average speeds for each type of road.

⁶ Data on employment and education of the labour force at the province level come from the Instituto Valenciano de Investigaciones Económicas (IVIE) database.

distribution of market potential. With respect to the evolution over time, employment density, market potential and human capital have grown at a very high rate throughout the period. It is interesting to note that market potential and human capital have followed a very similar pattern. On the contrary, the index of industrial specialisation presents a slight reduction between 2002 and 2006.

Figure 1 presents the map of market potential for the Spanish provinces for 2006. The map shows a wide degree of variation between provinces, with higher market potential for those provinces located along the Mediterranean coast, the Basque Country in the north, and Madrid and its surrounding provinces. Map 2 displays the percentage change in travel time between the final and the initial year of the sample for each province computed as the sum of travel time from province j to the rest of provinces. The road infrastructure programs implemented from 1995 to 2006 have significantly reduced travel times for those provinces located in the north-west corner and, in general, in the western part of Spain and to a lesser extent for provinces located in the centre and south-east of the country along the Mediterranean coast. In general, the areas that have most benefited from road investment correspond to areas with a low level of market potential. The pattern of market potential over time has followed very closely that of changes in travel time (Figure 3). This relation is confirmed by a correlation coefficient of -0.82 between change in travel time and change in market potential.

Figure 1. Market potential for 2006

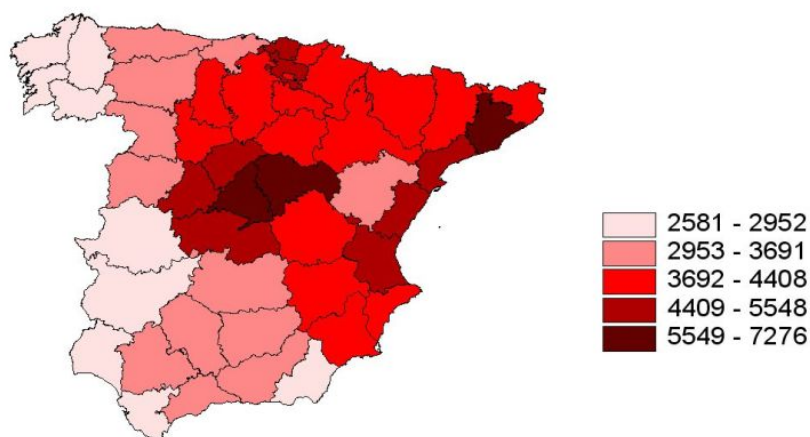


Figure 2. Percentage change in travel time

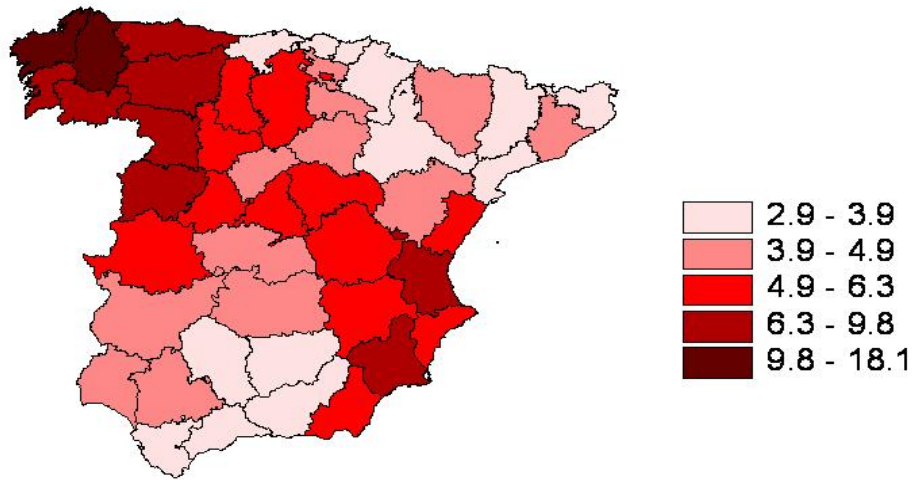
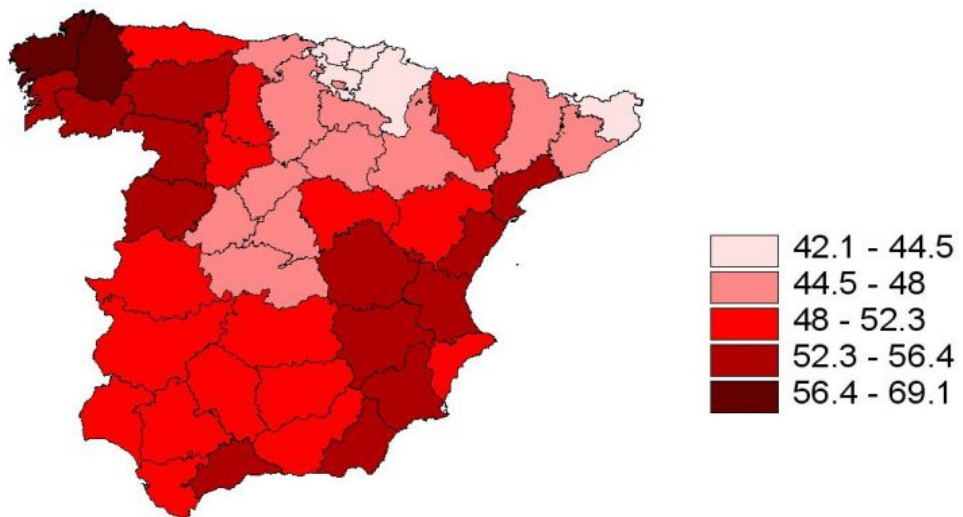


Figure 3. Percentage change in market potential



4. Estimated equations

As has been explained, the estimation approach selected is the wage equation. The dependent variable is the log of gross monthly wage in Euros deflated by the Spanish consumer price index and the base year is 2006.

The selected regressors are employment density, market potential, specialization and human capital. We also include straight-line distance to the French border to account for the geographical location of each province. Indirectly, this variable is used as a proxy for accessibility to European markets.

The use of worker's level data from the SES makes it possible to account for individual heterogeneity through a large number of employee and workplace variables. We control for the following individual characteristics: age, gender, level of education (9 levels) and tenure, which are among the main determinants of individual wage. We also control for a wide range of characteristics of the workplace: working time (full/part time), type of contract (indefinite/fixed term), industrial disaggregation (two digits) and type of occupation (12 categories). Finally, we include time dummy variables. In our view, controlling for educational level and other individual features highly contributes to alleviating the frequently faced econometric problem of omitted variable bias when estimating the impact of spatial externalities.

The equation is estimated for all sectors in the sample and for manufacturing and service sectors in order to allow for different impacts between industrial groups.

As is standard, we estimate the equation in logs, so we can interpret the estimated coefficients as elasticities. The first estimates are obtained by applying ordinary least squares (OLS). Preliminary work showed that the effect of employment density on wages might not be linear. This result is in line with Martin et al (2011). Although in the standard wage equation specification the relation with density is linear, we propose a quadratic form based on the econometric evidence⁷.

The covariance matrix has been obtained by the White method robust to heteroskedasticity. The estimated coefficients for individual and workplace characteristics all have the expected sign and are statistically significant. The full

⁷ A more flexible functional form using splines was first tried suggesting that a parsimonious quadratic form describes well the behaviour of the density effect on wages.

equation is presented in Appendix 1, whereas Table 3 in the text offers the coefficients estimated for the variables of interest to our analysis. This Table shows that market potential, specialization and human capital all have a positive effect on productivity with elasticity values that are roughly in line with empirical evidence for OLS equations. As for employment density, we obtain a positive sign for the first coefficient and a negative one for its square, which are both highly statistically significant.

It has to be noted that the coefficients of interest are highly stable to the selection of control variables.

Table 3. Estimation results for the OLS equation

	All sectors	Manufacturing	Services
ln (market potential)	0.104726 (25.77)	0.093585 (19.08)	0.133138 (19.41)
ln (employment density)	0.121010 (27.52)	0.079249 (15.05)	0.171342 (23.43)
(ln (employment density))^2	-0.01221 (20.86)	-0.00637 (9.08)	-0.01929 (19.65)
ln (specialization)	0.041588 (35.75)	0.040170 (31.67)	0.054697 (11.18)
ln (human capital)	0.067284 (17.543)	0.081762 (17.04)	0.046082 (7.19)
Distance to French border	-0.000067 (17.16)	-0.000117 (23.11)	-0.000019 (2.86)
R square	0.5928	0.5476	0.6206

However, as has been largely documented, the OLS estimates can be flawed due to possible endogeneity problems. As explained in Section 2, in our context the potential sources of endogeneity can not be neglected⁸. In accordance with the literature, we consider that the troublesome variables are: employment density, market potential, specialisation and human capital stock. We deal with endogeneity by means of instrumental variable estimates (IV) following the standard practice of using lagged values of endogenous variables as instruments under the hypothesis that these variables are correlated with the endogenous explanatory variable but, at the same time, are independent from the random error term. Market potential is instrumented by the same variable computed for 1980, the first year travel time between provinces are

⁸ Combes et al (2011) discuss the main sources of bias in the identification of agglomeration effects.

available. Employment density is instrumented by population density computed for 1860 and specialization with data of this variable in 1980. Finally, following Dalmazzo and de Blasio (2007) we used the demographic structure of the population to instrument human capital. Specifically, we used the difference between the share of population between 15 and 19 years of age and the share of those between 5 and 9 years of age⁹. The results are presented in Table 4.

Table 4. Estimation results for the 2SLS equation

	All sectors	Manufacturing	Services
ln (market potential)	0.079132 (12.58)	0.085238 (12.15)	0.085729 (7.91)
ln (employment density)	0.085643 (11.72)	0.061729 (7.14)	0.111801 (9.50)
(ln (employment density))^2	-0.00693 (7.08)	-0.00374 (3.24)	-0.01044 (6.50)
ln (specialization)	0.045020 (32.52)	0.040690 (26.66)	0.039886 (5.53)
ln (human capital)	0.045728 (7.51)	0.058212 (7.94)	0.033145 (3.14)
Distance to French border	-0.000076 (19.24)	-0.000123 (23.60)	-0.000025 (3.35)
R square	0.5926	0.5475	0.6203

When dealing with estimation by instrumental variables, the problem of weak instruments emerges as a well documented issue in the econometric literature. Weak correlation between the instrument and the endogenous variable can make estimation by IV far worse than estimation by OLS. In our case, the hypothesis of weak instruments was tested by using the partial R-square. As Table 5 shows, in all cases the partial R-square is high enough to reject weak instruments and, therefore, the IV estimates can be considered valid. The Hausman test rejects the null hypothesis of exogeneity¹⁰.

⁹ The underlying hypothesis for this instrument is that those between 5 and 9 years of age in 1991 will be 15 and 19 years of age ten years of later. They could not be employed ten years later with a university degree. Conversely, the population between 15 and 19 years of age in 1991 can be employed ten years later with a university degree. Therefore, the larger the share of population between 15 and 19 in 1991, the larger the percentage of working population with a tertiary degree ten years later, and the larger the share of population between 5 and 9 years of age in 1991, the lower this percentage ten years later.

¹⁰ The results of testing the null hypothesis that variables are exogenous are:
All sectors: Robust score $\chi^2(5) = 500.27$ ($p=0.0000$); Robust regression $F(5,3103) = 101.22$ ($p = 0.0000$).

Table 5. Shea's Adjusted Partial R-square

	All sectors	Manufacturing	Services
ln (market potential)	0.4198	0.4858	0.4066
ln (employment density)	0.3548	0.378	0.3631
(ln (employment density))^2	0.3517	0.3764	0.3556
ln (specialization)	0.7205	0.7077	0.4558
ln (human capital)	0.3825	0.3832	0.3647

Comparing the coefficients estimated by OLS and IV reveals that endogeneity can affect elasticities. Overall, estimating by IV reduces the estimated coefficients for the spatial variables with a larger effect on service industries in comparison with manufacturing sectors. We find that human capital presents the largest endogeneity bias. The coefficient for market potential slightly decreases for the manufacturing sector whereas for the service sector the reduction is much more pronounced. The effect on the specialisation coefficient is almost unnoticeable for manufacturing and again stronger for service industries. As for density, the effect of endogeneity is relatively small when the compound effect of the two coefficients is computed.

5. Results

The estimated equations confirm that, after controlling for individual and firm characteristics, all the spatial variables included in the equation have a significant effect on firm productivity, indirectly approached by wages. Firstly, we find a positive and significant effect of road accessibility, measured through market potential, on wages with a similar impact on manufacturing and service industries. Secondly, market size positively influences productivity, although the effect is non linear and follows a different pattern for manufacturing and services. Thirdly, there is evidence of positive human capital externalities even after controlling for individual educational level. Fourthly, significant benefits are derived from economies of localisation and, finally, the

Manufacturing: Robust score $\chi^2(5) = 136.95$ ($p=0.0000$); Robust regression $F(5,1648) = 27.70$ ($p = 0.0000$)

Services: Robust score $\chi^2(5) = 287.79$ ($p = 0.0000$); Robust regression $F(5,1454) = 58.18$ ($p= 0.0000$)

distance to the French border is significant for manufacturing but only marginally for services.

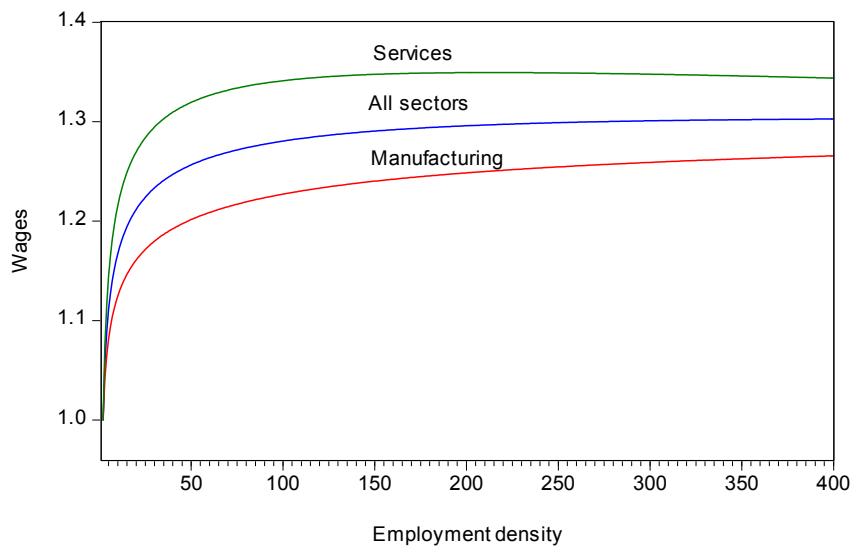
Table 6 shows the elasticities of wages with respect to the spatial variables in the equation. Market potential shows the highest effect on wages with an elasticity value of around 8.5%. Although this value is higher than the value of 4.6% reported by Mion and Naticchioni (2008) and that of 2.4% by Combes et al. (2009), it has proven highly robust to the different specification we have explored and is clearly in line with a mean elasticity of 10.1% and a median elasticity of 7.6% reported in the meta-analysis by Melo et al. (2009). An elasticity value of around 4% for the specialization index provides evidence of significant intraindustry externalities in the case of Spanish provinces. As for the education level (share of working population with tertiary degree) we found an elasticity value of 5.8% for manufacturing and 3.3% for service industries. It is important to remark that the estimated equation already includes the individual educational level; therefore, in our context, the level of education of the province can be interpreted as an approximation of human capital externalities.

Table 6. Wage elasticities

	All sectors	Manufacturing	Services
Market potential	0.0791	0.0852	0.0857
Specialization	0.0450	0.0407	0.0399
Human capital (semi-elasticity)	0.0547	0.0582	0.0331
Density (minimum)	0.0700	0.0533	0.0882
Density (mean)	0.0193	0.0260	0.0122
Density (maximum)	0.0036	0.0174	-0.0116

Given that we have specified a non-linear function for employment density, the elasticity is not constant. We have computed the effect of density on wages for a range of values that comprises all the observed values in the sample. Figure 5 shows that the relationship between density and wages is clearly non-linear for low levels of density and almost becomes flat after density has reached a certain threshold.

Figure 5. Relationship between employment density and wages



As for elasticities, Figure 6 shows a different pattern for manufacturing and service industries: for an employment density of under 50 workplaces per square kilometre, elasticity is higher for service industries; however, for higher values the effect of density is reversed. In the service sector very high employment density leads to negative values for elasticity

Figure 6. Elasticity wage-employment density

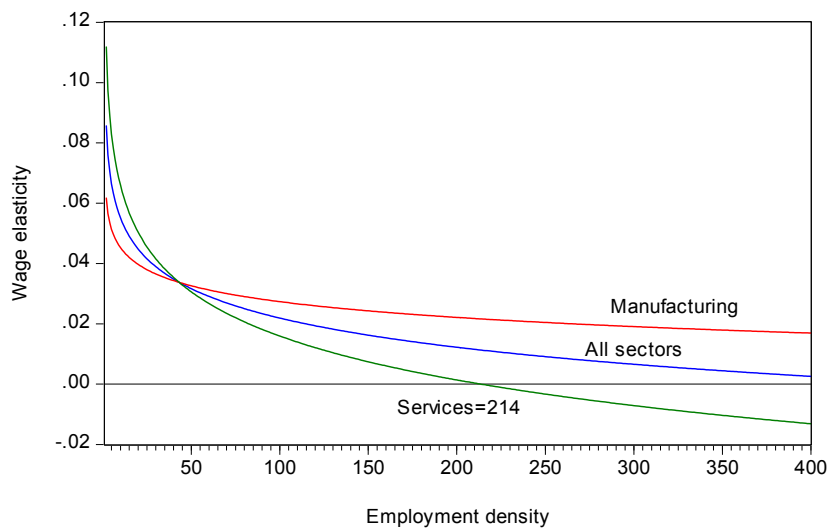


Table 6 reports the elasticity for the minimum, mean and maximum values of employment density in the sample. The computed elasticities show that those areas with low employment density can obtain substantial benefits from urban agglomeration, whereas the benefits are almost null in those provinces with high density levels. For the service sector, congestion costs appear to offset the benefits from agglomeration after

a value of 214 workplaces per square kilometre. The size of elasticity for the mean sample value is around 2%, in line with the most recent estimates.

6. Conclusions

We estimate a wage equation with individual data from Spanish workers in order to provide evidence for the effect of spatial externalities and, particularly, the impact of agglomeration and road accessibility on the performance of firms. We control for a large set of individual and firm variables and for the main spatial (local) characteristics that are known to contribute to the explanation of productivity differences. From an econometric viewpoint, accounting for endogeneity by using the instrumental variables approach results in some changes in the estimated coefficients of the spatial variables.

Increasing market size gives rise to productivity gains. However, the effect is non-linear with stronger externalities for low density provinces, albeit with a different pattern for the manufacturing and service sectors. Localisation economies also play a role in explaining wage differences.

Interurban accessibility plays the most important role in explaining wage (productivity) disparities. Our results support previous empirical findings that accessibility improvements positively affect firms' productivity (Graham, 2007). Therefore, road investments that increase market potential through reductions in travel time are likely to have a positive effect on productivity. Such external effects should be added to the benefits measured in the traditional CBA as a part of what is usually called wider economic benefits. Nonetheless, we want to stress that the elasticity of productivity with respect to accessibility is small and its effects are subject to effective reductions in travel time. The additional external benefits will depend on the characteristics of the investment project.

This paper measures the direct effects of accessibility on wages through market potential. However, in order to approximate the final effect of accessibility it would be necessary to take the feedback effects into account: Increasing accessibility increases productivity and, as a consequence, market potential. In a second round this increase in market potential further increases productivity and so on. In this context, the final elasticity wage-market potential would be higher than the first round effect, which is the elasticity of 0.08 estimated in the paper.

After controlling for individual level of education, there is also evidence of positive human capital externalities.

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