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Universidad Complutense de Madrid, Universidad Autónoma de Madrid, GRIPICO

2010

MICRO-DYN Working Paper no. 22/10

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This paper was produced in the framework of MICRO-DYN (www.micro-dyn.eu), an international research project funded by the EU Sixth Framework Programme (www.cordis.lu) with socio-economic sciences and humanities (http://ec.europa.eu/research/social-sciences/index_en.html). This publication reflects only the author's views, the European Community is not liable for any use that may be made of the information contained therein.

A different look at agglomeration effects in Spain[☆]

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Abstract

This paper explores the relationship between productivity and labour density at the municipality level for the Spanish economy and year 2001. Previous results on the mentioned relationship are confirmed. Whilst agglomeration effects at NUTs-3 level were important along the 1960s and 1970s, they seem to have disappeared along the second half of the 1980s. We show that agglomeration effects are still present, nonetheless when analysed at a higher degree of geographical disaggregation. Recent amendments in regional governance and the creation of *Comunidades Autónomas* —implying a higher degree of

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political and economic decentralization— along the 1980s may have resulted in this change in agglomeration patterns. Endogeneity problems associated to estimation of productivity elasticities with respect to labour densities are taken into account by means of instrumental variable (IV) regressions. To this respect, elevation turns out to be a valid and attractive instrument for the agglomeration variable. Also we test if proximity to labour dense areas may also have a positive effect on the productivity level of a given municipality. The results show that agglomeration forces mainly operate within NUTs-3 regions —the oldest administrative regional division of Spain—.

Key words:

Agglomeration, labour productivity, municipalities, IV estimation.

JEL: R10

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1. Introduction

A common result in the new economic geography (NEG) literature is that the size of cities and regions is positively correlated with corresponding wages and productivity, amongst an important number of other economic variables. Rosenthal and Strange (2004) conclude from their literature survey that labour productivity elasticities with respect to size range between 4 and 8 per cent. Ciccone and Hall (1996) seminal paper enhances interest for this field of the NEG literature as they suggest that agglomeration effects are more robustly captured when labour density instead of absolute regional size is used as a measure of spatial concentration in the economic activity dimension. Subsequent applications of this theoretical framework to regions and contexts different to the originally tested scenario, United States counties, have confirmed the mentioned relationship between regional productivity and the density of the economic activity. In this sense, Ciccone (2002) finds that the previously observed elasticity of 6 per cent for US counties reduces to 4.6 per cent in the case of some European NUTs-3 regions.

Many other papers, Dekle and Eaton (1999) for Japanese prefectures (observing elasticities between 1 and 2 per cent), Rice et al. (2006) for British NUTs-3 regions (3.5 per cent), Ottaviano and Pinelli (2006) for Finish NUTs-3 (positive elasticity), Braunerhjelm and Borgman (2004) for Swedish labour market regions (positive elasticity), Cingano and Schivardi (2004) for Italian labour market regions (6.7 per cent), Combes et al. (2008) for French labour market regions (4.8 per cent), Brülhart and Mathys (2008) for a panel of European regions and sectors (13 per cent), they all confirm the positive relationship between regional productivity and the density of the economic activity.

Results in the Spanish case may turn out inconsistent for certain time periods and given levels of geographical disaggregation. Ciccone (2002), using data on NUTs-3 regions of five European countries, including Spain for year 1986, obtained an elasticity of productivity on agglomeration of 5.1%. The analysis to a broader time perspective carried out in Martínez-Galarraga et al. (2007) using data only for Spanish NUTs-3 regions, shows that agglomeration effects on productivity were important along the 1860 to 1980 horizon, but have basically disappeared from the 1980s. In fact, using data of The Spanish Statistical Institute (INE) for years 1986 and 2001 and NUTs-3 Spanish regions only, we obtain an elasticity of 3.4 per cent for year 1986, but a statistically equal to zero elasticity for year 2001.

Some of these results are very interesting precisely because of their theoretical implications. If larger agglomeration implies higher productivity levels there is an incentive for enterprises to locate in agglomerated cities. As these new enterprises install, the density of economic activity increases, consequently raising productivity and generating an apparently attractive virtuous circle. Nonetheless, between 1986 and 2001, the standard deviation of labour density for NUTs-3 Spanish regions has only increased by just over 6 per cent, whilst corresponding standard deviation of regional productivity has decreased by more than 44 per cent.

Of course, this virtual circle is broken when congestion problems emerge in an over-agglomerated scenario (Broersma and van Dijk, 2008; Ciccone, 2002). Thus, one possible explanation behind the different results obtained in the Spanish economy could rely under the distinct stages in seeking or trying to achieve an optimal level of agglomeration. Spain is nevertheless a country with a low population density, 91 inhabitants per square kilometre (INE data at 01/01/2008). It is the second European Union (EU-27) country by size, the fifth in terms of population, and in contrast, the 19th in terms of population density, with a value well below the EU-27 mean of 115 (Eurostat data for year 2006). Nonetheless, as shown in Viladecans (2004), agglomeration economies play an important role in the location processes of Spanish manufacturing firms.

Comparing the procedures in Viladecans (2004) and Martínez-Galarraga et al. (2007), whilst the former uses data on large municipalities, the later is carried out for Provinces (NUTs-3). Thus a reliable explanation could be related to the regional level at which agglomeration processes take place. Additionally, *Comunidades Autónomas* (NUTs-2) were created in the 1980s, implying a higher level of self-governance at this regional level. Along the 1980s, large amount of effort was dedicated to avoid those inter-regional migration movements that had been so important along the 1950s, the 1960s, and the first half of the 1970s. Thus these political measures could have succeeded in holding inter regional movements back, and hence blocking agglomeration processes at NUTs-3 level.

Nonetheless, agglomeration forces must be still taking place, although at a different level of geographical disaggregation. In fact, Audretsch and Feldman (1996) and Ciccone and Hall (1996) point out that the geographical level at which agglomeration phenomena is studied is relevant, suggesting the use of a fine level of geographical disaggregation. Ciccone (2002) analysis does not take into account the different levels of governance or the extent of economic and political decentralisation. Certainly, the creation of regions and subsequent decentralisation processes in non Federal European countries take place along the second half of 1990s. These processes have been especially intense in Spain, whilst *Comunidades Autónomas* at the beginning of the 1980s were limited to those historically determined regions and had very limited economic and political autonomy, by year 2000 Spain had already become an *Estado Autonómico*, i.e. a State of *Comunidades Autónomas*, with a high level of economic and political decentralisation. For instance, 38 per cent of public expending in year 2007 was carried out directly by *Comunidades Autónomas.*

Additionally, regional policy in Spain and the European Union (EU) could have affected agglomeration patterns through the application of the EU Structural Funds. HERMIN model estimations show that along the 1988 and 1999 period, Spanish per capita income has substantially increased as a result of the European Cohesion Policy, reducing the gap with the EU-15 in 3.5 percentage points (European Commission, 2007). Nevertheless, there is no database including main economic variables of Spanish municipalities. To this respect, this article is the first to use calculated data for the complete set of Spanish municipalities with relevant economic activity. Consequently, if results were to show a positive effect of spatial agglomeration on labour productivity at this fine level of geographical disaggregation, this will imply that regional policy in the EU, the Spanish Central Government and *Comunidades Autónomas* would have defeated agglomeration forces at NUTs-3 level, hence confirming the importance of working at the right level of geographical disaggregation.

The aim of this paper is then to explore agglomeration effects at municipality level, considering the complete set of Spanish municipalities in year 2001. The paper is organised as follows. Next section summarises the theoretical model. We then describe the municipal database used for the analysis. The empirical models and estimation procedures to capture (i) agglomeration effects on productivity, and (ii) the possible influence of neighbours' agglomeration on own productivity, are described in third place. Results are discussed just before finishing the article off with conclusions and final remarks.

2. Model

The theoretical model we follow is the one proposed by Ciccone (2002). Output per square kilometre in a given municipality, q, depends upon regional total factor productivity, Ω, employment density, n, the average level of workers human capital employed on a square kilometre, H, physical capital endowments per square kilometre, k, as well as total output produced in the municipality, Q, and the size of the municipality in square kilometres, A.

$$q = \Omega f(nH, k; Q, A) = \Omega \left((nH)^{\beta} k^{1-\beta} \right)^{\alpha} \left(\frac{Q}{A} \right)^{\frac{\lambda-1}{\lambda}} \tag{1}$$

The specification in (1) assumes that spatial externalities are driven by the density of production Q/A. These spatial externalities have a positive effect on production if $\lambda > 1$. Returns to labour and capital on a square kilometre are captured by $0 \leq \alpha \leq 1$, and β is just a distribution parameter.

Assuming that labour and capital are equally distributed among the whole area of each municipality, i.e. $q = Q/A$ and $k = K/A$, K being physical capital endowment in the municipality, allows derivation of the aggregate production function in (2),

$$Q = Aq = A\Omega \left(\left(\frac{NH}{A} \right)^{\beta} \left(\frac{K}{A} \right)^{1-\beta} \right)^{\alpha} \left(\frac{Q}{A} \right)^{\frac{\lambda-1}{\lambda}} \tag{2}$$

where N denotes total number of workers employed in the municipality, thus $n = N/A$. Rearranging for average labour productivity in a given municipality one gets expression (3),

$$\frac{Q}{N} = \Omega^{\lambda} \left(H^{\beta} \left(\frac{K}{N} \right)^{1-\beta} \right)^{\alpha\lambda} \left(\frac{N}{A} \right)^{\alpha\lambda-1} \tag{3}$$

which could be estimated if physical capital endowments were known for each municipality. Ciccone (2002) overcomes this difficulty by assuming that the rental price of capital, r, is the same everywhere. He derives the capital demand function from equation (1),

$$K = \frac{\alpha (1-\beta)}{r} Q \tag{4}$$

which once substituted into (3), results in the following expression for labour productivity,

$$\frac{Q}{N} = \left[\frac{\alpha (1-\beta)}{r} \right]^{\frac{\alpha\lambda(1-\beta)}{1-\alpha\lambda(1-\beta)}} \Omega^{\frac{\lambda}{1-\alpha\lambda(1-\beta)}} H \left(\frac{NH}{A} \right)^{\theta} \tag{5}$$

where

$$\theta = \frac{\alpha\lambda - 1}{1 - \alpha\lambda(1-\beta)} \tag{6}$$

θ measures the effect of employment density and human capital on municipality labour productivity and will be referred to as the agglomeration effect parameter. Let

$$\Lambda = \left[\frac{\alpha(1-\beta)}{r}\right]^{\frac{\alpha\lambda(1-\beta)}{1-\alpha\lambda(1-\beta)}} \text{ and } \omega = \frac{\lambda}{1-\alpha\lambda(1-\beta)} \tag{7}$$

Λ depends on the rental price of capital. Substituting (7) into (5) and taking logarithms gives expression (8).

$$\ln\left(\frac{Q}{N}\right) = \ln(\Lambda) + \theta\ln\left(\frac{N}{A}\right) + (\theta+1)\ln(H) + \omega\ln(\Omega) \tag{8}$$

Thus we can estimate regressions of the form,

$$\ln y_i = \sum_j \gamma_j + \theta \ln d_i + \sum_1^5 \delta_l \ln(H_{l,i}) + u_i \tag{9}$$

where y_i denotes labour productivity in municipality i, γ are regional indicators to control for differences in exogenous total factor productivity across provinces or *Comunidades Autónomas*, and d_i is municipality's employment density. H_l accounts for the fraction of workers with human capital level l.

2.1. Agglomeration effects on labour productivity

Two regression models constitute the basis of our whole analysis. Regression model R.1 estimates agglomeration effects θ, of employment density d_i, on labour productivity y_i, conditional on five different human capital levels.

$$\text{R.1:} \;\; \ln y_i = \gamma + \theta \ln d_i + \sum_{l=1}^{5} \delta_l \ln \left(1 + \frac{hk_{l,i}}{HK_i} \right) + u_i \qquad (10)$$

Human capital is expressed as the percentage of workers with education level l, thus $hk_{l,i}$ is the number of workers with education level l in municipality i, and HK_i the total number of workers in that same municipality.

2.2. Neighbouring agglomeration effects

Spatial externalities are so far considered to be taking place at the municipality level. Proximity to labour dense areas may also have a positive effect on the productivity level of a given municipality (Dekle and Eaton, 1999; Rice et al., 2006). Assuming that total factor productivity Ω in a given municipality may be affected by the density of production in neighbouring regions, we get expression (11),

$$\Omega = \Phi \left(\frac{Q_n}{A_n} \right)^{\mu} \qquad (11)$$

where Φ denotes exogenous total factor productivity in the municipality, and sub index n indicates that variable is observed along a given neighbouring area. Incorporating (11) into (8) and (9), we can formulate regression model R.2, which goes a step further and includes additional regressors capturing agglomeration effects across ten different neighbouring areas.

$$\text{R.2:} \ \ln y_i = \gamma + \sum_{j=1}^{10} \omega\mu_j \ln d_{j,i} + \theta \ln d_i + \sum_{l=1}^{5} \delta_l \ln \left(1 + \frac{hk_{l,i}}{HK_i} \right) + u_i \qquad (12)$$

Thus $d_{j,i}$ is the average employment density of the different municipalities located around the neighbourhood of municipality i along area j. Neighbouring area $d_{1,i}$ includes all municipalities except municipality i, whose distances to i are at most 10 kilometres away, distances being calculated between town centres using the Great Circle Distance formula[1]. Neighbouring areas 2 to 10 are constructed in a slightly different manner, they include all munici-

[1] The Great Circle Distance formula gives the shortest distance between any two points on the surface of a sphere, measured along the closest path over the surface, as opposed to going through the sphere's interior. All distances in this paper are calculated this way.

palities whose distances to i are less or equal to $10j$ kilometres, and greater than $10(j-1)$ kilometres, for $j = 2, \ldots, 10$. Figure 1 illustrates the different irregular crowns that form areas d_1,i to $d_{4,i}$ around the neighbourhood of municipality i.

Hence, regression model R.2 estimates the elasticity of productivity with respect to employment density conditional on neighbouring agglomeration effects and human capital endowments.

[Insert Figure 1 around here]

3. Data

Spain has very rich statistical regional information. Main economic variables are available by *Comunidades Autónomas* (NUTs-2), and in some cases, the statistics are also published at Provinces level (NUTs-3). Unfortunately there is no such datasets at municipality level, there is only data for large cities (more than 15,000 inhabitants) until mid 1990s and not all regions are complete, hence we estimate some data for this level of geographical disaggregation[2].

[2] Viladecans (2004) uses this same level of geographical disaggregation nonetheless considering just municipalities of more than 15,000 inhabitants for only 14 of the 17 different Spanish NUTs-2 regions and including just manufacturing firms for year 1994. This in-

SABI database is used as a primary source for these purposes. This dataset is the Spanish branch of AMADEUS family of databases and is generated by the private firms INFORMA and Bureau Van Dyck. This database contains balance sheets and useful information for more than 525,000 enterprises in 2001, of a total of 2,645,000 (although only 1,409,000 have employees) according to the National Institute of Statistics (INE), and it covers more than 50 per cent of total employment. The main problem is the lack of sample representativeness in both, the sector and region dimensions, which hinders computation of correct universe indicators. For this reason we calculate expansion coefficients for each enterprise considering its headquarters regional location as well as the main type of performed economic activity, i.e. the industry or sector of economic activity in which the firm mainly operates. The used methodology is a refinement of the expansion coefficients proposal in Velázquez-Angona (1997), which has been actually adopted by the Bank of Spain to expand its firm-based Central Balance Sheet Database and compute macroeconomic aggregates (Banco de España, 1999).

formation comes from the reports of the official fiscal database for VAT, wage taxes and customs revenues, which it used to be elaborated by the Institute for Fiscal Studies. It is nowadays produced since mid 1990s by the State Agency for Tax Administration and unfortunately is only available at NUTs-3 level. Whilst this dataset only covered 4.1 per cent of total number of municipalities (331 out of 8110), it represented 62 per cent of total Spanish population in 1994.

INE provides Spanish Regional Accounts with data on value added and employment at NUTs-2 level and industry classification NACE A-31 classification, let us refer to it as INE-2, as well as at NUTs-3 level and NACE A-6, let us call this data INE-3. Expansion coefficients are thus built following a two-stage mechanism.

We exclude enterprises with negative or null value added and also those firms with no information on the employment variable. Value added is calculated for each enterprise as the difference between operating revenues and intermediate consumption plus other operating expenses, excluding labour costs.

We then obtain value added and employment for the sample of valid SABI enterprises at NUTs-2 level and A-31 industry classification; let us call this data SABI-2. The initial expansion coefficient ($e1$) is thus calculated as the ratio between the value given by the universe i.e. that given by Regional Accounts (INE-2), and the sample value calculated from aggregation (SABI-2). Thus this expansion coefficient is calculated for a firm i belonging to A-31 sector s, and located in region NUTs-2 R, following expression (13).

$$e_{1,s,R} = \frac{\text{INE-2}_{s,R}}{\sum_{i \in s,R} \text{SABI}_{i,s,R}} \tag{13}$$

Multiplying original SABI data by this expansion coefficient and aggregating resulting information to NUTs-3 and A-6 levels (let's refer to this as SABI-3), allows calculation of a second coefficient ($e2$) by simply dividing Regional Accounts INE-3 data by expanded SABI-3 data. This is, for all the firms operating in A-6 sector S, note that sector s belongs to sector S, that are located in NUTs-3 region r, where r is located within NUTs-2 region R, the expansion coefficient is thus calculated by expression (14).

$$e_{2,s,R} = \frac{\text{INE-3}_{S,r}}{\sum_{i \in S} \sum_{i \in r} e_{1,s,R} \cdot \text{SABI}_{i,S,r}}, \;\; s \in S \text{ and } r \in R \qquad (14)$$

The final expansion coefficient (e) is obtained by multiplying $e1$ by $e2$. Thus the municipal dataset is consequently built by expanding original and valid values of SABI microdata with expansion coefficients e. The nature of original microdata obliges to assume that firms are solely located on headquarters and produce in the declared main sector of economic activity. In the case of Spain, multiplant firms are just 1.1 per cent of total manufacturing firms and hence this assumption is not especially restrictive (Encuesta sobre Estrategias Empresariales, 2008). It is important to note that under this assumption, calculated employment corresponds to the workers employed by those enterprises located in a given municipality and participating in the productive system, a much more accurate and desirable scenario than just considering available work force in that municipality. We end up having two different datasets on value added and employment observed at NUTs-4, one including the agricultural sector and the other excluding it.

Data on human capital comes from 2001 Spanish Population Census. These statistics have information at municipality level and are available for five different education levels, nonetheless they are based on resident population and not on workers. However, this Population Census offers information on workers' geographical mobility, i.e. those living in a given municipality but working in a different one, allowing approximation of employees' qualification levels working in a given municipality.

Area is obtained from the Spanish National Institute of Statistics. To obtain the non-agricultural surface, we use data from the 1999 Agricultural Census. Nevertheless, this information is obtained from a survey to owners and agricultural entrepreneurs. For this reason, agricultural surface is assigned to the municipality where farmer lives, inducing an important bias in measuring agricultural area. We consequently introduce a procedure based on calculation of a given radius of influence around each municipality enough to correct biasness. A coefficient is calculated by dividing declared agricultural area of each municipality and its surrounding neighbours located at a maximum distance of 50 km, by the corresponding total area. Agricultural area is subsequently generated by multiplying this resulting coefficient by declared agricultural area. Additionally, this information has been revised and modified according to the Survey on Infrastructure and Local Equipment for year 2000, which classifies municipal land area as urban, building land, and protected from building land. There are alternative information sources such as Corine Land Cover dataset. The problem we detect with this last database is that it reports effective land uses and hence, legal availability of land for non agricultural economic activities cannot be appropriately determined. Construction of a new infrastructure or an urban complementary service such as a park or a parking would alter effective land use distribution and unfortunately, density values too, whilst legal availability of non agricultural land may have not changed at all. Consideration of land use distribution as dictated by the legal classification of land as urban, building land, and protected from building land, allows consistent and less erratic measurement of density.

Tables A.1-A.3 in the Appendix present summary statistics for the complete set of main variables used in the estimations of proposed empirical models described in next section. Statistics are calculated for the three data sets and the sample which turns to be valid when running regressions. Municipalities are removed from the sample when they have no operating firms as recorded by SABI. There are 8,110 municipalities in Spain for year 2001, from which 2,043 have no private economic activity and 228 have only agricultural firms. Excluded municipalities represent just 4 per cent of total Spanish population. We only consider private non-proprietary firms as in Ciccone and Hall (1996). Estimation results are presented and discussed along next section.

4. Agglomeration Effects on Productivity: Some Results on Municipal Data

4.1. Agglomeration effects for non agricultural activities and total area

The results from estimation of model R.1 over the dataset that includes total area and excludes agriculture and forestry sectors are registered in Table 1. The first column presents OLS results. Furthermore, estimations of agglomeration effects take also into account the possibility of failure of regional fixed effects in accomplishing their requested task. If fixed effects do not entirely pick up exogenous differences in total factor productivity across regions, estimates may turn to be inconsistent due to endogeneity problems, i.e. regions with higher productivity levels will be attracting more labour and hence becoming more employment dense. We thus estimate each regression model first by ordinary least squares, OLS, and then using the 2-stage-least-squares, 2SLS, estimator. We try a complete set of instruments for employment density, d_i, and average neighbouring employment density, $d_{j,i}$. Hence, the next four columns in Table 1 correspond to 2SLS regression results where employment density has been instrumented by (a) area, (b) average area of neighbour municipalities in a 5 km radius, (c) elevation, and (d) 2 period lagged employment density.

Moomaw (1981) is the first one to document the simultaneity problems associated to the estimation of agglomeration economies. Ciccone (2002) suggests land area and average neighbouring area (formed by the area of those Provinces sharing any of the boundaries of the reference geographical unit) as valid instruments for employment density, as Provinces were established in mid 19th century as an attempt to attain a more uniform spatial distribution of regional populations (Brülhart and Mathys, 2008, 349), creating larger Provinces across less populated areas, so Provinces would have similar population levels. Thus in principle, the spatial distribution of Provinces should be unrelated to modern total factor productivity. This may not necessarily be the case for municipalities. Their conformation processes are by far much more complex and dynamic, with the spatial distribution of municipalities changing over time until the present, where larger and more labour dense municipalities merge with those smaller neighbouring municipalities. In fact, the number of municipalities has decreased substantially, from 11,500 in 1842 to 8,110 in 2001, almost a 30 per cent decrease (Ministerio de Administraciones Públicas, 2008). The idea behind elevation being a valid instrument for labour density follows Combes et al. (2008), who assert that geological aspects are important determinants of settlement patterns. They recommend the nature of soils as a relevant variable to explain actual labour distributions. Instead, we choose elevation, which shows a higher degree of variability and should be strongly and negatively correlated to soil depth and quality. Original population settlements took place mainly along fertile valleys and the coast, taking advance of water supplies as well as less hostile conditions in terms of weather and communication. Finally, Ciccone and Hall (1996) introduce the idea of using as instruments for labour/population densities their past values, based on the strong persistence of population's spatial distribution.

[Insert Table 1 around here]

In order to evaluate the quality of the different instruments we run the OLS regression municipality labour density as a function of NUTs-3 indicators, and then, one additional regression for each instrument which simply adds to the former set of regressors the log of the variable used as an instrument for labour density. We register the gain in R^2, ΔR^2 row in Table 1, associated to this extended regression. In this respect, municipality area as instrument of labour density presents the minimum gain, 4.45 per cent, and the 2 period lagged employment density, the maximum, with a 69.18 per cent gain. Area is the instrument chosen by Ciccone in his NUTs-3 analysis, resulting in a positive agglomeration effect on labour productivity.

The analysis at municipality level shows that municipality area cannot be a good instrument for labour density as it predicts a negative relationship between productivity and agglomeration, with elasticities going from -5.5 to -3.8 per cent. Average neighbouring area provides statistically significant positive values for the elasticity of labour density on labour productivity, and in principle, these values are higher than those reported by OLS regressions. The explanatory power of this instrument is nonetheless low, with an R^2 gain of just 4.5 per cent. Moreover, the standard errors of estimated θ

parameters are high, oscillating between 2.2 to 3.6 per cent. More convincing results are found with the elevation instrument. This variable is correlated to labour density —a 13.15 per cent gain in explanatory power is achieved when regressing productivity on elevation in addition to NUTs-3 indicators— and it should not be related to exogenous total factor productivity.

The elasticities are always statistically significant at the 99.9 per cent significance level, with values in the range 3.1 —when NUTs-2 indicators are included in regression—to 5.1 per cent —when regional differences in total factor productivity are captured by NUTs-3 indicators—, and associated standard errors are in all cases well below 1 per cent. The remaining instrument, the 2 period lagged employment density, offers most promising results. These results should nonetheless be taken with caution. Endogeneity problems may have not been removed by just considering employment of year 1999.

Focusing now on OLS results, the elasticities of labour productivity with respect to employment density are always statistically significant at the 99.9 per cent significance level, and go from 5.04 per cent with a robust standard error of .46 per cent, when agglomeration effects are estimated conditional on human capital levels, to 5.90 per cent and a robust standard error of .52

per cent, when conditioning is augmented to the inclusion of NUTs-3 fixed effects. These values are very similar to those obtained by Ciccone (2002) for Spain (5.1 per cent) in year 1986 for NUTs-3 regions. The elasticity of productivity with respect to agglomeration increases when introducing regional fixed effects, attaining higher values when NUTs-3 indicators are included. Thus agglomeration effects are slightly higher when controlling for exogenous differences in total factor productivity across NUTs-3 regions, indicating that regional idiosyncratic factors may to some minor extent limit the agglomeration effects on labour productivity. Goodness of fit oscillates between 8.9 per cent and 12.6, and regional indicators are jointly significant at the 99.9 per cent significance level, even those representing multi-provincial NUTs-2 regions.

Thus using the Ciccone equivalent dataset, nonetheless for year 2001, municipality level, and using elevation as a valid instrument for labour density, the elasticity of agglomeration on labour productivity is along the range 3.06 (.81) to 5.90 (.52) at the 99.9 per cent significance level, standard errors in parenthesis, depending on the estimation method and the inclusion of regional fixed effects.

Next we turn to measure agglomeration effects nonetheless considering non agricultural land instead of total land, and only keeping 2SLS results for the elevation instrument.

4.2. Agglomeration excluding non agricultural land

Agglomeration effects are as expected, slightly higher when considering only non agricultural land when calculating area and hence labour density. Agriculture and forestry are much more land use intense than manufacturing and services, and their weight in total economic activity is limited. Main results are shown in Table 2.

[Insert Table 2 around here]

Independently of the estimation method, elasticities of productivity with respect to labour density attain maximum levels when controlling for provincial fixed effects, whilst minimum values are observed when considering NUTs-2 indicators. Parameter values oscillate between 3.46 (.92) to 5.89 (.53), with associated standard errors in parenthesis, at the 99.9 per cent significance level. Goodness of fit slightly increases and ranges from 9.2 to 12.6 per cent. Regional indicators are as usual statistically significant at the 99.9 per cent significance level.

The lowest agglomeration effects are observed when replicating estimations considering total economic activity and total land (see Table A.4 in the Appendix). We now turn to extension (R.2), focusing on estimation results over the data set that excludes non agricultural land. The results for the remaining 2 data sets can be consulted in the Appendix through Tables A.5-A.6.

5. Agglomeration Effects across Neighbouring Municipalities

In this section we estimate θ conditioned on the possible presence of neighbours' agglomeration effects. Further, the inclusion of neighbours' labour densities allows quantification of the geographical magnitude of agglomeration economies. Instrumental variable estimations are tried for a large number of instrument combinations. In one side we consider elevation and lagged employment as instruments for labour density, and in the other, neighbouring labour densities are instrumented by its 2 period lagged values and the average area of neighbouring areas $d_{i,j}$, Estimation results of regression model (R.2) are thus presented in Table 3.

[Insert Table 3 around here]

The consideration of average labour density for different neighbouring areas does not practically affect municipal agglomeration economies. OLS results are in fact very similar to those presented in Table 2. The elasticity of productivity with respect to labour density oscillates between 5.27 (.60) to 5.46 (.61) per cent, and the explanatory power of estimated regressions ranges from 9.6 to 13.0 per cent. Only in the absence of regional fixed effects, the average labour density of the area formed by municipalities situated more than 60 and at most 70 km far apart has a statistically significant elasticity at the 90 per cent significance level of 1.72 per cent with associated robust standard error of .98 per cent. This may be capturing the effect of the main cities and their close neighbourhood over municipal labour productivity. The result tells that if average productivity of neighbouring area within the 60 to 70 km distance doubles, municipal productivity increases by 1.7 per cent. The average radius of Spanish provinces (NUTs-3) excluding Ceuta and Melilla is around 60 km. This fact together with the disappearance of neighbouring agglomeration effects when introducing regional fixed effects reinforces the idea that neighbouring agglomeration effects as here defined are somehow capturing the positive correlation between the largest municipalities of each province, e.g. the provincial capital effect. This result may well be indicating the importance of regional boundaries in the process of production agglomeration. Whilst agglomeration economies do not operate across NUTs-3 regions, they do act within Provinces.

In terms of instrumental variable estimation results, things are not as straightforward as in previous section. It is definitely harder to find a right combination of instruments for labour density and average neighbouring labour densities. When the 2 period lagged values are used for both variables, elasticities turn out just slightly higher and the same conclusions as reported for OLS follow here. Average area of neighbours may not be a good instrument for average neighbouring labour densities. Elasticities increase substantially as well as their corresponding standard errors. Furthermore, regional indicators can only be included at NUTs-2 level, and they end up being equal to zero. Elevation again offers some neater results when average neighbouring labour densities is instrumented by their lagged values.

The elasticity of labour productivity with respect to the agglomeration variable is of 5.33 per cent, with standard error of 1.70 per cent. Neighbouring area between 60 and 70 km again shows a statistically significant elasticity of 1.73 (.99) per cent at the 90 per cent significance level, which vanishes off when statistically significant NUTs-3 level indicator are introduced to capture regional differences in total factor productivity. In this last case, θ elasticity is just below 4 per cent with a standard error of 1.55 per cent.

The results for the remaining data sets are registered in Table A.5 of the Appendix. Without agriculture and total land dataset offers elasticities ranging from 3.24 (1.44) to 6.32 (.60) per cent, and neighbouring agglomeration has no effect over municipality productivity. Consideration of all sectors of economic activity and total land brings in contrast statistically significant positive effects of agglomeration across neighbours within a 10 km radius, over municipality productivity. These elasticities range from 1.49 (.68) to 1.74 (.68) per cent and vanish off when estimating by 2SLS. Another positive externality emerges at neighbouring area d_{10}, municipalities at more than 90 and at most 100 km away, with values ranging from 1.73 (1.04) (OLS with NUTs-3 indicators) to 2.23 (.94) per cent, when no regional indicators are included and labour density is instrumented with elevation variable and neighbouring agglomeration with its lagged values. A negative externality across neighbours in d_5 of -1.77 (1.03) per cent appears just in the basic OLS estimation with no regional indicators. The results associated to this dataset reflect the peculiarities of the agrarian sector, often located along rural areas formed by small municipalities with low agglomeration levels.

To have a better idea of the extent and importance of agglomeration effects and their impact on labour productivity, Table 4 provides average values for the θ elasticities estimated up to now in one hand, and in the other, the median of labour densities along the four different quartiles and the proportional changes between consecutive quartiles. The numbers in bold represent the expected gain in labour productivity associated to the registered increase in densities once the corresponding elasticities are applied. The productivity gains range from 13 per cent —when shifting from the median of the first quartile to that of the second one, in the with agriculture dataset—, to more than 52 per cent, corresponding to the change in labour density from the third to the forth quartile median in the without agriculture and total area dataset.

[Insert Table 4 around here]

Productivity gains are systematically larger when shifting from third to fourth and from first to second quartiles. Agglomerated regions may present 10 times the level of productivity of less inhabited ones, demonstrating the importance and strength of agglomeration economies when studied at a fine level of geographical disaggregation. This result aids understanding the importance and the extent of agglomeration economies, as well as the possible difficulties that may arise when applying regional policies that may be compensating or limiting these agglomeration forces. Approximating production agglomeration forces by means of population density dynamics, whilst in 1960 66 per cent of total population was concentrated across the largest 10 per cent municipalities, in 2001, this same statistic increases up to 80 per cent (Goerlich et al., 2006).

6. Conclusions

The carried out analysis confirms that agglomeration processes seem to no longer have any effect on labour productivity from the second half of the 1980s, when studied at NUTs-3 level. This change may possibly be due to the conformation of Comunidades Autónomas, Spanish NUTs-2 regions, and the subsequent process of economic and political decentralisation. Nonetheless, agglomeration processes respond mainly to economic factors and hence they must be still taking place at a lower level of geographical disaggregation. Results corroborate the existence of agglomeration effects —agglomeration being measured by labour density— on labour productivity at the municipality level, with elasticities slightly over 5 per cent, in consonance with previous results. A positive effect of neighbouring agglomeration is also captured, in particular within the influential area of provinces, most probably signalling the provincial capital effect and the interrelations of those large towns leading the agglomeration processes of the economic activity. To conclude, obtained results reveal the importance of working at the appropriate level of geographical disaggregation, which turns out to be crucial to properly identify actual agglomeration effects in the Spanish economy. Decentralisation patterns in Spain and issued European regional policies have shifted agglomeration forces from an inter Province perspective, as it occurred along the whole of the 20th century up to the mid 1980s, to an inter municipality scheme as it has been shown in this article.

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A. Appendix

[Insert Table A.1 around here]

[Insert Table A.2 around here]

[Insert Table A.3 around here]

[Insert Table A.4 around here]

[Insert Table A.5 around here]

[Insert Table A.6 around here]

B. Figure Captions

Figure 1. Neighbouring areas of a given reference municipality. Illustration of irregular crown formation.

Source: Own elaboration from Spanish INE and National Geographical Institute (IGN) geographical data.

Table 1. Agglomeration effects with human capital controls and regional indicators. Without agriculture and total area dataset

	Regional Indicator	OLS	(a) 2SLS	(b) 2SLS	(c) 2SLS	(d) 2SLS
Parameter θ (%)		5.04***	-3.82**	6.13**	4.43***	5.53***
Standard error of θ (%)		.46	1.17	2.20	.65	.46
R^2 (%)		8.91	1.09	7.96	8.87	9.53
ΔR^2 (%)	*No regional indicators*	-	4.45	4.50	13.15	69.18
Parameter θ (%)		5.12***	-5.5***	5.73*	3.06***	5.67***
Standard error of θ (%)		.49	1.40	2.86	.81	.49
R^2 (%)		10.28	.42	10.00	9.91	10.87
Wald test (*ccaa = 0*)		7.07***	9.33***	6.80***	7.44***	6.72***
Wald test (*ccaa ≠ pro = 0*)	*NUTs-2*	6.62***	10.64***	6.41***	7.14***	6.34***
Parameter θ (%)		5.90***	-4.07**	9.62**	5.13***	6.56***
Standard error of θ (%)		.52	1.57	3.61	.86	.52
R^2 (%)		12.63	4.54	11.28	12.58	13.60
Wald test (*pro = 0*)	*NUTs-3*	85.1***	69.59***	4.55***	81.55***	89.08***

*** $p < .001$, ** $p < .01$, * $p < .05$, † $p < .10$.

Instruments: (a) municipality area, (b) average area of neighbours, (c) elevation, and (d) lagged density.

Table 2. Agglomeration effects with human capital controls and regional indicators. Without agriculture and non agricultural land dataset

	Regional Indicator	OLS	Elevation 2SLS
Parameter θ (%)		5.55***	5.65***
Standard error of θ (%)		.49	.83
R^2 (%)	*No regional indicators*	9.20	9.20
ΔR^2 (%)		-	12.41
Parameter θ (%)		5.35***	3.46***
Standard error of θ (%)		.50	.92
R^2 (%)		10.41	10.10
Wald test (*ccaa = 0*)		6.89***	7.33***
Wald test (*ccaa ≠ pro = 0*)	*NUTs-2*	7.01***	7.64***
Parameter θ (%)		5.89***	5.66***
Standard error of θ (%)		.53	.95
R^2 (%)		12.56	12.56
Wald test (*pro = 0*)	*NUTs-3*	93.34***	93.27***

*** $p < .001$, ** $p < .01$, * $p < .05$, † $p < .10$.

Table 3. Agglomeration effects with human capital controls, neighbouring agglomeration and regional indicators

	Regional Indicator	OLS	(a) 2SLS	(b) 2SLS	(c) 2SLS
Parameter (%)	*No regional indicators*	5.28***	6.14***	8.50*	5.33**
Standard error (%)		.59	.59	3.42	1.70
Parameter 70 (%)		1.72†	1.71†	-	1.73†
Standard error (%)		.98	.97	-	.99
R^2 (%)		9.60	10.21	-	9.63
Parameter (%)	*NUTs-2*	5.27***	6.13***	6.94*	-
Standard error (%)		.60	.60	2.72	-
R^2 (%)		10.73	11.35	-	-
Wald test (*ccaa = 0*)		6.92***	6.21***	1.21	-
Wald test (*ccaa ≠ pro = 0*)		7.32***	6.84***	1.32	-
Parameter (%)	*NUTs-3*	5.46***	6.33***	-	3.99**
Standard error (%)		.61	.60	-	1.55
R^2 (%)		12.95	13.99	-	12.88
Wald test (*pro = 0*)		5.50***	5.83***	-	5.43***

*** $p < .001$, ** $p < .01$, * $p < .05$, † $p < .10$.

(a) Labour density and average labour density across different neighbouring areas are instrumented with the 2 period lagged values, (b) labour density is instrumented with its 2 period lagged values, and density across neighbours with the average area observed along each considered irregular crown, (c) labour density is instrumented with the elevation variable, and density across neighbours with its 2 period lagged values.

Table 4. Productivity gains associated to density increases

Average		Percentile of valid observations			
θ	**Variable**	**12.5**	**37.5**	**62.5**	**87.5**
Without agriculture and non agricultural land dataset					
	Labour density	1.90	9.70	41.52	340.21
	Proportional change in labour density	-	4.11	3.28	7.19
5.26 (a)	Increase in labour productivity (%)	-	**21.59**	**17.25**	**37.84**
5.39 (b)	Increase in labour productivity (%)	-	**22.14**	**17.69**	**38.79**
With agriculture dataset					
	Labour density	.33	1.78	7.84	75.05
	Proportional change in labour density	-	4.39	3.40	8.57
3.99 (c)	Increase in labour productivity (%)	-	**17.54**	**13.59**	**34.22**
3.93 (d)	Increase in labour productivity (%)	-	**17.25**	**13.37**	**33.66**
Without agriculture and total area dataset					
	Labour density	.28	1.42	6.50	71.57
	Proportional change in labour density	-	4.07	3.58	10.01
5.16 (e)	Increase in labour productivity (%)	-	**21.01**	**18.46**	**51.66**
5.21 (f)	Increase in labour productivity (%)	-	**21.20**	**18.62**	**52.11**

Elasticities are calculated taking the mean of the θ values in: (a) Table 2; (b) Table 2 and Table 3: columns OLS, a and c; (c) Table A.2; (d) Table A.2 and Table A.3; (e) Table 1: columns OLS, d and e; (f) Table 1: columns OLS, d and e, and Table A.3. Labour density is measured in workers per squared kilometre. We only consider valid observations for regressions, i.e. those with strictly positive employment. Proportional changes in labour density calculated with respect to previous percentile.

Table A.1. Summary statistics. Without agriculture and non agricultural area dataset

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Municipalities	8,110	-	-	1	8,110
Comunidad Autónoma	8,110	-	-	1	18
Provincia	8,110	-	-	1	52
Value added (Thousands €)	5,839	82,402.09	1,078,722	.00	67,700,000
Employment (Number of workers)	5,839	2,192.99	23,796.48	.32	1,468,000
Area (km^2)	5,839	12.15	17.90	.01	376.11
Labour productivity (€ per worker)	5,839	29,560.43	48,053.70	.00	2,206,340
Labour density (Workers per km^2)	5,839	345.59	3,861.25	.02	252,177.40
Elevation (m)	5,839	529.86	334.88	2.00	1,692.00
Average neighbouring area	5,839	4.33	6.82	.00	144.39
Lagged labour density	5,839	307.67	3,128.06	.00	198,815.30
Average neighbouring area of neigh.	5,839	4.60	6.90	.00	144.39
Illiterates (%)	5,839	.03	.03	.00	.24
No studies (%)	5,839	.16	.13	.00	.89
Primary education (up to 16) (%)	5,839	.30	.12	.00	.78
Secondary education (up to 18) (%)	5,839	.42	.12	.06	1.00
University degree (%)	5,839	.08	.05	.00	.50

Levels of human capital expressed as a proportion of total workers.

Table A.2. Summary statistics. With agriculture dataset

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Municipalities	8,110	-	-	1	8,110
Comunidad Autónoma	8,110	-	-	1	18
Provincia	8,110	-	-	1	52
Value added	6,067	83,228.07	1,063,211	.00	67,900,000
Employment	6,067	2,295.84	23,746.50	.32	1,479,800
Area	6,067	71.91	103.77	.08	1,750.30
Labour productivity	6,067	29,019.65	39,577.58	.00	2,206,416
Labour density	6,067	71.54	855.32	.01	62,993.25
Elevation	6,067	538.78	336.16	2.00	1,692.00
Average neighbouring area	6,067	23.91	35.41	.00	682.84
Lagged labour density	6,067	65.19	689.01	.00	49,666.21
Average neighbouring area of neigh.	6,067	25.73	36.72	.00	682.84
Illiterates (%)	6,067	.03	.03	.00	.24
No studies (%)	6,067	.16	.13	.00	.89
Primary education (up to 16) (%)	6,067	.31	.13	.00	.86
Secondary education (up to 18) (%)	6,067	.42	.12	.06	1.00
University degree (%)	6,067	.08	.05	.00	.50

Levels of human capital expressed as a proportion of total workers.

Table A.3. Summary statistics. Without agriculture and total area dataset

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Municipalities	8,110	-	-	1	8,110
Comunidad Autónoma	8,110	-	-	1	18
Provincia	8,110	-	-	1	52
Value added	5,839	82,402.09	1,078,722	.00	67,700,000
Employment	5,839	2,192.99	23,796.48	.32	1,468,000
Area	5,839	72.89	105.33	.08	1,750.30
Labour productivity	5,839	29,560.43	48,053.70	.00	2,206,340
Labour density	5,839	70.39	869.81	.01	62,993.25
Elevation	5,839	529.86	334.88	2.00	1,692.00
Average neighbouring area	5,839	23.96	35.68	.00	682.84
Lagged labour density	5,839	63.29	699.47	.00	49,663.51
Average neighbouring area of neigh.	5,839	25.82	37.03	.00	682.84

Table A.4. Agglomeration effects with human capital controls and regional indicators. With agriculture and total land dataset

	Regional Indicator	OLS	Elevation 2SLS
Parameter θ (%)		4.14***	4.80***
Standard error of θ (%)		.46	.68
R^2 (%)	*No regional indicators*	7.23	7.19
ΔR^2 (%)		-	14.09
Parameter θ (%)		3.92***	2.77***
Standard error of θ (%)		.49	.80
R^2 (%)		8.34	8.23
Wald test (*ccaa = 0*)		6.33***	6.61***
Wald test (*ccaa ≠ pro = 0*)	*NUTs-2*	5.65***	5.81***
Parameter θ (%)		4.38***	3.94***
Standard error of θ (%)		.52	.83
R^2 (%)		10.18	10.16
Wald test (*pro = 0*)	*NUTs-3*	69.92***	66.39***

*** $p < .001$, ** $p < .01$, * $p < .05$, † $p < .10$.

Table A.5. Agglomeration effects with human capital controls, neighbouring agglomeration and regional indicators. Without agriculture and total land dataset

	Regional Indicator	OLS	(a) 2SLS	(b) 2SLS
Parameter (%)		5.14***	5.99***	4.68**
Standard error (%)	*No regional*	.59	.59	1.42
R^2 (%)	*indicators*	9.28	9.88	9.3
Parameter (%)		5.19***	6.03***	-
Standard error (%)		.6	.6	-
R^2 (%)		10.62	11.23	-
Wald test (*ccaa = 0*)		7.36***	6.85***	-
Wald test (*ccaa ≠ pro = 0*)	*NUTs-2*	7.9***	7.65***	-
Parameter (%)		5.47***	6.32***	3.24*
Standard error (%)		.61	.6	1.44
R^2 (%)		12.98	13.98	12.72
Wald test (*pro = 0*)	*NUTs-3*	5.86***	6.24***	5.85***

*** $p < .001$, ** $p < .01$, * $p < .05$, † $p < .10$.

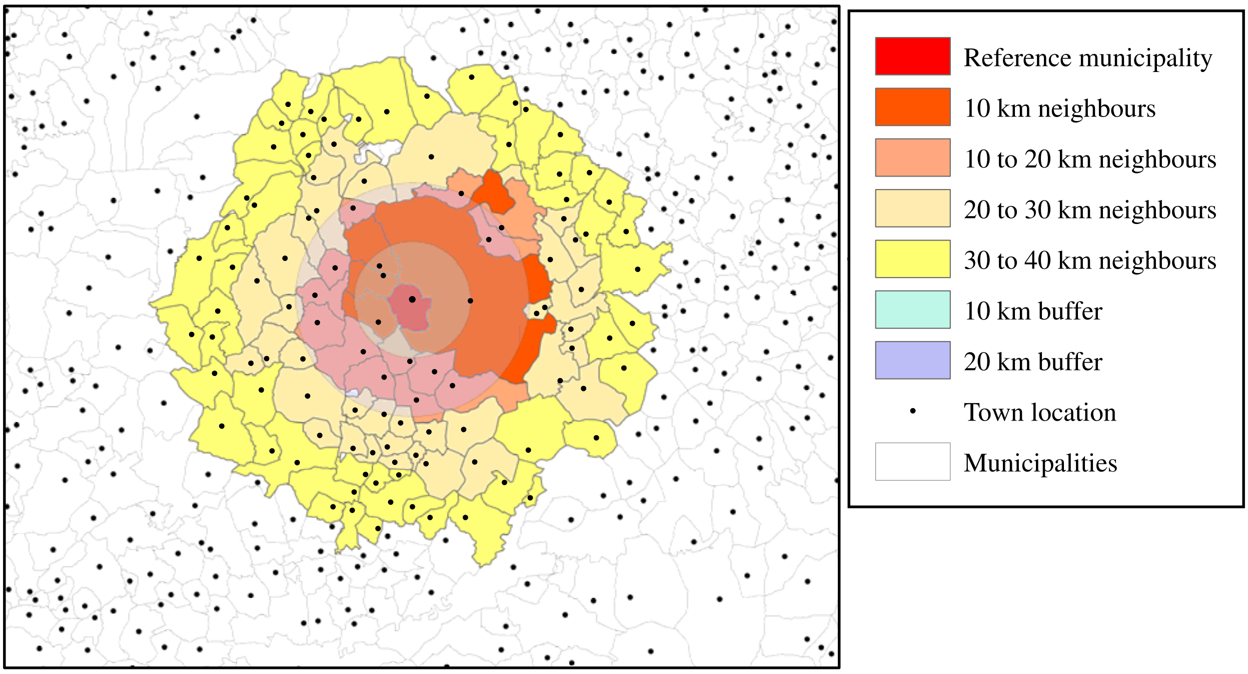
(a) Labour density and average labour density across different neighbouring areas are instrumented with the 2 period lagged values, (b) labour density is instrumented with the elevation variable, and density across neighbours with its 2 period lagged values.

Table A.6. Agglomeration effects with human capital controls, neighbouring agglomeration and regional indicators. With agriculture and total land dataset

Parameter (%)		3.43***	4.17***	3.94**
Standard error (%)		.6	.62	1.46
Parameter 10 (%)		1.66*	-	-
Standard error (%)		.67	-	-
Parameter 50 (%)		-1.77†	-	-
Standard error (%)		1.03	-	-
Parameter 100 (%)		2.13*	2.21*	2.26*
Standard error (%)	*No regional*	.94	.93	.94
R^2 (%)	*indicators*	7.79	8.15	7.75
Parameter (%)		3.44***	4.16***	-
Standard error (%)		.6	.63	-
Parameter 10 (%)		1.49*	-	-
Standard error (%)		.68	-	-
R^2 (%)		8.77	9.11	-
Wald test (*ccaa = 0*)		5.63***	5.06***	-
Wald test (*ccaa ≠ pro = 0*)	*NUTs-2*	5.5***	4.8***	-
Parameter (%)		3.6***	4.35***	-
Standard error (%)		.61	.63	-
Parameter 10 (%)		1.74*	-	-
Standard error (%)		.68		-
Parameter 100 (%)		1.73†	-	-
Standard error (%)		1.04	-	-
R^2 (%)		10.66	-	-
Wald test (*pro = 0*)	*NUTs-3*	4.5***	4.55***	-

*** $p < .001$, ** $p < .01$, * $p < .05$, † $p < .10$.

(a) Labour density and average labour density across different neighbouring areas are instrumented with the 2 period lagged values, (b) labour density is instrumented with the elevation variable, and density across neighbours with its 2 period lagged values.


Reference municipality
10 km neighbours
10 to 20 km neighbours
20 to 30 km neighbours
30 to 40 km neighbours
10 km buffer
20 km buffer
Town location
Municipalities