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How Local are Spatial Density Externalities? evidence from square grid data

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- evidence from square grid data

Martin Andersson[⊗], Johan Klaesson[⊕] and Johan P Larsson[∅]

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1. INTRODUCTION

The relationship between density of economic activity and productivity belongs to the classic lines of inquiry in economic geography and spatial economics. Since the ‘geographical turn’ around the 1990s the interest in this issue has surged, with several empirical and theoretical contributions focusing on the effects of density on productivity and their underlying micro-foundations (Ciccone and Hall 1996, Baptista 2003, Combes 2000, Glaeser and Maré 2001, Andersson and Lööf 2011). The ‘big picture’ regarding estimates of the elasticity of worker wages or firm productivity with respect to density suggests that a doubling of density raises productivity with between 2 to 7 percent (Combes et al 2008, Yankow 2006). Density externalities are often put forth as a main explanation of this pattern (e.g. Tveteras and Battese 2006, de Groot et al. 2008, Duranton and Puga 2004).

Even though the density-productivity relationship is well established, an issue in the literature concerns the spatial scale of analysis and the associated assumptions about the scale at which density externalities operate. The spatial level of analysis often differs from study to study and the general notion of ‘spatial density’ tells us little about the relevant geographic scale. Our knowledge of the spatial scale of density effects and their attenuation with distance is in fact limited (c.f. Overman 2004). How local are density externalities and how sharply do they attenuate with distance? Do they span whole labor market regions and metropolitan areas, or are they confined to the neighborhood level? Is the effect of density on productivity at the level of wider regions in fact the outcome of a number of localized density effects at the neighborhood level that add up to a region effect, or do region-wide and neighborhood effects operate simultaneously?

In this paper, we explore these questions using geo-coded data at a fine spatial resolution. The paper contributes to the literature with an analysis of the density-wage relationship across uniform square grids of small sizes, allowing for inference about how local density effects are as well as the extent of their distance decay. We also test whether density effects and their attenuation with distance are stronger for better educated workers, as has been found in recent studies (Gould 2007, Möller and Haas 2003).

1.1 Motivation and related literature

The question of the spatial extent of density externalities is important for several reasons. First, it bears directly on the empirical relevance of alternative micro-foundations for density externalities. Learning effects involving face-to-face interaction between people, for instance, are in general expected to be more localized than effects related to sharing of infrastructure and specialized suppliers, such that more localized effects would support the former explanation rather than the latter. In other words, how local density effects are have implications for how we think and conceptualize about density externalities. Second, the issue of geographic scale and decay of density externalities also have implications for policy. The 'localness' of such effects bears for example on both city planning and land-use strategies, as well as for policies on cluster formation. More local effects would support a built environment with higher density of offices and workplaces, e.g. through high office buildings, at least from the perspective of productivity.

There are few previous analyses addressing this issue. One is Rosenthal and Strange (2008), who draw concentric circles of different radius using the place-of-work PUMA in the US. In their analysis, the smallest circle extends 5 miles (or about 8 kilometers) from the work places in their sample. They find substantial attenuation of the spillover effects after the first circle. Another study is van Soest et al (2006), who use census data for South-Holland at the level of ZIP-codes. This is a spatial level smaller than a city, and represents areas of about 6 km^2. The authors relate employment growth and establishment birth in different industries to agglomeration measures and find that agglomeration (especially industry diversity) promotes both employment growth and establishment creation. They also find quite sharp attenuation in the sense that the own-ZIP code agglomeration indicators have a much stronger effect on growth than indicators of agglomeration in nearby ZIP codes.

The analyses in this paper bear on these previous studies, but we take a different approach regarding both spatial aggregation level and identification strategy.

1.2 Identification of density effects at different spatial levels using square grid data

We employ geo-coded data for Sweden to re-assess the density-wage relationship at different levels of spatial resolution, and test for attenuation effects by estimating the influence of density in first- and second-order neighbors. The analyses rest on data in which Sweden is divided into a uniform grid of squares, such that our observational geographic units are equally-sized squares in terms of area. Our squares are much smaller than the geographic units typically employed in the literature on density externalities. The area of the smallest circles in the Rosenthal and Strange (2008) study, for instance, is about 200 km^2, which is in fact larger than many Swedish regions, and clearly larger than a neighborhood. Moreover, the average size of the ZIP codes in van Soest et al (2006) is about 6 km^2, which is significantly larger than the spatial level in our study.

We observe squares of two different sizes: (i) 1000 times 1000 meters (1 km^2) and (ii) 250 times 250 meters (0.0625 km^2). These reflect neighborhood-levels rather than the levels of regions or metropolitan areas. We effectively test for density externalities at a very local level, while controlling for the overall density of the region to which a square belongs (cf. Briant et al 2010). This set-up allows us to empirically identify neighborhood effects operating at within larger agglomerations. A further novelty in our analysis is the longitudinal structure of the data. We observe each square over a 20-year period, 1991-2010. We exploit the panel structure of the data and account for unobserved time-invariant heterogeneity at the square level. Numerous studies show that this is crucial for identification of density externalities, as time-invariant heterogeneity generally has a large influence on the estimated parameters (cf. Mion and Naticchiono 2009).[1]

The use of equally sized squares brings advantages in terms of how density is measured as well as in terms of identification of neighbor structures. Since Ciccone and Hall (1996), a standard measure of density is employment per square kilometer. Most studies employ administratively delineated geographical areas, such as municipalities, counties or metropolitan regions, between which the size as well as shape differs greatly.[2] In the cross-section, the employment density of a municipality may thus in principle be higher than another either because it is smaller in terms of land area or because it hosts a large number of employees. The fact that the areal size of the squares is held constant implies that any difference in the number of employees between two squares reflects a difference in employment density. Since the denominator (km^2) is invariant across observational units, the sheer number of employees becomes an 'exact' measure of employment density.

By construction of the grid, every square has eight first-order and 16 second-order neighbors. We include the density in first- and second-order neighbor squares as separate variables and estimate their influence on the average wages of a square, while controlling for the internal density. This allows us to test for the attenuation of density externalities in a way akin to Rosenthal and Strange (2008) and van Soest et al (2006). We compare the coefficient estimates of 'internal' and 'external' densities, where strong attenuation would imply that the coefficients for neighbor density are significantly smaller than the ones for the internal densities.

1.3 The modifiable areal unit problem assessed on uniform squares

We also test if our results hinge on the choice of spatial resolution, i.e. whether we employ 0.25 km or 1 km squares. The modifiable areal unit problem (MAUP) states that correlations between variables can differ significantly across spatial scales and shapes (Openshaw and Taylor 1979). Scale refers to the spatial resolution (or size) of observational units, whereas shape refers to how the boundaries of the units are drawn at a given spatial resolution. Although the MAUP has been extensively debated and analyzed in the geography literature (Wrigley 1995), it is rarely discussed in the urban and spatial

[1] Many studies using data on finer spatial aggregation levels are cross-section studies, such as Rosenthal and Strange (2008).
[2] In Sweden, for instance, the difference in square kilometers between municipalities amounts to a factor of over 2 100.

economics literature (Burger et al 2010, Briant et al 2010). As we have uniform squares we eliminate shape distortions in the sense that differences in estimates across spatial resolutions cannot be caused by differences in the shapes of the geographic observations at different spatial scales. By estimating our models in an equivalent way for the squares of different size we can isolate so-called size distortions, i.e. the extent to which our results change as we only change the spatial size of our observational units. In our empirical context, this issue is tightly connected to the spatial extent of density effects.

With regard to the MAUP, our paper lines up with a set of recent studies by in particular Holmes and Lee (2010), Burger et al. (2010) and Briant et al (2010). Burger et al. (2010) test the MAUP with data for the Netherlands. They analyze determinants for employment growth for varying initial spatial units of analysis. They confirm the MAUP and find different effects of agglomeration forces across geographic levels. Briant et al (2010) focus on MAUP for France and assess to what extent different zoning systems, such as employment areas and grids, produce different patterns of spatial concentration and agglomeration economies, including the elasticity of wages to employment density. Their general finding for France is that the size of the areas matter more than their shape and that specification (i.e. the set of control variables) is much more important than both the size and the shape of the geographical units. For square grids, they find that the use of larger grids generally produce larger estimates of the density elasticity of wages.

1.4 Summary of main findings

Our main finding is that highly localized density externalities operate simultaneously as region-wide density effects. For 1 km^2 squares we find strong and economically significant neighborhood effects that attenuate sharply with distance, while controlling for region-wide density effects. These results are robust to a finer spatial resolution, though a finer geographic scale generally produces lower wage-density elasticities. The density elasticities also differ between highly educated workers and other workers. The share of the labor force holding the equivalent of a bachelor's degree gain more from proximity to economic activity across square sizes. The difference is more pronounced in the smaller squares, indicating that such workers gain more from localized human capital spillovers. Further, graduate workers exhibit sharper attenuation effects than the private labor force as a whole. Our main results also hold across different spatial resolutions.

1.5 Outline

The paper proceeds as follows: Section 2 presents the structure of the data and describes the construction of the variables in the analysis. Section 3 presents the empirical strategy, provides descriptive statistics and also presents our results for 1 km^2 squares. Section 4 asks if our results are sensitive to the spatial resolution and re-produce the analyses in Section 3 on squares of 250 by 250 meters. Section 5 concludes.

2. DATA AND VARIABLES

2.1 Data

The data are audited register data maintained by Statistics Sweden (SCB). The data cover the period 1991-2010 and include information on wages, employment, education and sector composition. The data are constructed based on geo-coding, where each establishment in Sweden is assigned to a geo-code (X and Y coordinates). The geo-code is in turn derived from a uniform grid of squares covering the whole of Sweden. Every square is of equal size and represents a one-by-one kilometer square (1 km^2). For agglomerated areas, defined by SCB as places with at least 200 inhabitants and a maximum distance of 200 meters between houses, we also have a finer geographical resolution corresponding to squares with sides of 250 m (0.0625 km^2). The analyses only cover such agglomerated areas. For every establishment in the private sector the data include yearly information on wages, sector affiliation and employment by education level. By aggregating over a common geo-code, we arrive at a dataset at the level of squares, containing the abovementioned information.

2.2 Variables

Density

The variable of main interest is employment density. Density is more often than not measured as the intensity of labor, human, and physical capital relative to physical space (Ciccone and Hall 1996), and this means that density is high when there is a large amount of labor and capital per square kilometer. This definition is conceptually quite unproblematic. However, in empirical applications such a density variable can be difficult to interpret. At a given spatial level, such as municipality or county, the land area of the units of observations differs substantially. For example, the land area in terms of km^2 of Swedish municipalities differ by a factor of over 2 100. Sundbyberg municipality has a land area of 8.7 km^2 whereas Kiruna municipality has a land area amounting to 19 371 km^2.

As argued by Holmes and Lee (2010), differences in employment between two areas can be thought of as arising on two margins: (i) one area could be larger in terms of land area than another, or (ii) one area could have higher employment density per fixed unit of area. The substantial difference in land area of observational units at a given spatial level means that margin (i) can explain a large fraction of the observed differences. By using observational units of exactly the same size, we completely eliminate this first margin. Any difference in employment between two areas will reflect a difference in density, because the denominator in standard measures of density (km^2) is invariant across observational units. The sheer number of employees of a square *i*, E_i, is thus our measure of density in square *i*.

As argued previously, the size of the square reflects a fine spatial resolution corresponding to the neighborhood level. Studying such small squares captures density of economic activity in a better way; a municipality with a large land area but small population will have low density when dividing employment with the total land area. Yet, the employment may in any case be concentrated to a small part of the total land area in the municipality. This is the norm rather than the exception across municipalities and counties in Sweden. Our data can capture such areas of high density in regions that may appear sparse based on their general employment density per square kilometer.

Productivity

We use average wages in a square as a proxy for the level of productivity. These are based on the total private wage-sums paid by the establishments. The wage-sum of a square is simply the aggregate wage payments to employees working for establishments located in the square in question. Denote this by W_i where *i* denotes a given square. Then our productivity measure, w_i, is:

$$(1) \qquad w_i = {W_i}/{E_i}$$

which is the average wage of employees in square *i*. Average wage is not a perfect measure of productivity, but higher average wages should, by simple theoretical arguments, mean that firms have higher average productivity (or that the employees have higher average marginal product).

Controls

We control for a set of standard variables. Wages could of course be higher due to differences in the sector composition or the education level of employees between squares. Therefore, the analysis includes employees with a university degree ($\geq$ 3 years) as a fraction of the total number of employees as well as the fraction of employees in manufacturing, low-end services and high-end services (base category), respectively. This controls for the basic employment and sector structure in each square. In addition, the regression analyses include time dummy variables to account for business cycle effects.

We also control for the overall density of the municipality in which each square *i* is located (cf. Briant et al 2010). If density externalities apply to a wider region rather than at the level of small squares within the region, then it should be the total density of the municipality that matters more. The density of a municipality can be thought of as a distance-decay weighted sum of accessibility to economic activity in all localities of a country. Denoting municipalities (N=290) by r, municipalities aggregated to the level of functional regions (N=81) by k, and municipalities in the rest of the nation by l:

(2) $$De_r^{Tot} = De_r^M + De_r^R + De_r^E \,,$$

where

$De_r^M = W_r \exp\{-\lambda_M t_{rr}\}$, municipal accessibility to total wage earnings of municipality r

$De_r^R = \sum_{k \in R_r} W_k \exp\{-\lambda_R t_{rk}\}$, regional accessibility to total wage earnings of municipality r

$De_r^E = \sum_{l \notin R_r} W_l \exp\{-\lambda_E t_{rl}\}$, extra-regional accessibility to total wage earnings of municipality r

De_r^{Tot} is our region-wide density variable, reflecting the total accessibility to economic activity of the municipality a square is located in. The measure represents a continuous view of geography (cf Tobler 1970) and may be thought of as a market potential measure. It is based on average time-travel distances by car (t), where the distance decay parameters (λ) are estimated using data on commuting behavior (Johansson et al., 2003). In addition to providing a measure of region-wide density, accessibility measures have been shown to alleviate problems with spatial autocorrelation (Andersson and Gråsjö 2009).

Further, we exploit the longitudinal properties of the data and include fixed effects to assess whether results are sensitive to time-invariant unobserved square-specific effects.

Neighbor characteristics and attenuation of density externalities

By construction of the square grid, every square (1 km^2 or 0.0625 km^2) has eight first-order neighbors and 16 second-order neighbors. This is illustrated in Figure 1. By identifying the first- and second-order neighbors of each square, we can test for the attenuation of density externalities.

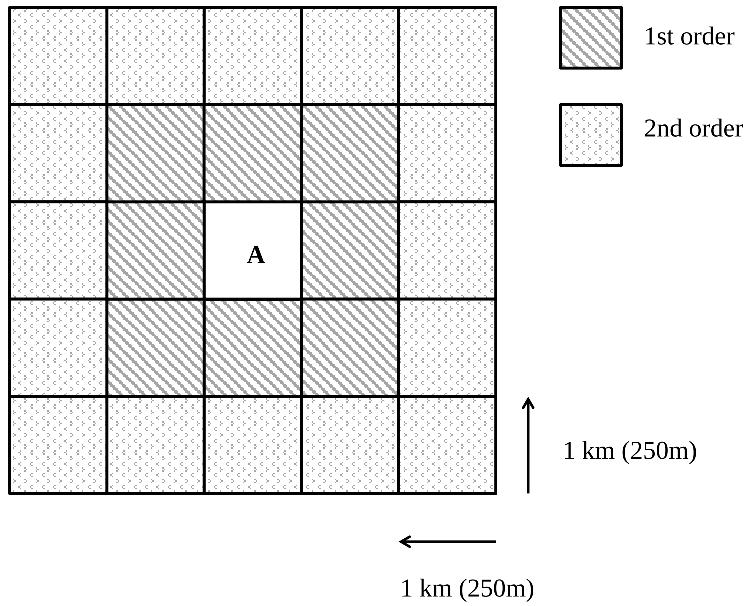

Figure 1. *Squares and neighbors.*

We expect that the productivity of a square, such as **A** in the figure, not only depends on its own density but also on that of its neighbors. This would for instance be the case if the attenuation of square density effects is limited. We construct variables that for each square represent the density in first- and second-order neighbor squares. Density of neighbors is simply the sum of the employees in the neighbor squares. The total density area associated with each 1 km^2 square is the size of a small municipality or urban region.

In the estimations we include these two neighbor variables as two separate regressors, and we expect that they have a positive influence on the productivity of a square. Yet, attenuation of density externalities should mean that the effects decay with distance. We test for this by examination of how the magnitude of the parameter estimates of the neighbor densities compare to the internal square density. This identification strategy of attenuation effects is similar to Rosenthal and Strange (2008) and van Soest et al (2006).

3. PRODUCTIVITY AND DENSITY ACROSS SQUARES

3.1 The variance in neighborhood density within regions and attenuation of density externalities

The intra-regional variance in density and productivity across squares is substantial. Some neighborhoods show high density whereas other areas are sparse. To illustrate this, Figure 2 shows the density of 1 km^2 squares with at least 50 employees in the wider Stockholm region – a region that is generally considered dense. Empty spots on the map mean that there are no squares with at least 50 private sector employees in the area.

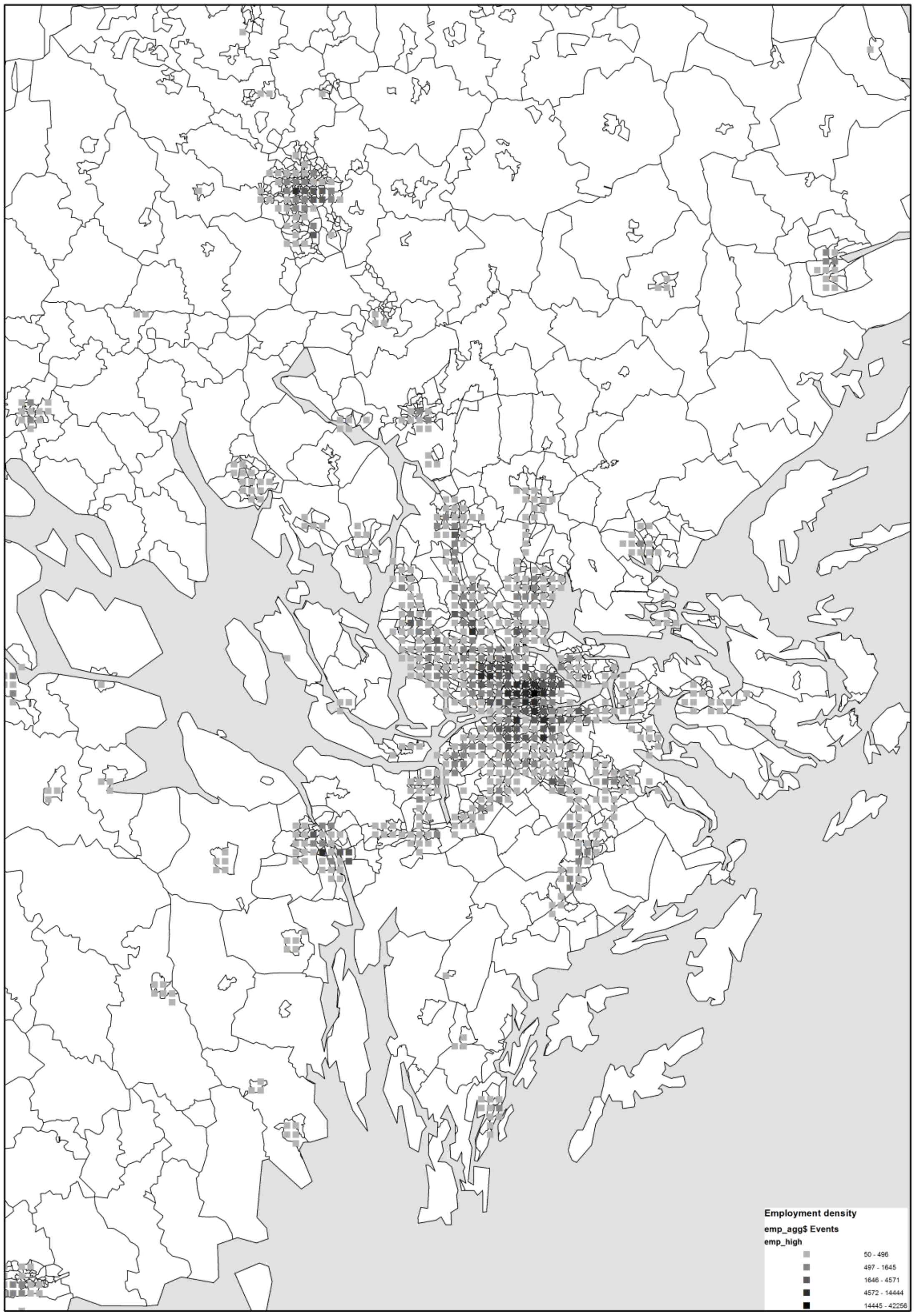

Figure 2. *Squares (1km^2) with at least 50 employees in the wider Stockholm region (average 1991-2010).*

The map illustrates that in the wider Stockholm region, there are scattered clusters of high-density squares, with the largest cluster being in the city center. This is a typical pattern in most regions. These patterns clearly point to the large variance in density that appear when zooming in on the neighborhood level, in this case squares of 1 km^2. They also illustrate how crude approximations of the actual geographic density measures like employment per square kilometer of a whole region produce. A measure of the employment per square kilometer of the whole region in Figure 1 would conceal the fact that the employment is highly concentrated to a few clusters of high-density squares at the neighborhood level.

From this it follows that an important question for the research literature on density externalities concerns the spatial extent and decay of such externalities. The pattern in Figure 1 reinforces the issue we raised in the introduction of this paper – estimates of the effect of a region's density on its productivity may in fact be driven by a larger number of highly localized density effects operating at the neighborhood level inside the region. A counter perspective would be that mobility within regions is high and the attenuation of externalities between different neighborhoods in the same region is so low that the location inside the region matters little. Even if a square is located far away from the region's main cluster of high density squares, it may still be so close that it enjoy the same extent of density externalities as it would had it been located in the main cluster.

The issue described above is mainly empirical and sorting out how important the neighborhood level is and the strength of attenuation of density externalities requires analyses of data at a very fine spatial resolution. In fact, lack of data at a fine geographic level means that empirical analyses in many studies effectively implies an assumption of zero attenuation within large spatial units of observation and uniformly distributed activity within those units of observation (cf Rosenthal and Strange 2008). Our empirical context is such that we can deal with these issues at a uniquely fine spatial level, allowing us to relax the implicit assumptions of zero attenuation and geographic uniformity within large spatial observational units plaguing empirical analyses of density externalities.

3.2 Overall patterns of density and wages across squares

Figures 3 and 4 provide a basic description of the overall relationship between the average wages in a square and its internal density as well as the density of its neighbors. Figure 3 illustrates that there is indeed a positive correlation between the density of a square and its average wage level. Note here that configuration of the data is such that the only source of differences in employment density is the number of employees. All squares have exactly the same area.

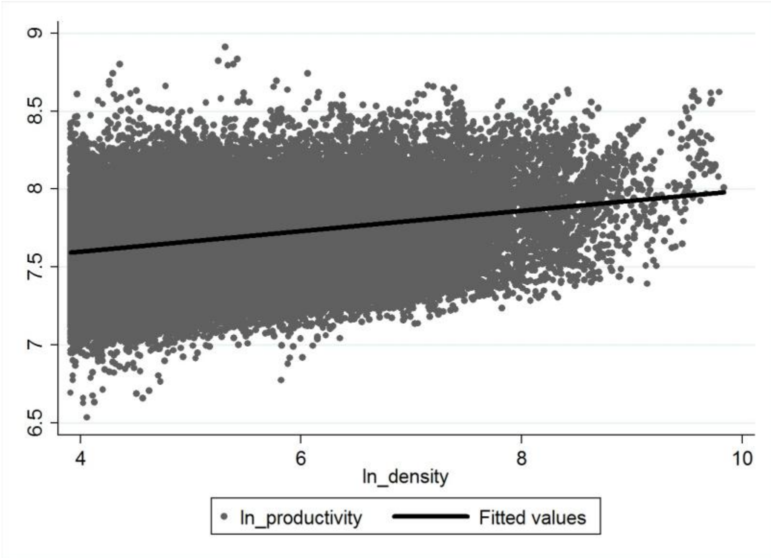

Figure 3. *The relationship between productivity of a square and its internal density, 1 km² squares.*

A simple linear regression of the log of the internal density of a square on the log of its productivity produces an elasticity of 0.06. Thus, doubling the number of people working in a square is in general associated with 6.5 percent higher average wages. This crude estimate is roughly in line with previous literature (cf. Yankow 2006).

Figure 4 presents the association between the density of first- and second-order neighbors and productivity, respectively. It is clear that squares of higher productivity tend to have first- and second-order neighbors of higher density. This is what one would expect from the argument of inter-square spillover effects. A simple estimation of the linear relationship between a square's productivity and the density of its first-order neighbors yields an elasticity of 0.017, which is almost identical to the same elasticity for the density of second-order neighbors. This overall pattern is consistent with neighbors playing a role, but at a rate decaying with distance. The same crude estimate for the internal square density is roughly four times as large.

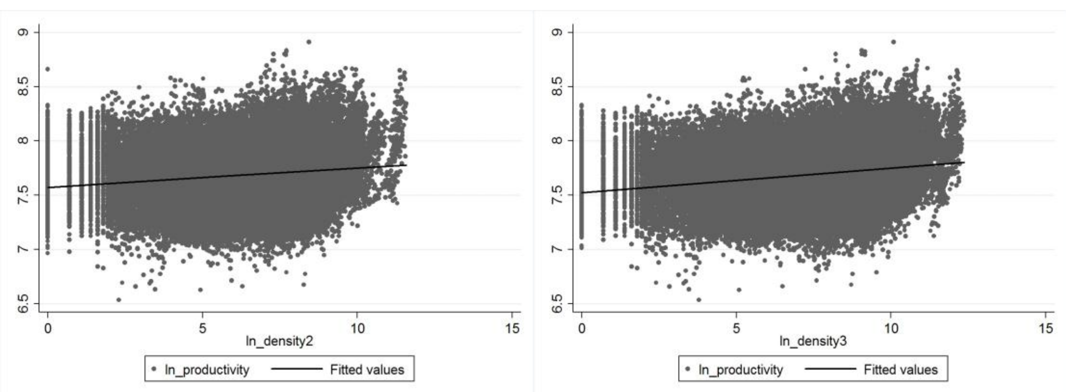

Figure 4. *The relationship between productivity of a square and density in first-order (left panel) and second-order (right panel) density,1 km² squares.*

3.3 Estimating the elasticity between density and productivity at a fine spatial resolution

Model, identification strategy and descriptives

To isolate the effect of internal and neighbor density on the productivity of a square we set up the following estimating equation:

$$\ln w_{it} = \alpha + \beta \ln E_{it} + \phi \ln EN(1)_{it} + \theta \ln EN(2)_{it} + \ldots$$

(3)

$$\ldots + \sigma \ln De_r^{tot} + \boldsymbol{\lambda}'\mathbf{X}_{\mathbf{it}} + \sum_{t=1}^{T} \delta_t D_t + \varepsilon_{it}$$

where w_{it} is productivity of square i in year t. The parameters of main interest are β, ϕ, θ and σ which are the elasticities of average wages with respect to internal and neighbor densities as well as the region-wide density. E_{it} denotes internal density in year t. $EN(1)_{it}$ is employment density in the eight first-order neighbor squares and $EN(2)_{it}$ is the density in the 16 second-order neighbors (see Figure 1). De_r^{tot} denotes the region-wide density measured according to the total accessibility (or market potential) of the municipality in which square i is located.[3]

Based on the model in (3), our identification of the spatial extent and attenuation of density externalities rests on a comparison of the density parameters β, ϕ, θ and σ. If $\beta = \phi = \theta > 0$ and $\sigma = 0$, then density externalities are local, but the attenuation of their effect is effectively zero across first- and second-order neighbor squares. If on the other hand $\beta > 0$ and $\phi = \theta = \sigma = 0$, then the effects are highly localized. The other extreme would be a case where $\beta = \phi = \theta = 0$ and $\sigma > 0$, corresponding to significant region-wide density effects but no effect of the immediate neighborhood.

In general, we expect that β, ϕ, θ and $\sigma > 0$ but $\beta > \phi, \theta, \sigma$ which would suggest that there are local neighborhood effects decaying over distance as well as region-wide density effects operating simultaneously. Such a pattern is consistent with e.g. local learning effects from face-to-face interaction operating the level of neighborhoods at the same time as there are region-wide density effects arising from e.g. sharing of infrastructure and specialized suppliers.[4]

[3] Each municipality hosts several squares,

[4] The various micro-foundations of agglomeration economies and density effects are indeed not mutually exclusive (cf. Duranton and Puga 2004).

We include a number of control variables in the **X** matrix:

- <u>Industry structure</u>: *manufacturing, low- and high-end services employment, respectively, as a fraction of total employment*

- <u>Human capital</u>: *employees with a long university education (≥ 3 years) as a fraction of total number of employees*

- <u>Share of males</u>: *the fraction of the employees in the square that are males*[5]

- <u>Region-wide density</u>: *accessibility to economic activity (market potential) of the municipality the square is located in (see equation 1)*

The data span the 1991-2010 period and we include year dummy variables (D_t) to control for shifts over time due to e.g. the business cycle. For instance, Sweden experienced a large recession in the early 1990s, which influenced both wages and employment.

We estimate the model in equation (3) with two alternative estimators: (i) a standard OLS estimator and (ii) a fixed effects panel (FE) estimator. These two estimators differ in terms of how the parameters are identified. In the OLS estimator, the parameters are identified based on differences in productivity and density between different squares, i.e. the 'between' variation in the data. In the FE estimator, the parameters are instead identified based on the 'within' variation in the data, i.e. variation within a square over time. The within-transformation means that any time-invariant characteristics are wiped out from the regression.[6] The FE estimator thus eliminates unobserved time-invariant heterogeneity of the observational units. Identification of the parameters is solely driven by changes in density (either internal or in the neighbors) over time, and changes in density only takes place through changes in the sheer number of employees in the squares. This is a significant advantage of the FE estimator compared to OLS, and is also one reason why the FE estimator is generally recognized to allow for more causative interpretations. We estimate one model with OLS estimator for reasons of comparison, but acknowledge that the FE estimator is more suitable.

Table 1 presents descriptive statistics for all variables in the empirical analysis. All numbers refer to average values for 1 km^2 squares with at least 50 employees over the 1991-2010 period. Productivity is

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[5]Males typically have higher wages and also work part-time to a lesser extent than females.

[6] We can think of the error term, ε_{it}, in (3) as consisting of two parts in the fixed estimation. One time-invariant square-specific part, v_i, and one random (white-noise) part, μ_{it}.

total wages (in SEK) paid to employees in a square divided by the total number of employees in the private sector, i.e. the average wage of private sector workers in a square.

Table 1. Descriptive statistics for main variables.

Variable	Mean	Std. deviation
Productivity (SEK)	226 210	60 274
Productivity, graduate workers (SEK)	302 898	111 274
Employment density	454	1 155
Employment density, neighbors	2398	5533
Employment density, second neighbors	6683	15618
Region-wide density (ln)	21.38	1.19
Share manufacturing	.343	.337
Share low-end services	.551	.313
Human capital	.073	.084

Note: The figures are based on Swedish data for 1 km^2 spatial squares with at least 50 employees (N=67327). All numbers refer to average values over the period 1991-2010. Productivity is measured in Swedish kronor (SEK). Density is the sheer number of employees in a 1 km^2 square (hence employment per square kilometer). Density neighbors are the total number of employees in the eight squares surrounding each square (see Figure 1). Density in second neighbors is the total number of employees in the 16 second-order neighbor squares. Manufacturing, and low-end services refer to the fraction of employees in each industry category, respectively (base category: high-end services). Human capital is measured as the fraction of employees with a university education of at least three years. Human capital neighbors is defined in the same way but refers to the eights squares surrounding a given square.

A main observation from Table 1 is there is substantial heterogeneity across the 1 km^2 squares with regard to all the listed variables. The mean density of the 1 km^2 squares is 454 employees but the standard deviation is over two times higher than the mean. There are also vast differences across squares in terms of characteristics of their neighbors. For the density of both first- and second-order neighbors, the standard deviation is over two times the mean. Part of this is due to that some squares are isolated islands in geographic space with no activity in the eight first- or 16 second-order neighbors.

Results

Table 2 presents results from an estimation of the model in Equation (3) with both the OLS and the fixed effects estimator. A general pattern is that the estimated parameters for internal density are statistically significant and have the expected sign. The OLS estimate indicates that a doubling of density would produce a 3.6 percent increase in average wages, while keeping the economic activity at the region level constant.

Table 2. Estimated effects of density on productivity across 1 km^2 squares.

	OLS	**FE**
Density (log)	0.0361*** (0.00158)	0.0286*** (0.000839)
Density (first order neighbors, log)	-0.00251 (0.00193)	0.00274** (0.00110)
Density (second order neighbors, log)	-0.00106 (0.00180)	-0.00204 (0.00126)
Region-wide density (accessibility, log)	0.0135*** (0.00151)	0.0109*** (0.00125)
Human capital (share graduate workers)	1.078*** (0.0407)	0.862*** (0.00798)
Manufacturing share	0.153*** (0.0123)	0.0710*** (0.00350)
Low-end services share	0.111*** (0.0132)	0.0628*** (0.00348)
Male share	0.509*** (0.00941)	0.469*** (0.00427)
Year dummies?	YES	YES
Square fixed effects?	NO	YES
# observations	67 327	67 327
# of 1 km^2 squares	4 840	4 840
R^2	0.83	0.91

Note: The table reports estimated parameters associated with the variables in the left column. The log of productivity is the dependent variable (see equation 1). The data are panel data over the 1991-2010 period. Two estimators are employed; OLS (middle column) and fixed effects (right column). All variables are defined in Section 2. Standard errors are presented within brackets. *, ** and *** denote significance at the 0.1, 0.05 and 0.01 level, respectively.

The FE estimator reveals that part of the elasticity is explained by square-specific, time-invariant heterogeneity. With the FE estimator the estimate drops to 2.9 percent. The coefficients referring to neighboring densities are all close to zero. Using fixed effects estimation reveals that a doubling of first-order neighbor density is associated with a 0.2 percent increase in wages, but the effect of second-order neighbors is insignificant. These results indicate strong attenuation of neighborhood density externalities – as we study effects further away from the square (keeping region density constant) there is clearly a diminishing role of such effects. One interpretation of this results is that the neighborhood density effects indeed capture highly localized non-market interaction effects, such as knowledge spillovers through face-to-face interactions and 'local buzz', that attenuate sharply with distance.

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We yet find a significant and positive region-wide density effect that is robust to the inclusion of the neighborhood densities as well as the other controls. This suggests that localized neighborhood and region-wide density effects operate simultaneously. The neighborhood density effect is however more than twice as large as the region-wide effect. The estimated elasticity of the square density is about 3 percent compared to about 1.1 percent for the region-wide elasticity. In general, we can think of the region-wide effect as capturing less distance-sensitive effects such as sharing of infrastructure and input-output linkages amongst firms in the region.

The control variables reflecting industry structure reveal that productivity is higher in squares with high fractions of employees in manufacturing sectors. This may in part be understood as a consequence of the fact that that we proxy productivity with average wages and we lack data on regional capital stocks. Manufacturing sectors are in general capital-intensive compared to services. Increasing the share of low-end services relative to high-end services and manufacturing is also associated with higher wages, but this result must be interpreted with caution, since the human capital dimension is kept constant. A higher fraction of graduate employees is positively associated with wages; the coefficient has a *t*-value in excess of 100 and is hence highly significant. Robustness tests indicate that the effect of human capital dominates the effect of an increasing share of high-end services, which is a human-capital intensive sector.

Is the neighborhood more important for university graduates?

Recent literature on agglomeration economies emphasize that the benefits of density may depend on worker characteristics (Glaeser 1999, Bacolod et al. 2009). A general argument is that density – which is assumed to stimulate knowledge and information flows in a local milieu – should matter more for firms and workers for whom knowledge and information is important. At the same time, workers with higher skills and education levels may also be assumed to be better apt to absorb and materialize knowledge and information flows.[7] This has been confirmed in a series of studies which estimate returns to density for workers in different industries, occupations and education levels (Bacolod et al. 2009, Glaeser and Maré 2001, Brülhart and Mathys 2008). These studies indicate that the returns to density are higher for workers with knowledge- and communication-intensive jobs.

[7]Such an argument may be derived from the work on 'absorptive capacity' (see e.g. Cohen and Levinthal 1990).

If the neighborhood effect is more prone to capture non-market interactions involving face-to-face meetings between people, such as knowledge spillovers and local buzz (Storper and Venables 2004, Bathelt et al 2004), the above arguments would suggest that it is particularly the neighborhood effect that is stronger for better educated workers. These are workers for whom knowledge is more important and who are also better apt to absorb and materialize such knowledge spillovers.

To test these ideas in the current empirical context with uniform squares of high spatial resolution, we conduct separate estimations for graduate workers ($\geq$ 3 years of university education). Let E_{it}^{L} denote such workers in square *i* year *t*. If W_{it}^{L} then denotes the total wage sum associated with graduate employees we get a productivity measure as follows:

(4) $$w_{it}^{L} = W_{it}^{L} / E_{it}^{L}$$

which gives us the average wage of graduate employees in square *i* year *t*. Table 3 presents results from the panel fixed effects estimator when we estimate the model in (4) with the new dependent variable.[8]

Consistent with expectations, we find that the estimated elasticity between density and productivity is substantially higher for graduate employees. The point estimate rises to an elasticity of about 7 percent; considerably larger than the same estimate for all workers in Table 2. The effect of region-wide density is still significant and positive and slightly larger for graduate workers, 2 percent in Table 3 compared to 1.1 in Table 2. While the big picture confirms previous findings in the literature, our results here show that it is primarily the neighborhood effect that is larger for employees with a university degree. We argue that one reason for this is that the neighborhood level is more apt to capture effects associated with knowledge flows and local buzz, which are primarily important for better educated workers.

We also find sharper attenuation of neighborhood density effects for highly educated workers. The estimated relationship between productivity and the density of neighbor squares is effectively zero for the first-order neighbors and even a negative 2 percent for second-order neighbors, indicating sharp attenuation effects of the density spillovers, and possibly a competition effect when distant squares experience an increase in density, keeping internal density, first-order neighboring density and region density constant.

[8]We only report the results for the panel FE estimation because the ordinary OLS provide similar results, and the FE estimator accounts for unobserved time-invariant heterogeneity across squares. Results from OLS estimations are available from the authors upon request.

Table 3. Estimated effects of density on productivity of graduate workers across 1 km^2 squares, panel FE estimator.

	FE
Density (log)	0.0716*** (0.00383)
Density (first order neighbors, log)	-0.0001 (0.00505)
Density (second order neighbors, log)	-0.0212*** (0.00581)
Region-wide density (accessibility, log)	0.0195*** (0.00552)
Human capital (share graduate workers)	0.847*** (0.0357)
Manufacturing share	0.168*** (0.0159)
Low-end services share	0.0205 (0.0158)
Male share	0.418*** (0.0198)
Year dummies?	YES
Square fixed effects?	YES
# observations	62 932
# of 1 km^2 squares	4 741
R^2	0.19

Note: The table reports estimated parameters associated with the variables in the left column. The log of productivity is the dependent variable (see equation 1). The data are panel data over the 1991-2010 period. The coefficients are fixed effects estimates. All variables are defined in Section 2. Standard errors are presented within brackets. *, ** and *** denote significance at the 0.10, 0.05 and 0.01 level, respectively.

4. DOES A FINER SPATIAL RESOLUTION IMPACT THE RESULTS?

So far the analysis has been undertaken at the level of squares of 1 km^2, which is a fine spatial resolution in itself. Our data yet make it possible to zoom in on squares of size 250 by 250 meters (or 0.065 km^2). By doing so, we keep all the advantages of analyzing squares of the same land area. The only difference is that we employ a finer geographic resolution. The literature on MAUP states that results may be dependent on the level of aggregation. Are our results for 1 km^2 squares robust to a finer spatial resolution?

In our case, we do not compare different administratively drawn geographic boundaries, such as municipalities and counties. Instead, we compare results obtained with 1 km^2 squares with squares of 0.0625 km^2. The MAUP would predict that we might end up with different results due to our shift of spatial resolution. However, as argued by Burger et al (2010), the MAUP reflects a theoretical issue as much as an empirical (or technical) one in that the spatial scale of analysis should relate to the theoretical underpinnings of the effects under scrutiny. This is indeed a main argument underlying the analysis in this paper. In our empirical context, zooming in on 250 by 250 meter squares allows us to test if we find a localized density effect even at this very fine level of spatial aggregation.

We estimate the model in Equation 2 in exactly the same way as in Section 3, the only difference being that the unit of observation is now 250 times 250 meter squares (0.0625 km^2) instead of 1 km^2 squares. The results are presented in Table 4. We start by looking at the influence of the internal density of squares as well as the influence of first- and second-order squares.

For all workers in Table 2, we found with the FE estimator that the internal square density as well as the first-order neighbor density had a positive influence on the average of workers in a square. As the square density effects for all workers span over 1 km^2 squares, we expect that the both the first- and second-order neighbor density is significant and positive in the estimations on the 250 meter squares. The reason is that, taken together, these neighbors still cover an area smaller than the first-order neighbor squares for the 1 km^2 squares, and the attenuation should be weaker at finer geographic scale.

The results for all workers are consistent with these expectations. The internal square density as well as the density of first- and second-order neighbors is all significant and positive. The point estimate for the internal density is indeed smaller than the one for 1 km^2 squares, 0.7 percent (Table 4) compared to 2.8 percent (Table 2), but the estimated influence of the neighbor squares are roughly in line with those for first-order neighbors in Table 2.

For university graduates, only the internal square density was significant in Table 2, which means that there is no clear reason why we would expect the neighbors to be significant in the estimations on 250 meter squares. In general, however, one could expect that attenuation effects are weaker at a finer spatial resolution. The results in Table 4 reveal that the density of both first- and second-order neighbors is statistically insignificant. Yet, despite being insignificant, the point estimate for first-order neighbors is positive and whereas it is negative (but insignificant) for 1 km^2 squares in Table 3. We interpret this as further evidence of strong localized density effects for university graduates but that the attenuation is weaker when zooming in on a finer spatial resolution.

Table 4. Estimated effects of density on productivity across 250 times 250 meter squares (0.0625 km^2).

	FE ALL WORKERS	FE GRADUATES
Density (log)	0.00762*** (0.000703)	0.0485*** (0.00275)
Density (first order neighbors, log)	0.00272*** (0.000507)	0.00204 (0.00201)
Density (second order neighbors, log)	0.00251*** (0.000540)	-0.00128 (0.00215)
Region-wide density (accessibility, log)	0.00952*** (0.000980)	0.0123*** (0.00374)
Human capital (share graduate workers)	0.805*** (0.00541)	0.673*** (0.0209)
Manufacturing share	0.0941*** (0.00239)	0.145*** (0.00942)
Low-end services share	0.108*** (0.00221)	0.0953*** (0.00866)
Male share	0.439*** (0.00343)	0.345*** (0.0137)
Year dummies?	YES	YES
Square fixed effects?	YES	YES
# observations	125 308	114 979
# of 1 km^2 squares	11 889	11 391
R^2	0.86	0.17

Note: The table reports estimated parameters associated with the variables in the left column. The log of productivity is the dependent variable (see equation 1). The data are panel data over the 1991-2010 period. All variables are defined in Section 2. Standard errors are presented within brackets. *, ** and *** denote significance at the 0.10, 0.05 and 0.01 level, respectively.

The qualitative patterns using 1 km^2 squares thus remain when zooming in at a finer spatial scale. For all workers as well as for the subset of university graduates the region-wide density is also significant and positive. In terms of the magnitude of the estimated parameters, the general pattern is that the elasticity of internal square density variable is lower for smaller squares. These findings are broadly in line with Briant et al (2010), who also find that smaller squares produce smaller estimates of the elasticity of wage with respect to density using data for France.

5. CONCLUSIONS

This paper raises the question of how local density effects are. The answer is that some are highly localized whereas as some pertain to the wider region. Our analyses provide evidence of different density effects taking place at different geographic scales, i.e. highly localized density externalities operate simultaneously as region-wide density effects.

In addition to a role played by a region-wide density effect measured in a conventional way, we show that there are strong and economically significant neighborhood effects that attenuate sharply with distance. We identify the latter by estimating the effect of density on average wages using observations of equally-sized squares with a respective area of 1 km^2 and 0.0625 km^2, while controlling for overall density of the region in which the squares are located. The neighborhood density effect is quantitatively about twice as large as the region-wide effect.

The results provide a better understanding of the spatial scale of density effects and their attenuation with distance. The main conclusion here is that there is no such a thing as 'the' spatial scale of density effects. Different types of externalities within a region may operate at different scales. The alternative micro-foundations for density externalities put forth in the literature are indeed not mutually exclusive.

We emphasize in the paper that one way to appreciate the results is that the neighborhood density effects, operating at a finer geographical resolution than a whole labor market region, capture localized non-market interaction effects, such as knowledge spillovers and 'local buzz' driven by face-to-face interactions between people. Effects of this type are indeed likely to attenuate sharply with distance. Further support for this interpretation is provided by the fact that the neighborhood effect is particularly strong for university-educated workers, for whom knowledge spillover phenomena should be more important. Region-wide effects, on the other hand, may capture density effects of a different kind that do not require as close proximity. An example of this could be sharing of infrastructure and specialized suppliers in an urban region, or input-output linkages between firms.

For research, our results highlight the need of thinking carefully about linking the spatial scale of analysis to the type of effects one wishes to illustrate. If a distinguishing feature of knowledge spillovers and effects of 'local buzz' is that they operate at the neighborhood level, a study using a spatial aggregation level corresponding to metropolitan statistical areas or whole labor market regions have difficulties in sorting out these effects from other types of density effects operating at that level of aggregation. In general, sorting out the relative importance of the alternative micro-foundations of density externalities appears as virtually impossible without strong arguments about their pertinent geographic scale (with associated mechanisms) in combination with disaggregated spatial units of observation.

For policy, the results suggest that fostering productivity effects is as much a question of planning for density of neighborhoods within regions as it is planning for density of the region as a whole. Policy measures pertinent for the former include the built environment where the higher office buildings are a way to increase neighborhood density. For the latter perspective relevant measures could mean better inter-region transportation networks.

REFERENCES

Andersson, M and U. Gråsjö (2009), "Spatial Dependence and the Representation of Space in Empirical Models", *Annals of Regional Science*, 43, 159-180

Andersson, M, and H. Lööf (2011), "Agglomeration and Productivity – evidence from firm-level data", *Annals of Regional Science*, 46 (3), 601-620

Bacolod, M., B. S Blum, and W.C Strange (2009). "Skills in the City", *Journal of Urban Economics*, 65(2), 136-153

Baptista, R. (2003), "Productivity and the Density of Local Clusters", in Bröcker, J., D. Dohse and R. Soltwedel (2003) (eds.), *Innovation Clusters and Interregional Competition*, Springer-Verlag, Berlin, 163-181

Bathelt, H., A. Malmberg and P. Maskell (2004), "Clusters and knowledge: local buzz, global pipelines and the process of knowledge creation", *Progress in Human Geography*, 28, 31-56

Briant, A, P-P Combes and M. Lafourcade (2010), "Dots to boxes: do the size and shape of spatial units jeopardize economic geography estimations?", *Journal of Urban Economics*, 67, 287-302

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

Burger, M.J, F.G. van Oort and G.A. van der Knaap (2010), "A Treatise on the Geographical Scale of Agglomeration Externalities and the Modifiable Areal Unit Problem". *Scienze Regionali*, 9, 19-40

Ciccone A. and Hall R.E. (1996), "Productivity and the Density of Economic Activity", *American Economic Review*, 86, 54-70

Cohen, W. and D. Levinthal, (1990), "Absorptive Capacity: a new perspective on learning and innovation," *Administrative Science Quarterly*, 35, 128–152

Combes P, G Duranton and L Gobillon (2008), "Spatial wage disparities: sorting matters!", *Journal of Urban Economics*, 63, 723-742

Combes, P.P. (2000), "Economic Structure and Local Growth: France 1984-1993*", Journal of Urban Economics*, 47, 329-355.

de Groot, H., J. Poot and M.J Smit (2008), "Agglomeration Externalities, Innovation and Regional Growth: theoretical perspectives and meta-analysis", Working Papers in Economics 08/01, University of Waikato, Department of Economics

Duranton, G. and D. Puga (2004), "Micro-foundations of Urban Agglomeration Economies," in: J. V. Henderson and J. F. Thisse (ed.), Handbook of Regional and Urban Economics, edition 1, Vol. 4, chapter 48, 2063–2117.

Glaeser E (1999), "Cities, Information and Economic Growth", *Cityscape*, 1, 9-47

Glaeser, E. and D. Maré, (2001), "Cities and Skills," *Journal of Labor Economics*, 19, 316–342

Gould E.D (2007), “Cities, workers and wages: a structural analysis of the urban wage premium”, *Review of Economic Studies*, 74, 477-506

Holmes, T.J and S. Lee (2010), “Cities as Six-by-Six-Mile Squares – Zipf’s Law?”, in Glaeser, E (ed) (2010), *Agglomeration Economics*, NBER Books, National Bureau of Economic Research, Inc, March, 105-131

Johansson, B, J. Klaesson and M. Olsson (2003), “Commuters’ non-linear response to time distances”, *Journal of Geographical Systems*, 5, 315–329

Mion, G and P. Naticchiono (2009), “The spatial sorting and matching of skills and firms”, *Canadian Journal of Economics*, 42, 28-55

Möller J and A Haas (2003), “The agglomeration differential reconsidered: an investigation with German micro data 1984-1997”, in Bröcker J, D Dohse and R Soltwedel (Eds.), *Innovation Clusters and Interregional Competition*, Springer. Berlin

Openshaw S. and Taylor P.J. (1979), “A Million Or So Correlation Coefficients: Three Experiments on the Modifiable Areal Unit Problem”, in Wrigley N. (ed.), *Statistical Applications in the Spatial Sciences,* London, Pion,127-144.

Overman, H (2004), “Can we learn anything from economic geography proper?”, *Journal of Economic Geography*, 4 (5), 501-516

Rosenthal, S.S and W.C Strange (2008), “The attenuation of human capital spillovers,” *Journal of Urban Economics*, 64, 373−389.

Storper, M and A.J Venables (2004), “Buzz: face-to-face contact and the urban economy”, *Journal of Economic Geography*, 4, 351-370

Tobler WR (1970), “A computer movie simulating urban growth in the Detroit region”, *Economic Geography*, 46, 234–240

Tveteras, R and G.E Battese (2006), "Agglomeration Externalities, Productivity and Technical Inefficiency", *Journal of Regional Science*, 46(4), 605-625

van Soest D, S. Gerking and F.G van Oort (2006), “Spatial impacts of agglomeration externalities”, *Journal of Regional Science*, 46, 881-899

Wrigley, N (1995), “Revisiting the modifiable areal unit problem and the ecological fallacy”, in Cliff, AD, PR. Gould, AG Hoare,and NJ Thrift (eds), *Diffusing Geography*, Blackwell: Oxford, UK.

Yankow, J. J. (2006), “Why do cities pay more? – an empirical examination of some competing theories of the urban wage premium”, *Journal of Urban Economics*, 60(2), 139-161

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