A Treatise on the Geographical Scale of Agglomeration Externalities and the Modifiable Areal Unit Problem

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ERIM REPORT SERIES *RESEARCH IN MANAGEMENT*	
ERIM Report Series reference number	ERS-2008-076-ORG
Publication	November 2008
Number of pages	40
Persistent paper URL	http://hdl.handle.net/1765/13834
Email address corresponding author	mburger@few.eur.nl
Address	Erasmus Research Institute of Management (ERIM) RSM Erasmus University / Erasmus School of Economics Erasmus Universiteit Rotterdam P.O.Box 1738 3000 DR Rotterdam, The Netherlands Phone: + 31 10 408 1182 Fax: + 31 10 408 9640 Email: info@erim.eur.nl Internet: www.erim.eur.nl

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ABSTRACT AND KEYWORDS	
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Free Keywords	agglomeration externalities, employment growth, spatial econometrics, MAUP
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Classifications	The electronic versions of the papers in the ERIM report Series contain bibliographic metadata by the following classification systems: Library of Congress Classification, (LCC) LCC Webpage Journal of Economic Literature, (JEL), JEL Webpage ACM Computing Classification System CCS Webpage Inspec Classification scheme (ICS), ICS Webpage

A Treatise on the Geographical Scale of Agglomeration Externalities and the Modifiable Areal Unit Problem

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Abstract

The modifiable areal unit problem (MAUP) refers to the sensitivity of statistical research results to the initial spatial nomenclature used. Despite a substantial literature in the related field of geography on the potential influence of the MAUP, the urban economic modeling tradition has not paid much attention to this issue. In this article, we test to what extent the MAUP moderates the effect of agglomeration externalities on areal sectoral employment growth by varying the initial geographical scale of analysis. Using spatial cross-regressive modeling in which we account for spatial spillover effects of agglomeration externalities, we find different effects of agglomeration forces across geographical scales. As the MAUP is a theoretical as well as a methodological problem, research should not only work with proper statistical specifications of spatial agglomeration models incorporating different geographical scales, but also relate this more explicitly to hypotheses concerning the geographical scale at which agglomeration externalities operate.

Keywords: agglomeration externalities, employment growth, spatial econometrics, MAUP

JEL-classification codes: C21, O18, R11, R12

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1. Introduction

Since the early 1990s, economists have shown an increasing interest in the question of whether spatial circumstances give rise to agglomeration externalities that endogenously induce localized economic growth (see e.g., Glaeser et al. 1992; Henderson et al. 1995; Ciccone and Hall 1996; Combes 2000; Rosenthal and Strange 2003). This development can mainly be ascribed to the failure of mainstream economics to give appropriate explanations for the variation in the wealth and poverty of cities and regions (Piore and Sabel, 1984). Inspired by the success of Silicon Valley, Cambridge (UK) and The Third Italy, compared to the decline of other regions in the West (in particular, the old industrial areas), questions have been raised about why industries or firms choose to locate in a particular area and which kind of concentration of economic activities is needed to foster economic growth. As this literature tends to combine the traditional urban economics and regional science literature with new growth theory (Lucas 1988), Glaeser (2000) casts this strand of research as the 'New Economics of Urban and Regional Growth'.

This 'rediscovery' of space in economics has resulted in a large volume of empirical literature that has investigated the relationship between agglomeration benefits and local economic growth (Rosenthal and Strange 2004). A relevant criticism of the empirical literature on agglomeration might be that it pays little attention to the spatial configuration of cities and regions and the geographical scale of agglomeration benefits. Although every treatise on the benefits of agglomeration is based on the idea that 'space matters', paradoxically, this same 'space' often appears to be poorly defined in empirical models of agglomeration and economic growth (Rosenthal and Strange 2003; Overman 2004; Van Oort 2004).

Although a growing body of research examines the spatial extent of agglomeration externalities by means of spatial econometric techniques, little is known about the scale sensitivity of research results for variations in the initial spatial unit of analysis. Despite repeated warnings about the potential influences of spatial composition and aggregation effects in the related geographical literature (see Kephart 1988; Cressie 1993; Wrigley 1995), better known as the modifiable areal unit problem (MAUP) (Openshaw and Taylor 1979), the economic modeling tradition on agglomeration externalities has not paid much attention to this issue.

This paper shows how spatial aggregation and the choice of the initial spatial unit of analysis can affect the parameter estimates in empirical research on agglomeration. Using employment data on three different geographical scales (municipality, district and region) in the Netherlands on which agglomeration externalities can work simultaneously, we examine the effects of sectoral specialization, urbanization and sectoral variety on sectoral employment growth (1996-2004) for the manufacturing and market services sectors. Varying the initial spatial unit of analysis, we test to what extent research results are robust across geographical scales. We control for explanatory variables other than those of agglomeration economies to isolate the spatial measurement's impact from inconclusiveness from omitted variables. Using spatial cross-regressive models (Anselin 1988; Florax and Folmer 1992; Fingleton and López-Bazo 2006) to account for spatial spillover effects, we find for most sectors that the choice of the initial spatial unit of analysis (municipality, district, or region) moderates the effect of agglomeration externalities on local employment growth. As the MAUP is both a theoretical and methodological problem, future empirical research should work on a proper statistical specification of spatial agglomeration models that incorporate different geographical scales and should more explicitly focus on hypotheses concerning the geographical scale at which agglomeration externalities operate.

2. Agglomeration externalities and spatial bewilderment

2.1. *A history and taxonomy of agglomeration externalities*

Despite the recent resurgence of interest in agglomeration and economic growth, this empirical research draws on a long tradition initiated by Alfred Marshall's theory of agglomeration developed at the end of the 19th century. In his seminal work, *Principles of Economics* (Book IV, Chapter X), Marshall (1890) mentions a number of cost-saving benefits or productivity gains external to a firm from which a firm can benefit through co-location. Marshall considered these *agglomeration externalities* to be uncontrollable and unregulatable for a single firm and, above all, to be immobile or spatially constrained. More specifically, Marshall pointed to the availability of a skilled and specialized labor force (labor market pooling), the presence of intermediate goods (input sharing), and the possibility to swiftly exchange product, technological, and organizational innovations (information and knowledge spillovers). Although Marshall only focused on single-industry areas and sector-specific externalities, the framework of agglomeration externalities was later expanded to recognize external economies accessible to all companies in a geographical concentration irrespective of the sector concerned (see e.g., Ohlin 1933; Hoover 1948; Isard 1956). The distinction between sector-specific localization economies and more universal urbanization economies would become generally acknowledged (O'Sullivan 2003), causing the research focus in the agglomeration literature to shift from the positive effects of geographical concentration of a specific industry to how a single firm is influenced by co-location and which spatial conditions cause greater than proportional growth in productivity and economic activity (Karlsson et al. 2006).

In the recent agglomeration literature, it is common to distinguish between *three sources of agglomeration externalities* (Van Oort 2004)[3]:

[1] External economies available to all local firms within the same sector and stemming from sectoral density: *localization externalities*.

[2] External economies available to all local firms irrespective of sector and stemming from urban size and density: *urbanization externalities*.

[3] External economies available to all local firms irrespective of sector and stemming from sectoral variety in cities: *Jacobs' externalities*.

Over the years, a substantial amount of empirical literature has focused on the question of which of these agglomeration externalities best promotes economic growth. However, this literature has failed to offer a consistent answer to this question (Glaeser 2000; Rosenthal and Strange 2004; De Groot et al. 2009). Evaluating studies that have used a comparative framework of agglomeration externalities, Rosenthal and Strange (2004) report mixed evidence on the type of externality that matters most for economic growth. For the United States, Glaeser et al. (1992) found evidence supporting the notion that diversity fosters employment growth, while Ó hUalluchain and Satterthwaite (1992) claim that local specialization and not regional diversity is most important for urban employment growth. Henderson et al. (1995) conclude that for high-technology industries, both specialization and diversity are conducive to growth. Rosenthal and Strange (2003) find positive effects of localization, urbanization and Jacobs' externalities, but also observe that, in particular, localization economies attenuate quickly with distance. Although U.S. studies constitute only

[3] A more detailed explanation on the micro-foundations of these externalities can be found in Rosenthal and Strange (2004) and Van Oort (2004).

a small proportion of all research on agglomeration and economic growth conducted worldwide, these studies can be considered examples of the existent inconclusive findings in the empirical literature (Glaeser 2000).[4] This apparent lack of robustness and consistency implies that localization, urbanization and Jacobs' externalities can exist concurrently, and that one type of agglomeration externality does not necessary lead to more economic growth than the other.

One of the main reasons why controversial research results may be found is the lack of a theoretical rationale about effective channels of agglomeration externalities (Martin 1999), as well as a consistent spatial research design allowing for the simultaneous modeling of multiple geographical scales (Van Oort 2004).[5] By tradition, most empirical studies that have investigated the relationship between agglomeration externalities and economic growth focus on the regional level of analysis (e.g., Metropolitan Statistical Areas in the United States and NUTS-2 / NUTS-3 areas in Europe). This generally applied approach yields two related problems: the treatment of the spatial extent of agglomeration externalities (spatial dependence) and the treatment of the geographical scale of agglomeration externalities (variations in the initial spatial unit of analysis). Whereas the former issue has been recognized and to some extent has been dealt with in the recent empirical literature on agglomeration (see e.g., Rosenthal and Strange 2003; Henderson 2003), research on the degree to which empirical estimates are sensitive to variations in the initial spatial unit of analysis is still insufficiently clear in this field of study (McCann and Shefer 2006).

2.2. Spatial dependence and the spatial extent of agglomeration externalities

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[4] See Rosenthal and Strange (2004) and De Groot et al. (2009) for a more extensive overview of this literature

[5] Other reasons include differences in methodology (model specification and definition of dependent and independent variables) across studies and the presumed context-specificity (with respect to sector, time and location) of agglomeration externalities (See also Neffke 2008; De Groot et al. 2009).

In many urban economic models (e.g., Glaeser et al. 1992; Henderson et al. 1995), agglomeration externalities are defined as spatially fixed at the geographical scale at which they are studied. This assumes that economic activities outside a certain territory do not have any effect on the economic activities within that territory, thereby treating each area as a club (Rosenthal and Strange 2003). Agglomerations are not spatial entities that operate on their own, though; certainly in the present day economy, most regions interact at least to some extent (Fingleton 2003). The growing awareness in the theoretical geographical literature on spatially expansive agglomerations is reflected in the introduction of new terms like 'economic suburbanization' and 'borrowed size' (cf. Phelps et al. 2001)

Recently, some studies have addressed this issue empirically by studying how far agglomeration externalities reach. Viladecans-Marshal (2004) finds that for some manufacturing sectors, not only agglomeration economies in a given city but also agglomeration economies in its neighboring cities influence the location of manufacturing activities. Analyzing local employment growth in The Netherlands using a spatial Durbin model, Van Oort (2007) finds significant effects of both local and regional agglomeration externalities on local employment growth However, compared to the local agglomeration effects, the absolute effects of the regional externalities are rather limited. Rosenthal and Strange (2003) measure the distance effects of own sector employment on firm entry using rings of different sizes around an establishment's zip code. They find that the impact of own sector employment on new firm employment quickly attenuates with distance, and beyond 10 to 15 miles, there is no effect of agglomeration externalities on the level of employment development for newly arrived firms. Henderson (2003) similarly considers the productivity effect of employment density in a plant's own county versus neighboring counties. He finds that productivity is influenced by employment in a plant's own county, but not by employment in a plant's neighboring counties. In line with the previous studies, this is a strong indication that the geographic scope of agglomeration economies is rather limited.

2.3. *The MAUP and the geographical scale of agglomeration externalities*

The Modifiable Areal Unit Problem (MAUP) refers to the fact that statistical results are sensitive to the spatial nomenclature used in the analysis. Whereas the problem of the spatial extent of agglomeration externalities is mainly related to spatial dependency *between* areal units, the MAUP is primarily a problem related to the fact that it is impossible to test for spatial heterogeneity *within* areal units (Van Oort 2004). The MAUP concerns both the problem of the aggregation of smaller spatial units into larger ones (scaling bias) and the problem of alternative allocations of zonal boundaries (gerrymandering) (Openshaw and Taylor 1979). No general solution has been found thus far to solve the modifiable areal unit problem. In fact, it is known as the most stubborn problem in geographical analysis (cf. Wrigley 1995).

Early research by Gehlke and Biehl (1934), Robinson (1950) and Yule and Kendall (1950) indicated that correlation coefficients can differ by the number and size of the spatial units under observation. More recently, Openshaw and Taylor (1979), Arbia (1989), Fotheringham and Wong (1991), and Amrhein (1995) have shown that outcomes of univariate statistics and regression analyses vary over spatial aggregations of data by changes in zonal boundaries (see Figure 1). The use of aggregated data may conceal the between-lower unit variations that are not observable at the higher aggregate level (Gotway and Young 2002). For this reason, it can be argued that 'spatial observations at one level of analysis do not necessarily provide useful information about lower levels of analysis, especially when spatial heterogeneity is present' (Anselin, 1999). Moreover, zonation at a given spatial scale can be arbitrary, although results in spatial analysis should *a priori* never depend on the spatial delineation used (Tobler 1990) and researchers should always take into account that localities are not simply areas one draws a line around (Massey 1991). At a given spatial scale, numerous zoning schemes are possible, and the outcomes of a given study may be just ‘one manifestation from a range of possible outcomes’ (Páez and Scott 2004).

INSERT FIGURE 1 ABOUT HERE

However, the MAUP is not only a methodological problem, but also a theoretical problem. By tradition, most empirical studies that have investigated the relationship between agglomeration externalities and economic growth take the region (e.g., Metropolitan Statistical Areas in the United States or NUTS-2 / NUTS-3 areas in Europe) as their unit of analysis. This choice is actually highly arbitrary and foremost a result of data limitations and confidentiality restrictions. Agglomeration externalities may well operate on smaller spatial scales, such as municipalities, boroughs, or even neighborhoods (Van Soest et al. 2006), or may well reach beyond the geographical borders of a functional region (Anselin et al. 2000). As indicated by Martin (1999), exactly the same statistical model can be applied to different geographical scales, while the choice of a geographical scale should ideally be based on the phenomenon that is studied and the questions that are being posed about it (Marceau 1999; Fischer and Varga 2003).

However, it is doubtful whether focusing only on one geographical scale is desirable at all, as this neglects the possible availability of agglomeration externalities at other scales (Olsen 2004). In Hoover’s (1948) and Isard’s (1956) distinction between localization and urbanization externalities, the spatial scale on which these externalities operate was a guiding principle (McCann 1995). Whereas urbanization externalities were thought to operate at the metropolitan level, localization externalities were associated with a more local action radius.

Hence, scale effects may also indicate the different workings of processes at different geographical scales. In addition, many processes do not scale linearly, which can also create analytical problems. Openshaw (1996) notes that “the MAUP will disappear once geographers know what the areal objects they wish to study are."

2.4. Analyzing the seriousness of the MAUP

Although the MAUP has brought about a considerable literature in geography, little attention is paid to the MAUP in empirical research on economic agglomeration (McCann and Shefer 2006). Most pessimistically, Fotheringham and Wong (1991) not only report that the shape and size of areal units can influence regression results, but also that the effects of the MAUP are rather unpredictable, while Dewhurst and McCann (2007) show that the relation between specialization and urban hierarchy is dependent on the initial scale of analysis. Examining the relationship between ethnic grouping and unemployment rates in England, Flowerdew et al. (2001) find that regression coefficients vary widely with the geographical scale at which the phenomenon is analyzed. Likewise, Briant et al. (2007) obtain for different economic geographical estimations (agglomeration model, spatial interaction model) that spatial aggregation influences results of regression analyses, although the shapes of the areas seem to matter less. Using computer simulations, Amrhein (1995) observes that regression parameter estimates show scale effects, standard deviations of regression parameters exhibit zoning effects, and correlation coefficients display both scale and zoning effects. Moreover, zoning effects are pronounced if the variance in the underlying population is high.

We focus on the current discussion of the geographical scale of agglomeration externalities and test to what extent the MAUP jeopardizes the effect of agglomeration externalities on economic growth in the Netherlands. We employ a sensitivity analysis by analyzing regression models at various geographical scales, holding sectoral composition, time period, and aggregate geographical area constant and controlling for variables other than those of agglomeration externalities (localization, variety, urbanization), as well as the spatial extent of agglomeration externalities. In our empirical test, we distinguish agglomeration effects that are (1) scale-independent, (2) expectedly scale-dependent and (3) unexpectedly scale-dependent. Whereas expected scale-dependency of agglomeration externalities would support the hypothesis that the various agglomeration externalities work differently at different geographical scales (McCann 1995), unexpected scale-dependency would point at a scale effect that is merely caused by aggregation bias. In this fashion, we provide an exploratory analysis of whether variations in research results across geographical scales – if existent – can be attributed to differences in the strength of agglomeration externalities across geographical scales or to differences in the spatial delineation and model specification used.

3. Spatial econometric models for sectoral employment dynamics

3.1. Data

We use a spatially detailed employment register (LISA – *National Information System of Employment*), which covers all establishments in the Netherlands between 1996 and 2004, to construct our dependent variable and indicators of the various types of agglomeration externalities, which are in line with the current literature. To analyze the scale-sensitivity of agglomeration effects, the dataset was aggregated to the level of municipalities (*local level*, N=483, average surface area 70 km^2), economic geographic areas (*district level*, N=129, average surface area 264 km^2) and labor market regions (*regional level*, N=40 (NUTS-3), average surface area 850 km^2).[6] Figures 2A-2C show maps of the different territorial delineations used. To compare, the average size of the ZIP code areas analyzed by Rosenthal and Strange (2003) is similar to the size of the labor market regions used in our analysis,

[6] Aggregations were based on the 2004 spatial classifications of Statistics Netherlands.

while the French employment areas analyzed by Combes (2000) have an average surface area of about 1600 km^2. In terms of the MAUP, in our research the difference between the local level of analysis and the district and regional levels is clearly an example of a scaling problem, whereas the difference between the district and regional levels has both a scaling and zoning dimension.

We aggregated the data into two-digit sectors because we are interested in estimating separate sectoral spatial models. As agglomeration theory underlies a market-based model (Ciccone 2002) and agglomeration externalities are most profound in sectors that lack exogenous endowments (Brülhart and Mathys 2008), we focus on agglomeration externalities and employment growth in the manufacturing and business service sectors. More specifically, we concentrate on five broad sectors: capital-intensive manufacturing, labor-intensive manufacturing, knowledge-intensive manufacturing, financial services, and producer services.[7]

INSERT FIGURES 2A-2C ABOUT HERE

3.2. *Variables*

We define our dependent variable, *SECTORAL EMPLOYMENT GROWTH (1996-2004)*, as the mean-corrected increase in the number of employees per square kilometer for a given sector in the spatial unit of observation. As indicated above, these spatial units can be at the local level (municipalities), the district level (economic geographic areas) or the regional level (functional regions). Although employment growth is often used as a dependent variable in the agglomeration literature in the absence of regional productivity data,

[7] An overview of the two-digit sectors included in the respective categories is provided in Appendix I. A more detailed description of these categories and considerations can be found in Van Oort (2004).

employment growth is only a proxy for productivity growth stemming from agglomeration externalities. Combes et al. (2004) note in this respect that labor productivity growth only leads to an increase in employment when higher labor productivity results in such a large price decrease that demand is boosted beyond production capacity. Yet, as the main goal of our paper is to show to what extent results of empirical research on agglomeration are sensitive to variations in the initial spatial unit of analysis, further discussion of this issue is beyond the scope of this paper.

LOCALIZATION EXTERNALITIES, or agglomeration externalities stemming from sectoral concentration, are measured by the number of employees in a given sector in the spatial unit of observation divided by the total national number of employees in that sector (in the base year, 1996). We choose an absolute measure of concentration (global specialization) instead of a relative measure of specialization (like in commonly used location quotients), as localization externalities are commonly associated with the clustering of a certain sector in a particular area. *URBANIZATION EXTERNALITIES*, or agglomeration externalities stemming from market size, are measured by means of the population density (1996), i.e., the number of inhabitants per square kilometer. *JACOBS' EXTERNALITIES*, or agglomeration externalities stemming from diversity, are measured by a Gini-coefficient (1996)[8]. This indicator assesses how evenly employment in a particular area is spread across economic sectors. More specifically, the Gini-coefficient measures the absence of sectoral diversity in the spatial unit under observation:

$$GINI_g = \frac{1}{2n}\sum_{i=1}^{n}\sum_{j=1}^{n}| s_{i,g} - s_{j,g} | \quad (1)$$

[8] An often used alternative measure of diversity, which bears resemblance to the Gini Index, is the Hischman-Herfindahl Index (see Henderson et al. 1995).

in which $s_{i(j)}$ represent the area's *i(j)* shares of employment in sector *g*. This area-based Gini-coefficient has a value of zero if employment shares among industries are distributed identically to the total employment in the reference region (in our case the Netherlands). Lower values of the Gini-coefficient thus implicate higher degrees of sectoral diversity. For this reason, *JACOBS' EXTERNALITIES* are in the reporting tables referred to as *LACK OF DIVERSITY*.

Besides indicators for the various agglomeration externalities, control variables measuring establishment size, areal wages and land use are introduced. *ESTABLISHMENT SIZE* is measured as the natural log of the number of establishments per worker in a particular industry in an area. Following Combes (2000), fast growing locations may be a result of the concentration of (a few) large firms within that area that exploit their internal economies of scale and not of the external economies of scale that are present at that location. Establishment size thus controls for internal economies of scale. *WAGES* is measured as the natural log of the initial locational (average) wage rate in 1996. With respect to land use, we introduce two dummy variables. *WORKAREA* is measured as the natural log of the ratio of population to the number of establishments in an area and indicates whether the areal function is predominantly work-oriented as opposed to residential. *INDUSTRIAL SITES* indicates the locational difference from national average growth of surface of industrial sites in 1996-2004 relative to the stock of industrial sites surface in 1996.

Although over time a consensus has emerged in urban and regional economics that agglomeration externalities enhance local and regional productivity and employment growth, the causality of this relationship is far from clear. On the one hand, a spatial concentration of economic activities is often associated with numerous benefits, such as labor market pooling, accessibility to intermediate goods and knowledge, and proximity to consumers, that would augment productivity and employment. On the other hand, firms and skilled workers may also be attracted to urban areas because of the presence of higher productivity or higher urban wages (Rosenthal and Strange 2004). In line with previous research on the relationship between agglomeration externalities and economic growth (e.g., Glaeser et al. 1992; Henderson et al. 1995), the independent variables are defined using lagged levels of past conditions (8 years) of the areas under observation in an attempt to control for this endogeneity.

3.3 Model and research methodology

In earlier empirical work on agglomeration, area-based sectoral employment growth is specified as a function of local specialization in that industry, the local market size and local industrial diversity (see e.g., Glaeser et al. 1992; Henderson et al. 1995; Combes 2000). More formally,

$$Y = C + X\beta + Z\theta + \varepsilon, \qquad (2)$$

where *Y* denotes a *N*xi vector of the spatially measured dependent variable sectoral concentration growth in terms of employment, *C* is the intercept, *X* is a matrix of observations on the independent or explanatory variables related to the different agglomeration externalities, *Z* is a matrix of observations of control variables (establishment size, wages, land use), β and θ are coefficient vectors, and ε is an error term.

One way to account for the roles of proximity and territorial spillovers would be to reformulate the traditional models as spatial cross-regressive models in which areal sectoral employment growth not only depends on the different agglomeration externalities present in the area being studied but also on the different agglomeration externalities present in other areas (Anselin 1988; Florax and Folmer 1992; Fingleton and López-Bazo 2006). The spatial cross-regressive model includes the spatial lag of one or more independent variables on the right hand side of the equation. More formally,

$$Y = C + X\beta + \lambda WX\gamma + Z\theta + \varepsilon, \qquad (3)$$

in which λ represents the coefficients of the spatial lag and $WX\gamma$ signifies the spatially lagged independent variables for weight matrix W, which incorporates the distances between locations. In our research, the elements of the W matrix are the row-standardized reciprocals of distance in kilometers between pairs of spatial units.[9] The spatial spillover effects are thus – in accordance with the existing empirical literature - modeled to decay as distances increase and barriers to interaction between areas intensify. The spatially lagged agglomeration variables control for spatial dependence present in the data.

The spatial cross-regressive models are initially estimated under OLS. We tested for the significance of first (W_1), second (W_2) and third (W_3) order inverse distance weights. Trial and error of the specifications revealed that the first order distance weights capture the spatial correlation of sectoral employment growth at the local level best, while at the district and regional levels, second distance weights appeared to be more appropriate. Heteroskedasticity is accounted for by using the White estimator to obtain robust standard errors.

After estimation of the final models, we examine whether the effects of the separate agglomeration externalities on sectoral employment growth are (1) scale-independent, (2) expectedly scale-dependent, or (3) unexpectedly scale-dependent. Research results are judged to be scale independent if the effect of a particular type of agglomeration externality on

[9] It should however be noted that several alternative specifications of the *W* matrix are possible (like contiguity, functional distance) and it is not possible to a-priori say which one is "best" (Griffith & Lagona 1998)

employment growth in a given sector is the same across all three geographical scales, and scale-dependent if these effects differ across geographical scales. We consider the results to be unexpected in terms of scale-dependency if the observed effect of a particular type of agglomeration externality on sectoral employment growth contradicts the predicted effect. Predictions are based on the observed agglomeration effects at other geographical scales as well as on the geographical scope of agglomeration externalities observed at other geographical scales. For example, if (1) local localization externalities have a positive effect on local employment growth and (2) local localization externalities of neighboring municipalities have a positive effect on local employment growth, one would also expect that (3) district level localization externalities have a positive effect on a district's employment growth, as this is an aggregate of (1) and (2). Using this research strategy, we provide an exploratory analysis of whether variations in research results – if they exist – can be attributed to differences in the strength of agglomeration externalities across geographical scales or to aggregation bias.

4. Empirical findings

4.1 Sectoral differences and the geographical scope of agglomeration externalities

Table 1 provides an overview of the spatial models for all six broad sectors at the three different geographical scales, while detailed research results of the estimated models can be found in Appendix II. These results show that most spatial models for sectoral employment growth are complex in form.[10] It can be inferred from these results that there are obvious differences across sectors. Localization externalities are more positively related to employment growth in services than to employment growth in industrial sectors. This is in

[10] Despite the inclusion of spatially lagged independent variables, spurious spatial dependence (spatial lag dependence (LM (ρ)) or spatial error dependence (LM (λ)) remains. Additional specifications including spatially lagged dependent variables and fixed effect terms did not improve the estimation results. Spatial regime estimation was not carried out, as this is beyond the scope of this paper.

line with earlier findings by Van Oort (2004), but contradicts the conclusions of Henderson et al. (1995). Similar to Moomaw (1988), we find that urbanization externalities are more positively associated with employment growth in services than with employment growth in manufacturing. Contrary to Glaeser et al. (1992), we do not find an effect of Jacobs' externalities on sectoral employment growth for most economic sectors.

Examining the effect of agglomeration externalities on sectoral employment growth at the *local level*, we find for most sectors that employment growth is not only dependent on localization and urbanization externalities of the own municipality but also on localization and urbanization circumstances in neighboring municipalities. The degree of spatial dependence appears to be minimal for capital-intensive manufacturing and financial services, as hardly any significant effect of spatially lagged agglomeration externalities for these sectors comes to the fore.

From the first two columns of Table 1 it can also be concluded that the local and spatially lagged versions of agglomeration externalities sometimes do not yield similar effects and are even sometimes diametrically opposed in their relation to local employment growth patterns (see also Van Oort 2007). For instance, for producer services, the local indicator for urbanization externalities is significant and positively related to municipal employment growth in producer services (β = 1.235, s_e = 0.128, $p<0.01$), while the spatially lagged indicator urbanization externalities is negatively related to municipal employment growth (γ = -1.416, s_e = 0.781, $p<0.10$). Likewise, for knowledge-intensive manufacturing, the degree of urbanization shows an inverse relation to sectoral employment growth in knowledge-intensive manufacturing (β = -0.718, s_e = 0.092, $p<0.01$) compared to its spatially lagged version (γ = 0.805, s_e = 0.833, $p<0.10$). These findings indicate that the effects of agglomeration externalities may differ across geographical scales simultaneously.

Comparing the local level with the *district* and *regional* level estimations, it appears that the spatial lag specifications at the municipal level are, as expected, more often significant than at the higher geographical scales. Whereas the first order (inverse) distance weights capture the spatial correlation of the dependent variable at the municipal level, for the district and regional levels, the second order distance weights fit the data best. This means that the spatial correlation of the variables decreases relatively more strongly with distance at the district and regional levels than at the municipal level. Moreover, the effect of the lagged agglomeration externalities variables on district and regional employment growth is only marginal. This emphasizes that agglomeration externalities typically do not reach farther than the district or regional level (compare Frenken et al. 2007).

4.2. *The scale-dependency of agglomeration externalities and the MAUP*

The same empirical analysis also reveals that sectoral employment growth in municipalities is often differently related to externality indicators than sectoral employment growth in districts and regions. For example, for financial services, local urbanization externalities are positively related to local employment growth in that sector (β = 0.381, s_e = .097, p<0.01), while there is neither an effect of district-level urbanization externalities on district-level employment growth (β = 0.207, s_e = .197, p = 0.289) nor an effect of regional urbanization externalities on regional-level employment growth (β = 0.338, s_e = 0.598, p=0.572). Similarly, we find for labor-intensive manufacturing a negative effect of urbanization externalities on municipal (β = -0.590, s_e = .098, p<0.01) and district employment growth (β = -0.879, s_e = .271, p<0.01), but no effect of regional urbanization externalities on regional employment growth (β = -0.290, s_e = .572, p=0.611). Similar results are found for the other sectors analyzed. Only the effect of Jacobs' externalities on employment growth in the different sectors is relatively independent of scale. At first glance, this appears to support the hypothesis that the function of agglomeration externalities may differ across geographical scales.

Overall, about 60% of the observed agglomeration effects appear to be (relatively) dependent on the geographical scale at which they are studied. At the same time, no clear pattern of the geographical scale of agglomeration externalities can be observed. Although the empirical findings might be attributed to the scale-dependency of agglomeration externalities, this is (unfortunately) only part of the story. The models also appear to be inconsistent and non-robust in nature, attributable to aggregation bias (Openshaw and Taylor 1979). In Table 1, the scale-dependent agglomeration effects that are consistent and robust in nature are shaded light grey, while the scale-dependent effects that are inconsistent and non-robust in nature are shaded dark grey.[11]

Focusing on results that are unexpected and cannot be explained by agglomeration externalities at different geographical scales, we find for producer services that local localization externalities are positively associated with municipal employment growth in this sector (β = 0.274, s_e = .132, $p<0.05$). Moreover, the results also predict that when a municipality's neighbors have a relatively dense concentration of producer services firms, municipal employment growth in this sector would be fostered (λ = 5.747, s_e = 1.90, $p<0.01$). However, estimates of the model at the district level suggest that district-level localization externalities are negatively associated with district-level employment growth in producer services (β = -0.286, s_e = .259, p=0.269). On a similar note, we find for financial services positive effects of both own and neighboring district's localization externalities on its employment growth (β = 0.359, s_e = .174, $p<0.05$; λ = 0.800, s_e = .404, $p<0.05$). However, the association between regional localization externalities and regional employment growth in

[11] Agglomeration externalities effects that turn out to be (relatively) scale-independent are marked white in Table 3.

financial services turns out to be negative (β = -0.522, s_e = .471, p=0.064). Other results also cannot easily be related to differences in the availability of agglomeration externalities at different geographical scales. For example, for capital-intensive manufacturing we find a positive effect of urbanization externalities on employment growth at both the municipal (β = 0.308, s_e = .089, $p<0.01$) and regional levels (β = 0.899, s_e = .175, $p<0.01$). However, looking at the district level, which can be regarded as a geographical scale in between municipalities and regions, we unexpectedly find a negative effect of district-level urbanization externalities on district-level employment growth (β = -0.551, s_e = .175, $p<0.01$). Similar results are found in this respect for capital-intensive manufacturing (Jacobs' externalities) and knowledge-intensive manufacturing (localization externalities). Overall, over fifty percent of the scale-dependent effect turned out to be unexpected in nature.

Table 1. Summary of regression results by sector, agglomeration externality and spatial level (see Appendix III, Table III.1.-III.5.)						
	Municipality		**District**		**Region**	
Localization Externalities	*LOC*	*W_LOC*	*LOC*	*W_LOC*	*LOC*	*W_LOC*
Capital-Intensive Manufacturing	−	0	+	0	0	0
Labor-Intensive Manufacturing	− − −	− − −	−	0	0	0
Knowledge-Intensive Manufacturing	− − −	0	0	0	− −	0
Financial Services	+	0	+ +	+ +	0	0
Producer Services	+ +	+ + +	0	0	+ +	−
Urbanization Externalities	*URB*	*W_URB*	*URB*	*W_URB*	*URB*	*W_URB*
Capital-Intensive Manufacturing	+ + +	0	− − −	0	+ + +	+
Labor-Intensive Manufacturing	− − −	− − −	− − −	0	0	0
Knowledge-Intensive Manufacturing	− − −	+	− − −	+	0	−
Financial Services	+ + +	0	0	0	0	0
Producer Services	+ + +	−	+ + +	0	+ + +	+
Jacobs Externalities	*JAC*	*W_JAC*	*JAC*	*W_JAC*	*JAC*	*W_JAC*
Capital-Intensive Manufacturing	0	0	− − −	0	+ +	0
Labor-Intensive Manufacturing	0	0	0	0	0	0
Knowledge-Intensive Manufacturing	0	0	0	0	0	0
Financial Services	0	+ +	0	0	0	+
Producer Services	0	+	0	0	0	0

+ = positive and significant effect; − = negative and significant effect; 0 = no significant effect
The number of signs indicates the degree of significance (either at 1%, 5% or 10% level).
Colors: White= (relatively) scale-independent, Light Grey = (relatively) consistent scale-dependent, Dark Grey=inconsistent scale-dependent
NB: *JAC* and *W_JAC* refer to the inverse of the Lack of Diversity variable used in the analyses; a + indicates a positive and significant effect of diversity on sectoral area-based growth.

5. Discussion

Although every debate on the localized benefits of agglomeration economies starts out by stressing the importance of space, it is this same space that is often rather unsophisticatedly dealt with in the empirical literature on agglomeration. Although a growing body of literature examines the scope of agglomeration externalities, the initial spatial unit of analysis is often chosen ad hoc and often depends on data availability. Using spatial cross-regressive models, which enable modeling of territorial spillovers, we find that the effect of agglomeration externalities on area-based sectoral employment growth is also dependent on the initial spatial scale taken into consideration. Holding methodology and context constant, we find that over three spatial scales in the Netherlands (local, district and regional levels) the areal and spatially lagged versions of agglomeration externalities often have unexpected different effects on sectoral employment growth. Likewise, the effects of agglomeration externalities on sectoral employment growth vary by geographical scales. Although it can be inferred that agglomeration externalities most often do not reach further than (just beyond) the district or regional levels, the sources of sectoral employment growth in municipalities are often different from the sources of further identically defined growth at the district or regional levels. This supports the hypothesis that the impact of agglomeration externalities differs across geographical scales, and hence that the same rules do not always apply to all geographical scales (Overman 2004).

However, these models appear to be inconsistent and non-robust in nature, which might be ascribed to the modifiable areal unit problem (MAUP) (Openshaw and Taylor 1979). In other words, the outcomes of empirical research appear to be ambiguous in terms of aggregation bias. This may result not only in drawing incorrect conclusions about which kinds of agglomeration circumstances foster local and regional economic growth, but also in misinterpreting individual-based area inferences. It remains unclear whether variations in research results can be attributed to differences in the strength of agglomeration externalities across geographical scales or to differences in the spatial delineation and model specification used. Yet, one should also recognize that empirical research on agglomerations may also be sensitive to the time period, geographical area, and sector under consideration, to the definition of the agglomeration externalities and economic growth applied and to included or excluded controls in the models (De Groot et al., 2009). Hence, besides more explicit treatment of the theoretical question of at which geographical scale agglomeration externalities operate, future empirical research on agglomeration externalities should examine to what extent analyses of areal growth factors are influenced by these choices of the researcher.

Our results also suggest that it is critically important to take the micro-economic foundations of urban growth very seriously (Rosenthal and Strange 2004). Using continuous space modeling (Arbia 2001) or multilevel analysis (Jones 1991; Goldstein 2003), one might focus on the firm level more seriously by using individual firms, cohorts of individual firms or even entrepreneurs as the unit of analysis. Continuous space models (Arbia 2001), in which the firm in space is taken as the basic spatial unit, can alleviate the MAUP in the sense that the models are freed from zoning issues, while with multilevel modeling (Goldstein 2003), the scale-dependent effects of agglomeration externalities on firm growth are appropriately accommodated. After identification of a model at the micro-level, one is more accurately able to draw policy implications at the meso-level.

Acknowledgements

We thank an anonymous reviewer and participants in the Workshop on Agglomeration and Economic Growth in Kiel for useful suggestions and comments on earlier versions of this paper. All errors remain ours.

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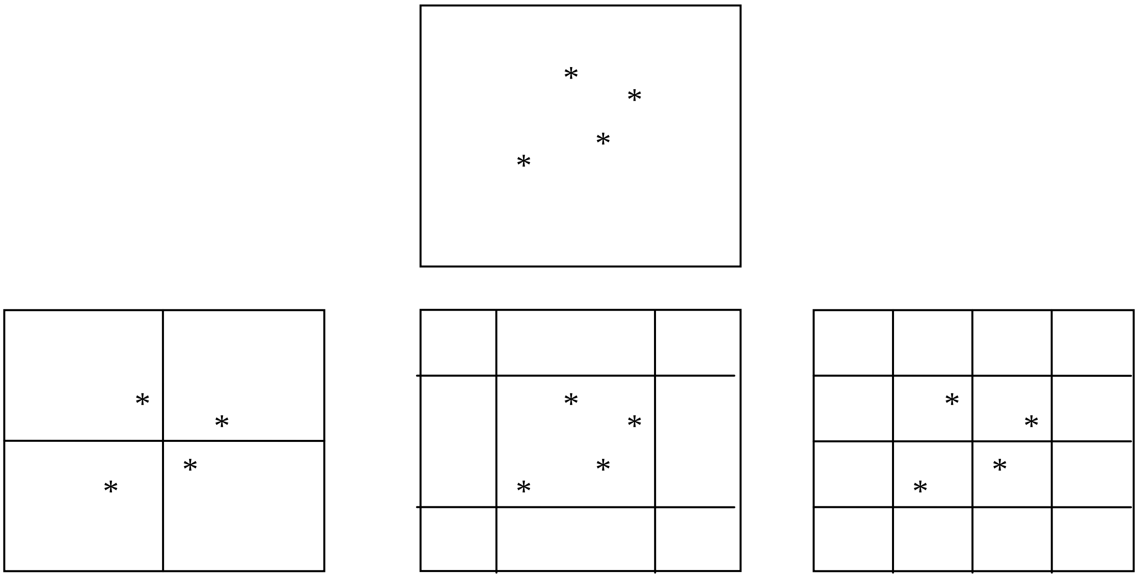
Figure 1: Modifiable Areal Unit Problem



(a) Minimum concentration (b) Maximum concentration (c) Intermediate concentration

Source: Arbia (2001); An asterisk represents a firm. Figures (a) and (b) illustrate the zoning problem, while figures (a) and (c) indicate the scale problem.

Figure 2A: Territorial Delineation of the Netherlands at the Local Level ('Gemeenten')

Figure 2B: Territorial Delineation of the Netherlands at the District Level ('EGG')

Figure 2B: Territorial Delineation of the Netherlands at the Regional Level ('COROP')

Appendix I

Categorization of Two-Digit Sectors Used in Analysis of Concentration Growth

Capital-Intensive Manufacturing	Food & Beverage Industry Tobacco Industry Paper Industry Synthetic & Rubber Industry Glass & Ceramic Industry
Labor-Intensive Manufacturing	Textile Industry Apparel Industry Leather Goods Industry Timber Industry Metal Products Industry Furniture Industry Recycling Industry
Knowledge-Intensive Manufacturing & Process Industries	Oil-Processing Industry Chemical Industry Primary Metal Industry Machinery Industry Computer Industry Electronics Industry Audio & Telecommunications Industry Cars & Other Transport Industry
Financial Services	Financial Institutions (Banks) Insurance & Pension Funds Insurance & Financial Services
Producer Services	Publishing & Reproduction Real Estate Intermediates Movable Estate Intermediates Computer Services Research & Development Other Business Services

Appendix II : Regression Results by Sector

Table II.1 Spatial Cross-Regressive OLS Estimates for Concentration Growth (1996-2004) in Capital-Intensive Manufacturing			
Explanatory Variables	*Municipal Level (W_1)*	*District Level (W_2)*	*Regional Level (W_2)*
CONSTANT	-7.145 (4.72)	-6.024 (8.53)	-7.298 (15.9)
LOCALIZATION	-0.123 (.074)#	0.200 (.106)#	-0.047 (.146)
W_LOCALIZATION	0.972 (2.01)	-0.085 (.186)	-0.381 (.238)
URBANIZATION	0.308 (.089)**	-0.551 (.139)**	0.899 (.175)**
W_URBANIZATION	0.646 (.850)	0.060 (.224)	0.359 (.212)#
LACK OF DIVERSITY	0.159 (.304)	0.284 (.072)**	-0.607 (.307)*
W_LACK DIVERSITY	0.359 (3.93)	-0.055 (.167)	-0.080 (.228)
ESTABLISHMENT SIZE	-0.125 (.106)	-0.494 (.230)*	-0.399 (.242)#
WAGES	0.891 (.463)*	1.154 (.912)	-0.200 (1.62)
INDUSTRIAL SITES	0.005 (.158)	-0.121 (.379)	0.250 (.726)
WORKAREA	-0.106 (.202)	-0.938 (.365)**	0.326 (1.15)
Summary Statistics			
N	483	129	40
-2LL	-723.3	-155.6	-17.20
Akaike IC	1468	333.3	56.47
LM (ρ)	0.105	0.00	3.19
LM (λ)	0.117	0.07	3.47
Adjusted R^2	0.534	0.402	0.145

**p<0.01, *p<0.05, #p<0.10, robust standard errors between parentheses.

W_LOCALIZATION, *W_URBANIZATION* and *W_LACK OF DIVERSITY* represent the spatial lags of the different agglomeration variables.

LM (ρ) tests for the significance of the spatial dependence coefficient. LM (λ) tests for additional spatial residual correlation (critical value 3.85 at 5% level of significance) (tested under non-robust standard errors).

Table II.2 Spatial Cross-Regressive OLS Estimates for Concentration Growth (1996-2004) in Labor-Intensive Manufacturing			
Explanatory Variables	*Municipal Level (W_1)*	*District Level (W_2)*	*Regional Level (W_2)*
CONSTANT	3.038 (5.10)	-5.549 (15.2)	15.76 (40.4)
LOCALIZATION	-0.278 (.103)**	-0.326 (.187)#	-0.165 (.281)
W_LOCALIZATION	-1.872 (.707)**	-0.071 (.350)	-0.263 (.658)
URBANIZATION	-0.590 (.098)**	-0.879 (.271)**	-0.290 (.572)
W_URBANIZATION	-1.214 (.409)**	0.139 (.384)	0.286 (1.10)
LACK OF DIVERSITY	-0.432 (.263)	0.023 (.137)	0.039 (.672)
W_LACK DIVERSITY	-1.518 (.931)	0.025 (.454)	-0.508 (1.10)
ESTABLISHMENT SIZE	-0.436 (.176)*	-0.470 (.321)	-0.424 (.640)
WAGES	-0.048 (.509)	1.096 (1.59)	-1.471 (5.06)
INDUSTRIAL SITES	0.304 (.204)	-0.362 (.543)	0.286 (.872)
WORKAREA	0.101 (.240)	-0.078 (.667)	-0.263 (.817)
Summary Statistics			
N	483	129	40
-2LL	-805.0	-210.1	-47.29
Akaike IC	1632	442.2	116.6
LM (ρ)	0.833	0.377	2.839
LM (λ)	1.300	0.271	3.896*
Adjusted R2	0.412	0.398	0.215

**p<0.01, *p<0.05, #p<0.10, robust standard errors between parentheses.

W_LOCALIZATION, *W_URBANIZATION* and *W_LACK OF DIVERSITY* represent the spatial lags of the different agglomeration variables.

LM (ρ) tests for the significance of the spatial dependence coefficient. LM (λ) tests for additional spatial residual correlation (critical value 3.85 at 5% level of significance) (tested under non-robust standard errors).

Table II.3 Spatial Cross-Regressive OLS Estimates for Concentration Growth (1996-2004) in Knowledge-Intensive Manufacturing			
Explanatory Variables	*Municipal Level (W_1)*	*District Level (W_2)*	*Regional Level (W_2)*
CONSTANT	-2.820 (5.51)	16.36 (14.2)	18.28 (30.8)
LOCALIZATION	-0.245 (.072)**	0.038 (.179)	-0.809 (.353)*
W_LOCALIZATION	-0.313 (.954)	-0.385 (.312)	0.161 (.462)
URBANIZATION	-0.718 (.092)**	-0.815 (.272)**	0.744 (.634)
W_URBANIZATION	0.805 (.433)#	0.535 (.291)#	-1.145 (.597)#
LACK OF DIVERSITY	-0.387 (.271)	-0.107 (.059)	-0.923 (.749)
W_LACK DIVERSITY	-0.181 (.869)	-0.154 (.394)	-0.748 (.559)
ESTABLISHMENT SIZE	-0.284 (.107)**	-0.534 (.280)	-0.869 (.507)#
WAGES	0.604 (.549)	-0.970 (1.48)	-2.479 (3.15)
INDUSTRIAL SITES	-0.049 (.207)	-0.039 (.870)	0.661 (2.24)
WORKAREA	-0.211 (.234)	-0.453 (.615)	0.258 (2.96)
Summary Statistics			
N	483	129	40
-2LL	-812.9	-214.4	-49.31
Akaike IC	1648	450.9	120.6
LM (ρ)	0.078	0.001	7.200**
LM (λ)	0.108	0.023	4.545*
Adjusted R^2	0.419	0.408	0.366

**p<0.01, *p<0.05, #p<0.10, robust standard errors between parentheses.

W_LOCALIZATION, *W_URBANIZATION* and *W_LACK OF DIVERSITY* represent the spatial lags of the different agglomeration variables.

LM (ρ) tests for the significance of the spatial dependence coefficient. LM (λ) tests for additional spatial residual correlation (critical value 3.85 at 5% level of significance) (tested under non-robust standard errors).

Table II.4 Spatial Cross-Regressive OLS Estimates for Concentration Growth (1996-2004) in Financial Services

Explanatory Variables	*Municipal Level (W_1)*	*District Level (W_2)*	*Regional Level (W_2)*
CONSTANT	-3.695 (5.43)	-18.35 (11.2)	21.53 (24.7)
LOCALIZATION	0.182 (.095)#	0.359 (.174)*	-0.522 (.471)
W_LOCALIZATION	-1.644 (1.18)	0.800 (.404)*	-1.352 (1.08)
URBANIZATION	0.381 (.097)**	0.207 (.197)	0.338 (.598)
W_URBANIZATION	-0.282 (.457)	-0.340 (.327)	0.241 (.555)
LACK OF DIVERSITY	-0.027 (.268)	-0.081 (.096)	-0.667 (.887)
W_LACK DIVERSITY	-2.575 (1.01)*	0.133 (.239)	-1.190 (.678)#
ESTABLISHMENT SIZE	-0.131 (.189)	0.541 (.232)#	0.106 (.470)
WAGES	0.294 (.539)	1.711 (1.14)	-2.839 (2.32)
INDUSTRIAL SITES	0.428 (.213)*	0.805 (.624)	0.130 (1.80)
WORKAREA	0.307 (.214)	-0.332 (.578)	3.279 (2.99)
Summary Statistics			
N	483	129	40
-2LL	-743.5	-190.3	-48.63
Akaike IC	1491	402.5	117.3
LM (ρ)	28.9**	1.784	7.584**
LM (λ)	21.6**	1.786	2.907
Adjusted R^2	0.191	0.361	0.092

**p<0.01, *p<0.05, #p<0.10, robust standard errors between parentheses.

W_LOCALIZATION, *W_URBANIZATION* and *W_LACK OF DIVERSITY* represent the spatial lags of the different agglomeration variables.

LM (ρ) tests for the significance of the spatial dependence coefficient. LM (λ) tests for additional spatial residual correlation (critical value 3.85 at 5% level of significance) (tested under non-robust standard errors).

Table II.5: Spatial Cross-Regressive OLS estimates for Concentration Growth (1996-2004) in Producer Services

Explanatory Variables	*Municipal Level (W_1)*	*District Level (W_2)*	*Regional Level (W_2)*
CONSTANT	-7.044 (7.55)	-39.03 (21.4)#	-2.522 (11.2)
LOCALIZATION	0.274 (.132)*	-0.286 (.259)	0.308 (.120)*
W_LOCALIZATION	5.747 (1.90)**	0.285 (.721)	-0.538 (.292)#
URBANIZATION	1.235 (.128)**	1.173 (.345)**	0.855 (.166)**
W_URBANIZATION	-1.416 (.781)#	0.696 (.657)	0.300 (.158)#
LACK OF DIVERSITY	0.359 (.362)	0.223 (.294)	0.295 (.258)
W_LACK DIVERSITY	3.087 (1.75)#	0.299 (.686)	-0.062 (.237)
ESTABLISHMENT SIZE	0.303 (.245)	1.087 (.578)#	0.049 (.189)
WAGES	0.049 (.645)	2.945 (2.17)	0.176 (1.09)#
INDUSTRIAL SITES	0.406 (.288)	1.729 (1.00)#	0.195 (.697)
WORKAREA	0.126 (.351)	0.548 (1.26)*	1.353 (.715)
Summary Statistics			
N	483	129	40
-2LL	-912.7	-246.7	-2.534
Akaike IC	1847	515.4	27.07
LM (ρ)	4.260*	0.203	0.778
LM (λ)	9.736**	0.283	0.534
Adjusted R^2	0.509	0.579	0.894

**p<0.01, *p<0.05, #p<0.10, robust standard errors between parentheses.

W_LOCALIZATION, *W_URBANIZATION* and *W_LACK OF DIVERSITY* represent the spatial lags of the different agglomeration variables.

LM (ρ) tests for the significance of the spatial dependence coefficient. LM (λ) tests for additional spatial residual correlation (critical value 3.85 at 5% level of significance) (tested under non-robust standard errors).

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