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# WHAT WHEN SPACE MATTERS LITTLE FOR FIRM PRODUCTIVITY?
## A multilevel analysis of localised knowledge externalities[1]

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**Abstract**

This paper contributes to the debate on localized knowledge externalities as potential source for firm productivity gains. We apply multilevel analysis to link firm productivity (and growth) to knowledge intensive spatial contexts in the Netherlands. If localized knowledge externalities are important, then firms are hypothesised to co-locate in order to capitalize on each other's knowledge stocks. We conceptualise the regional knowledge base by three dimensions: local 'research and development' intensity, local 'innovativeness', and the characterization of locations by a ‘knowledge workers’ dimension (based on ICT use, educational level, communicative and creative skills). Controlling for firm's heterogeneity, we find a relatively small spatial effect: regional characteristics contribute for only a few percents to firm productivity. The regional intensity of 'innovation' most significantly contributes to this effect. We do not find a contextual spatial effect for productivity growth. These results suggest that the territorial dimension of knowledge externalities should not be exaggerated.

**Keywords**

Firm productivity, knowledge economy, innovation, multilevel analysis, geographical context, knowledge externalities

## 1. Introduction

*Knowledge* is quintessential in fostering economic growth. That is the universal belief of policymakers around the world (Döring and Schnellenbach 2006). The knowledge economy is the central theme in Europe's strategy to become the most competitive and dynamic economy in the world (EU 2000). Due to the substantial theoretical foundation of the role of knowledge in modern endogenous growth theory and industrial organisation theory, the opinion is that 'knowledge' is an explicit and crucial factor for generating sustained economic growth in western economies (Audretsch *et al* 2006). Knowledge relevant to organizations can be obtained by experience, science or learning (Foray 2004). Not only firm internal, but also external knowledge sources are stressed in the literature: knowledge externalities form a key mechanism in a discussion on firm-external economies and economic growth (Koo 2005). A considerable literature suggests that knowledge diffusion between firms is spatially bounded, although the actual mechanisms of the transmittance of knowledge causing growth are unclear (Audretsch *et al* 2006). There is a growing literature on the spatial concentration of economic activities enhancing productivity of firms, arguing that knowledge externalities - learning effects from knowledge intensive external circumstances of firms - are one of the important causes (Rosenthal and Strange 2001). When these learning effects are unintentional, one speaks of spillovers. An important step in penetrating the black box of contextual space related to spillovers was made by Glaeser *et al*. (1992) and Feldman and Audretsch (1999), who demonstrate that economic growth is influenced by the way economic activity is spatially organized: by proximity to own industry firms, or by the nearness of a large variety of industries. The level of measurement is – mainly because of a lack of firm level data - commonly spatially defined. Although important as a decision-making agent, the firm has usually been neglected in the debate on spatial knowledge conditions (Maskell 2001, Taylor and Asheim 2001).

Empirically, agglomeration and spillovers have been investigated separately. Regional scientists and urban economists have focused on the relation between agglomeration and productivity: for example on productivity levels increasing with industry size (localization economies) or city size (urbanization economies), (Moomaw 1981). On the other hand, economists have probed technology spillovers (Grilliches 1979, Cohen and Levinthal 1989, Dosi 1988). Admittingly, the micro foundations on agglomeration economies and the role of proximity for firm performance are conceptually vague (Rosenthal and Strange 2006). Nonetheless, there is a empirical need for addressing the relation between individual firm performance and localised knowledge externalities simultaneously (Harrison *et al*. 1996). In this paper we try to fill this empirical gap and assess the impact of proximity on productivity level and growth of firms in different contexts in space. We place the firm (micro-level) central in this paper, contrary to most of the knowledge spillover studies that often aggregate to spatial units such as cities or industries located in cities (Van Oort 2004). Following Audretsch and Lehmann (2005) and Harrison *et al* (1996) we focus on the impact of external knowledge on firm productivity. Due to data limitations, productivity indicators are not commonly used in previous studies. Instead, prior research focused on knowledge spillovers captured by innovation and R&D (Audretsch and Lehman 2005) or employment growth (Glaeser *et al* 1992, Henderson *et al* 1995). We model individual firm characteristics and performances simultaneously with its (higher-level) economic geographical context. For this we introduce the for (spatial) economics relatively new technique of multilevel analysis. This modelling technique is more common in social sciences, concerning the relationship between and individual and society (its context). The central question is whether knowledge intensive locations attribute to firm's productivity level and growth, additionally (or in contrary) to firm-specific characteristics.

Since the knowledge intensity of regions is hypothesised to be important for firm performances, the localized 'knowledge economy' has to be defined accurately. We therefore define knowledge (intensity) and the locally embedded knowledge economy in relation to economic growth in section 2. We bind the knowledge economy to a relatively low spatial scale, because the capacity to absorb flows of new technological and entrepreneurial knowledge appears to be facilitated by proximity on a low spatial scale, for instance the zipcode level (Rosenthal and Strange 2001, Van Soest et al 2006, O'Callaghan and Andreu 2006) or cities (Feldman and Audretsch 1999). We model the contextual knowledge intensity at the level of (496) Dutch municipalities. Besides the wish for a low spatial contextual scale from conceptual reasons, this is also desirable from the point of view of urban economic policy incentives that are issued on this scale. Section 3 introduces the firm level controls used in the analyses.

## 2. The knowledge economy in contextual space

Within endogenous growth theory, knowledge spillovers are hypothesised to be a key mechanism in the discussion on firm-external economies (Romer 1986, Koo 2005). Spatial economists consider knowledge spillovers as important drivers for agglomeration. Marshall (1890) introduced reduced transaction costs, diverse intermediate goods suppliers, regional labour pools and knowledge spillovers as key elements in urban and regional economic growth processes. The 'spatial dimension' is hypothesised in many studies that show that agglomeration in regions coincides with higher regional productivity rates and productivity growth, thereby fostering economic growth (Henderson 1986, Feser 2001, Feldman and Audretsch 1999, Kim 1997).

Complementary aspects of spillover potentials through external economies are also described in industrial organization theory (Koo 2005, Caroll and Hannan 2000, Thurik and Audretsch 1996). Knowledge is hypothesised to flow between local firms and between firms and knowledge institutions (universities) via especially face-to-face contact (McCann and Simonen 2005). These flows usually do not diffuse instantaneously to economic activities around the world. Patterns of knowledge diffusion can explain regional differentials in growth of production and incomes (Döring and Schnellenbach 2006). If knowledge spillovers are important, it follows that firms tend to locate in *proximity* of each other and knowledge institutions to capitalize on the mutual knowledge stock In addition, these firms often create local innovation networks through which information on newly developed technologies and innovations is transmitted (Koo 2005). Moreover, in a study on R&D-spillovers (patent citation), Jaffe *et al* (1993) show that these knowledge externalities are geographically localized. The literature on the knowledge economy, particularly the diffusion of knowledge, emphasizes its urban character (Glaeser et al. 1992, Lucas 1993). The rationale is that if knowledge is important to innovation and growth, its impact increases by degree of agglomeration because in larger urban agglomeration many economic, social and cultural activities and actors are concentrated in a relatively small geographic space so that knowledge can be transmitted more easily.

The recent interest in and discussion of the knowledge economy is embedded in a long tradition. The term 'knowledge economy' was introduced by Machlup (1962) and Drucker (1959). It is usually understood as an economy in which the production factors labour and capital are aimed at the development and application of new technologies (OECD 2003). This definition falls short in the sense that the ultimate goal of the knowledge economy is taken to be the application of new technologies as such, while, in fact, this application is instrumental to the goals of innovation and economic (productivity) growth. Since its introduction, many theoretical and empirical contributions have refined and broadened the concept. We distilled (measurable) indicators from this literature that are relevant for firm level and contextual productivity models (Raspe and Van Oort 2006). For this, it is also necessary to conceptualise knowledge.

As observed in the preceding section, knowledge may lead to innovation: the commercial exploitation of knowledge. For our purposes we define knowledge as the ability to recognize and solve problems, by collecting, selecting and interpreting relevant information. Hence, a basic feature of the knowledge economy is the use of knowledge in interrelationships among market actors to produce goods and services, from the first idea to final products. Lucas (1988) and Mathur (1999) argue that human capital, particularly education, is a crucial feature of the knowledge economy. A well-educated workforce has ample opportunities to absorb and use information. In measuring the localized knowledge economy, we therefore use the average educational level of the working population per municipality as our first indicator. Florida (2002) though, identifies creative capital embodied in knowledge workers and artists as a major indicator of the knowledge economy. The difference between human and creative capital is that the 'creative class' (as Florida labels it) does not necessarily need to have a high educational level in order to create added value. In addition to direct productivity effects produced by knowledge workers, Florida emphasizes indirect growth effects from consumption by the creative class in the amenity–rich urban environments they live in. Since data on the creative class itself is not available, we use a proxy, i.e. the density of creative industries in which creative capital is employed (Raspe and Van Oort 2006) as the second knowledge economy indicator. The literature on the knowledge economy also emphasizes two indicators that reflect accessibility and transfer of knowledge. Particularly, Drennan (2002) and Black and Lynch (2001) analyze the growth potentials of firms related to an increased accessibility of information through the adoption of information- and communication technologies (ICT). Hence, we take ICT density (measured by computer usage per employee per industry) as third indicator. Cooke and Morgan (1998) and Clement *et al* (1998) identify social, cultural and communicative capital as sources of employment growth. Van der Laan *et al.* (2006) measure this variable via a proxy, i.e. the classification of occupations according to the degree of communicative skills needed for interaction (as suggested by McCloskey and Klamer 1995). Following Van der Laan *et al* (2006), we define the sectorally weighted average degree of communication skills as fourth indicator.

Our definition of the locally defined knowledge economy also addresses technical and production oriented aspects. As shown by amongst others Black (2004), traditionally most attention has been paid to research and development (R&D) in this context. We use the sectorally weighted share of R&D employees as fifth indicator. Additionally, Cortright and Mayer (2001) emphasize the role of high- and medium tech firms as indicators of the knowledge economy and drivers of economic and employment growth. Besides R&D-intensity, the OECD argues that high- and medium tech firms are characterized by their export intensity. We take the density of high- and medium tech industries as sectorally defined by the OECD (2003) relative to the total population of firms, as sixth indicator. Innovation is generally regarded as the most important driver of economic and employment growth. Several indicators of innovation exist, like new product announcements, publications, patents and firm self-ratings (Jaffe and Trajtenberg 2002). In this paper we use firm self-ratings in terms of new products and processes (as expressed by firms in the CIS-questionnaire for the Netherlands). We distinguish between technical and non-technical innovations. While technical innovations relate to new products and production processes, non-technical innovations concern management, organization and services. Both aspects are taken into account as the proportion of innovative firms in a municipality. They are the seventh and eighth indicators.

The above introduced variables are indicators of underlying latent variables, and are therefore strongly correlated. Regions specialized in ICT-intensive activities usually also are characterised by a highly educated labour force. And R&D-intensive regions usually also contain many high- and medium tech firms. Direct inclusion of the indicators would thus lead to multicollinearity and hence an increase of the estimated variances of the estimators of their coefficients so that one might be led to drop some of the variables incorrectly from the productivity model. Therefore, we include three latent variables into the model rather than the indicators (see Van Oort *et al* 2007). The latent variables are related to their observable indicators via a (principal component) measurement model. We distinguish the following latent variables:

1. 'Knowledge workers' with indicators: ICT sensitivity, educational level, creative class, and communicative skills
2. 'R&D' with indicators: the density of high and medium tech firms and the share of R&D employees
3. 'Innovativeness' with indicators: technical and non-technical innovations.

Table 1 shows the factor scores for these principal components. Bold values mark the loading of the indicators that are taken together in the three factors.

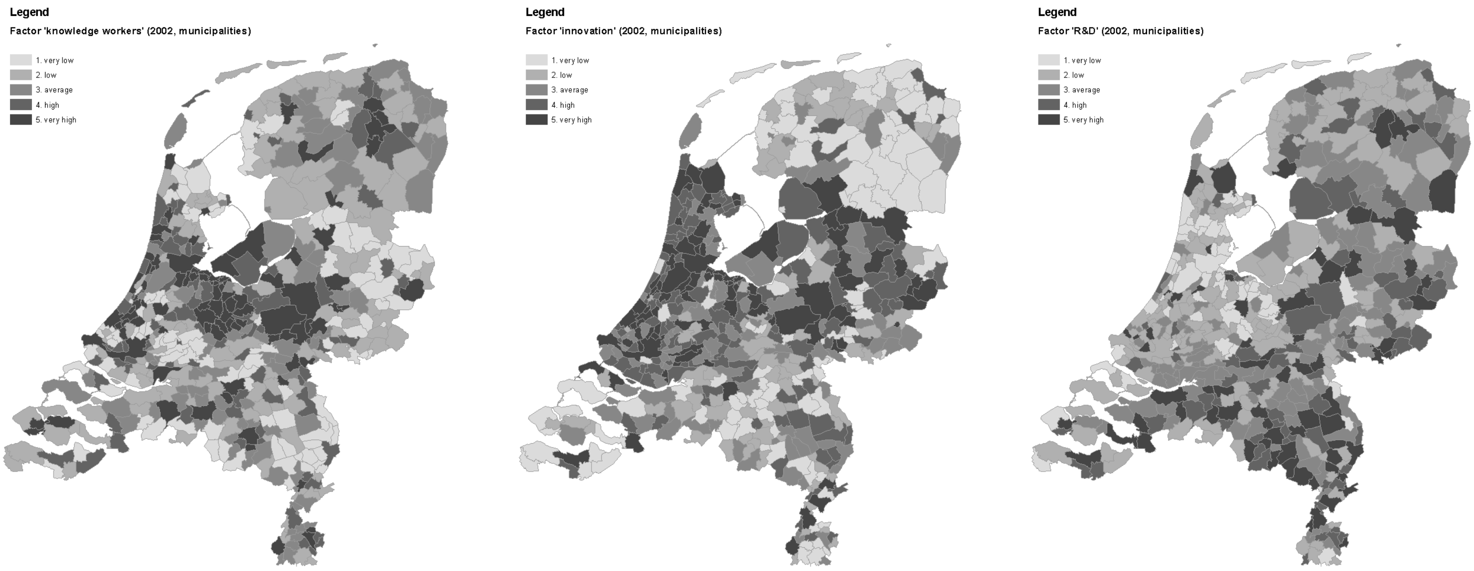
Table 1 Factor scores of principal components (eight indicators knowledge economy).

| Indicators: | Factors: | | |
|---|---|---|---|
| | Factor 1 'Knowledge workers' | Factor 2 'Innovation' | Factor 3 'R&D' |
| ICT-sensitivity | **0,753** | 0,365 | 0,268 |
| Education level | **0,949** | 0,164 | 0,044 |
| Creative economy | **0,516** | 0,024 | -0,198 |
| Communicative skills | **0,927** | 0,040 | -0,069 |
| High-tech and medium-tech | -0,175 | 0,146 | **0,840** |
| Research and Development | 0,080 | 0,129 | **0,836** |
| Innovation (technological) | 0,130 | **0,878** | 0,246 |
| Innovation (non-technological) | 0,147 | **0,914** | 0,054 |

Source: Raspe and Van Oort (2006)

The spatial patterns of the knowledge economy components are presented in figures 1a-c. From Figure 1a it follows that the knowledge workers component is concentrated in larger cities and regions in the Randstad region, the western economic core region of the country. This applies in particular to large cities like Amsterdam and Utrecht as well as their suburban surroundings. The rural regions and de regions in de national periphery are lagging behind. The spatial distribution of the ‘R&D’ component (Figure 1c) is quite different from that of knowledge workers. While the latter is concentrated in the western and central part of the Netherlands, R&D is concentrated in the southern and eastern periphery. These are the regions that have a strong industrial orientation (Van Oort 2004). The regions of Eindhoven (with Philips and ASML), Wageningen (university), Delft (university), and Dordrecht and Terneuzen (with technologically oriented multinational firms) are the R&D hotspots in the Netherlands. Regarding the factor Innovation, figure 1b shows that innovative firms are concentrated in the Randstad region, and in the eastern part of the Netherlands. The Amsterdam and Rotterdam regions are relatively innovative.

Figure 1a-c Spatial pattern of 1. 'Knowledge workers', 2. 'Innovation' 3. 'R&D'




Source: Raspe and Van Oort (2006)

### 3. Firm level controls

The previous section showed that within the Netherlands, a considerable spatial differentiation in knowledge intensities exists. Related to our research question - whether these differences are related to firm level productivity and productivity growth - we focus on firm level controls in this section.

On the firm level, the literature on industrial organization stresses the importance of firm *size* being of key relevance for firm's productivity (growth) (Caroll and Hannan 2000, Klomp 1996). Due to 'internal economies of scale', causing a reduction in per unit costs over the number of units produced, efficiency advantages emerge. Small firms have to overcome costs disadvantages contrary to larger firms, and hence it is often argued that firm size matters for firm's productivity. Besides size, also the firm's *age* is noted as important for firm performance. In the literature this is often related to firm dynamics (Evans 1986). A debate centres around Gibrat's law – stating that firm growth rates are distributed independently of firm size. Jovanovic (1982) added the firm's age to the growth-size relationship. A common hypothesis is that firm level productivity growth decreases with age. This is in line with Audretsch and Lehmann (2005) who discuss a large number of empirical studies on estimating firm growth in relation to firm age. Also the relationship between firm age and the level of productivity is well documented but presents contrasted results (Durand and Coeurderoy 2001). When related to the experience of the firm, it is argued that age is an advantage for productivity. But on the other hand, empirical evidence supports the view that older firms are more likely than young firms to achieve lower performance on average, hypothesised by the potential ossification of routines and learning processes.

Besides size and age also the type of economic activity the firms takes business in plays a part: *the sector*. Productivity generally differs between economic activities (sectors). In terms of employment, during the last decades an evolutionary change in sectoral structure occurred, with business services growing fast and manufacturing activities relatively declining. While both grew in added value, manufacturing activities have a relative high productivity level compared to services. But also within the manufacturing sector there are marked differences between for example knowledge and capital and labour intensive manufacturing activities. The interpretation of a test for the relation between productivity (growth) and local knowledge externalities for all firms becomes fuzzy when the productivity differs largely between sectors. In our analyses we therefore make a distinction in business services and three types of manufacturing (see appendix 3 and Van Oort (2004) for the definition and a discussion on these sectors).

Table 2 shows that knowledge intensive manufacturing at the aggregated national level shows the highest productivity level and the highest productivity growth rates in the period 2000-2005. Knowledge services have higher productivity levels than labour intensive and capital intensive manufacturing and also their productivity growth rates are higher.

Table 2 National productivity (levels and growth) in sectors

| | Level of productivity (euro's / fte) | | Productivity growth (index 2000=100) |
|---|---|---|---|
| | 2000 | 2005 | 2005 |
| Labour and capital intensive manufacturing | 45.306 | 55.133 | 121,7 |
| Knowledge intensive manufacturing | 70.936 | 87.802 | 123,8 |
| Knowledge services | 55.435 | 67.936 | 122,6 |
| National | 43.020 | 51.466 | 119,6 |

Source: Statistics Netherlands

As a fourth firm-level characteristic relevant for internalising knowledge externalities we introduce an indicator for a firm's *absorptive capacity*. Cohen and Levinthal (1990) introduced the concept of 'absorptive capacity' as: the firm's ability to identify, assimilate, and exploit knowledge from the environment, building on a stock of prior knowledge (Van den Bosch *et al* 1999). 'Knowledge' can - besides its role of 'renewer' (as in R&D investments) - also be a facilitator or assimilator in the absorption of knowledge mainly coming from outside the firm. A firm, not able to innovate itself, can benefit for example from research findings of firms in their horizontal network (co-operators or competitors) working along similar lines. Capabilities and absorptive capacities influence how external knowledge is absorbed or exploited internally (O'Callaghan and Andrue 2006). The firm's capacity to absorb knowledge, defined as its ability to identify, assimilate and apply for commercial purposes know-how generated outside it's own organisation, has in this way been considered one of the most relevant business characteristics in determining the productivity and innovativeness of firms this effort (Nieto and Quevebo 2005). The concept, however, remains fuzzy, despite the burgeoning empirical literature trying to measure various dimensions of it and relate it to more traditional and economic performance indicators (Abreu *et al.* 2006). Most commonly, absorptive capacity is related to a firm's efforts to innovate in the past. This means that firms that have a record of innovating in the past will have higher potentials for present innovation and this also gives rise to a larger innovative effort in the future. Thereby the importance of 'a minimal accumulated sufficient knowledge capability' to absorb external knowledge is stressed (Sena 2004). Conceptually, absorptive capacity is much related to the amount of knowledge intense activities within the firm. We introduce the dimension of absorptive capacity by measuring the number of employed persons in firms that are related with consultancy and R&D occupations.

Linked to the concept of absorptive capacity, the firm's communication system is important. In the present knowledge economy, communication and *transfer of information* becomes more important. In relation to the transfer mechanisms and communication of inter-firm relations there is considerable debate in the literature. Especially for productivity, recent empirical evidence suggests that ICT enhances firm level productivity (Becchetti et al 2003, Van Ark and Piatkowski 2004). On the one hand it is argued that ICT opens the opportunities to have global network relations, rendering geographical embeddedness to be of little importance (Cairncross 2001). On the other hand, the importance of face-to-face contacts and the transfer of tacit knowledge - augments in favour of proximity – are stressed (Glaeser 1999, McCann and Simonen 2005). The face-to-face content of firm interaction networks is introduced in our analysis as fifth firm-level control. Note that both ICT-usage and communicative skills were used in aggregated form to capture the contextual (regional) dimension of 'knowledge workers' in the previous section as well.

## 4. Multilevel modelling

In social sciences, multilevel analysis is used to study issues that link individual and societal phenomena. The general idea of multilevel analysis is that individuals in the same social context show similar progressive behaviour. The most researched cases are within educational studies on school performances: students learn by individual and class influences (Raudenbusch and Bruyk 2002, Rasbasch *et al* 2004). Generally, the individuals and the social groups are conceptualised as a hierarchical nested system with individuals and groups defined at separate levels (Hox 2002, Goldstein 2003). Examples of spatial or area related studies (who are in the minority of studies, Westert and Verhoeff 1995) of multilevel analysis for example model individual health (see Mitchell *et al* 2000, Duncan *et al* 1993, Sacker *et al* 2006), social contacts (Völker and Flap 2007) and voting behaviour (see O'Loughlin 2004). In these cases the lowest (micro) level is an individual, and higher levels consist neighbourhoods, areas or countries. Mulltilevel models study how this hierarchical structure affects the measurements of interest. Thus, if we are measuring educational achievement, it is known that average achievement varies from one school to another. This means that students within a school will be more alike, on average, than students from different schools. Pupils in the same class tend to be similar to each other, because of the selection processes, for instance in social economic status or common history.

We apply multilevel analysis to firm's productivity (levels and growth) that (potentially) interact with their economic, knowledge intense contexts. Therefore we hypothesise that firms are hierarchically nested in and influenced by their environment and the properties of those contexts are in turn influenced by the individual firms. Multilevel models – contrary to standard multivariate models – control for the assumption of independence of observations in grouped data. Considering that due to the potential of knowledge spillovers, a knowledge intensive context has potential for economic performance of firms, and this context is not independent for firms. Since firms within a geographical context are close in space we expect that they are more similar in performance than firms in other regions (similarities of performance enhancing factors in it's spatial context). The co-variation between firm's performances sharing the same regional externalities can be expressed by the *intra-class* correlation (Hox 2002). With intra-class correlation, the between-regions variance contributes to individual firm growth, additionally to the between-firm growth variance. When ordinary significance tests are used (like in linear multivariate regressions), treating the individual as the unit of analysis, the important assumption of independence of residual error terms is violated, leading to large errors and too liberal significance levels (Barcokowski 1981). Analysing processes that play a role on different (individual or spatial) levels at one single level is causing conclusions to be harmed by ecological fallacies (aggregated correlations and individual correlations are not the same, either in magnitude or in sign). Multilevel analysis is developed for this cause en solves these kinds of problems (Hox 2002).

When localized knowledge externalities exist, firm performance has to be understood not only in terms of individual firm-specific characteristics, but also in relation to local structures. Our assumption is that places or location matter, and more specific that the knowledge intensity of the place leads to firm-level benefits from 'knowledge externalities'. For example: in a highly knowledge-intensive region a firm can profit from his individual 'talents', but also from knowledge investments and capabilities in neighbouring firms. The proximity to this knowledge-intensive context is potentially profitable for interaction and cooperation. To be able to reap the benefits from complex interactions in full, it is often argued that co-location attributes to face-to-face contact, enhancing trust and cooperation (Ponds *et al* 2007). Knowledge workers in these highly interactive environments are hypothesised to be above average productive as well (Storper and Venables 2004).

Hox (2002) and Goldstein (2003) introduce multilevel regression modelling. The model assumes that we have data from $J$ groups, with a different number of respondents $n_j$ in each group. On the respondent level, we have the outcome of respondent $i$ in group $j$, variable $Y_{ij}$. There is an explanatory variable $X_{ij}$ on the respondent level, and one group-level explanatory variable $Z_j$. To model these data, a separate regression model in each group is formulated:

$$Y_{ij} = \beta_{0j} + \beta_{1j} X_{ij} + e_{ij} \qquad (1)$$

The variation of the regression coefficients $\beta_j$ is modelled by a group-level regression model:

$$\beta_{0j} = \gamma_{00} + \gamma_{01} Z_j + \mu_{0j} \qquad (2)$$

and

$$\beta_{1j} = \gamma_{10} + \gamma_{11} Z_j + \mu_{1j} \qquad (3)$$

The individual-level residuals $e_{ij}$ are assumed to have a normal distribution with mean zero and variance $\sigma_e^2$. The group-level residuals $\mu_{0j} + \mu_{1j}$ are assumed to have a multivariate normal distribution with expectation zero, and to be independent from the residual errors $e_{ij}$. The variance of the residual errors $\mu_{0j}$ is specified as $\sigma_e^2$ and the variance of the residual errors $\mu_{0j}$ and $\mu_{1j}$ is specified as $\sigma_{\mu 0}^2$ and $\sigma_{\mu 1}^2$. Maas and Hox (2005) write this model as a single regression model by substituting Equations (2) and (3) into equation (1). Substitution and rearranging terms gives:

$$Y_{ij} = \gamma_{00} + \gamma_{01} X_{ij} + \gamma_{01} Z_j + \gamma_{11} X_{ij} Z_j + \mu_{0j} + \mu_{1j} X_{ij} + e_{ij} \qquad (4)$$

The segment $\gamma_{00} + \gamma_{01} X_{ij} + \gamma_{01} Z_j + \gamma_{11} X_{ij} Z_j$ in Equation 4 contains all the fixed coefficients; it is the fixed (or deterministic) part of the model. The segment $\mu_{0j} + \mu_{1j} X_{ij} + e_{ij}$ in Equation 4 contains all the random error terms; it is the random (or stochastic) part of the model. The term $X_{ij} Z_j$ is an interaction term that appears in the model because of modelling the varying regression slope $\beta_{1j}$ of the respondent-level variable $X_{ij}$ with the group level variable $Z_j$.

Even if the analysis includes only variables at the lowest (individual) level, standard multivariate models are not appropriate. Multilevel models are needed because grouped data violate the assumption of independence of all observations. The amount of dependence can be expressed as the intra-class correlation (ICC) $\rho$. In the multilevel model , the ICC is estimated by specifying an empty model, as follows:

$$Y_{ij} = \gamma_{00} + \mu_{0j} + e_{ij} \qquad (5)$$

This model does not explain any variance in $Y$. It only decomposes the variance of $Y$ into two independent components $\sigma_e^2$, which is the variance of the lowest-level errors $e_{ij}$, and $\sigma_{\mu 0}^2$, which is the variance of the highest-level errors $\mu_{0j}$. Using this model, the (ICC) $\rho$ is given by the equation:

$$\rho = \sigma_{\mu 0}^2 / (\sigma_{\mu 0}^2 + \sigma_e^2) \qquad (6)$$

In our outcome variable $Y_{ij}$ is the firm performance, measured as productivity or growth. In the regression line (1) $\beta_{0j}$ is the usual intercept and $\beta_{1j}$ is the usual regression coefficient (slope) for the explanatory variable, and $e_{ij}$ is the usual residual error term. The subscript $j$ is for the region (Dutch municipality, in this research $j$ =1-136) and the subscript $i$ is for individual firms ($i$ =1-2009). The difference with a usual regression model is that we assume that each region $j$ has a different intercept coefficient $\beta_{0j}$, and a different slope coefficient $\beta_{1j}$ (since the intercept and slope vary across the regions they are often referred to as random coefficients, see Hox 2002).

We hypothesised that firm specific characteristics, like firm's size of age, are related to firm performance, but the focus is on the firm's regional, knowledge intensive circumstances: 'the three knowledge economic dimensions: 'knowledge workers', 'innovation' and 'R&D'. We expect that in a highly knowledge intense regional context, firm's can benefit more from knowledge externalities and therefore perform better due to this context. In modelling terms, a region with a high intercept is predicted to have better firm performances than regions with a low intercept. Similarly, differences in the slope coefficient for the knowledge intensity and predicted performance are not the same in all regions. Some regions have a high value for the slope coefficient of knowledge intensity, others lower.

**5. Research framework and variables**

For the micro, firm level, data the paper draws on a survey, with data concerning 2009 firms in manufacturing and business services. The survey was conducted in 2005 among more than 28.000 selected (see table 3) firms (establishments) with more than one employee, in eight regions (see appendix 1) in the Netherlands. A random stratified sample, taking size, sector and regions into account, was taken form the LISA database (an employment register of all Dutch economic establishments, see Van Oort *et al* 2006). For this research we included only firms in manufacturing and business services. These basic sectors are not directly bounded to consumers for their location –as for example retail is. The response was approximately 7% (representative for the stratification by region, size and sector).

Table 3. Population, Survey and Response

| | Population # firms (>1 wp) | survey | response | response % |
|---|---|---|---|---|
| Region Amsterdam | 17.141 | 5.980 | 399 | 6,7% |
| Region Rotterdam | 9.710 | 4.818 | 357 | 7,4% |
| Region Groningen | 2.720 | 2.128 | 167 | 7,8% |
| Region Eindhoven | 6.287 | 3.763 | 289 | 7,7% |
| Region Stedendriehoek | 3.204 | 2.217 | 162 | 7,3% |
| Region Arnhem-Nijmegen | 5.324 | 3.259 | 271 | 8,3% |
| Region The Hague | 4.921 | 3.117 | 185 | 5,9% |
| Region Utrecht | 5.486 | 3.355 | 179 | 5,3% |
| TOTAL | 54.792 | 28.637 | 2.009 | 7,0% |

On the firm level our performance indicator is the level of labour productivity, measured as:

$$PROD_{iy} = \frac{TURNOVER_{iy} - PURCHASES_{iy}}{EMPLOYMENT_{iy}} \qquad (7)$$

$$i = firm\ ,\ \ y = year\left(2005\right)$$

Turnover is measured as gross yearly turnover. Purchases are all intermediate goods and service needed in de production process of the firm. The numerator shows the added value of the firm (including the firm's taxes, subsidy, wages, and profits). Labour productivity is distilled by dividing the added value by the number of employees (in fulltime equivalents). Absolute productivity growth is the log of the productivity in 2005 (y) minus the productivity in 2000 (y-1) (formula 8). Relative productivity growth is the log of the productivity in 2005 (y) divided by the productivity in 2000 (y-1) (formula 9):

$$\Delta PROD_{ABS\,i} = \log\left(PROD_{iy} - PROD_{iy-1}\right) \qquad (8)$$

$$\Delta PROD_{REL\,i} = \log\left(\frac{PROD_{iy}}{PROD_{iy-1}}\right) \qquad (9)$$

We take firm *size* into account by the number of the employees (defined in jobs more that 12 hours a week). Our hypothesis is that firm size is positively related to labour productivity (growth). *Age* is measured by the number of years since the firm has entered business (year of foundation of the establishment). Our hypothesis is that, especially because we include age besides size in the analysis, age is negatively related to firm's productivity. The *sector* distinction in our study is made by NACE-codes (based on Van Oort, 2004, see appendix 3 for codes per sector and codes). Our hypothesis is that productivity and productivity growth are higher in manufacturing activities, especially in the capital- and knowledge- intensive parts (see also table 2).

For the firm's *absorptive capacity* we use the indicator 'number of jobs in research and consulting (technological, market and design related), in the total number of jobs in a firm'. Other jobs within the firm concern management, facilitating services, purchasing, logistics or production. This indicator represents a firm's potential absorptive capacity in volume of internal knowledge base. We expect that a higher number of R&D- and advice-related employees lead firms to be able to absorb more external knowledge and profit form (localized) knowledge surroundings.

We take the use of *ICT* and *face-to-face* contact into account by selecting this mechanism from a survey question on the types of transfer mechanism used in inter-firm relations. This is expressed as a share of the sum of all types of transfer mechanisms (personal, written, telephone, e-mail, e-commerce and other types of contact). This direct measurement of how a firm handles it inter-firm relations by different communication channels enables us to test the hypothesis that use of ICT in communication will enhance productivity, but also face-to-face contacts are hypothesised to be important for embedding localized knowledge spillovers in firms. ICT is defined as the degree of e-mail plus e-commerce contacts.

Our knowledge intense spatial contexts were discussed in from section 2: knowledge workers, innovation and R&D. These data are on the municipality level and not based on the survey, but on all establishments of all economic sectors (NACE codes) of the LISA database (with annually over 800.000 establishments) linked with indicators of the knowledge economy (Raspe and Van Oort 2006). The data on the higher level therefore represent different types spatially aggregated knowledge related employment intensities. In the models we include a lagged effect in the relation between the firm's knowledge context and firm performance. As put forward by Henderson (2003) it is to be expected that it takes time for knowledge to spill over and get embedded in firms. Following

Henderson (2003), we use a two to three year 'lag' by linking firm performance in the period 2000-2005 to variables in the industrial environment in 2002.

We control for regional heterogeneity by including regional dummies of the eight daily urban systems where the questionnaire was set out. Table 4 shows the descriptive statistics of the variables. All variables are log transformed and standardized (firm specific variables for 2009 firms, regional variables for 136 municipalities in the eight regions)

Table 4. Descriptive Statistics (non-transformed/non-standardized internal characteristics)

| | Min | Max | Mean | s.d. |
|---|---|---|---|---|
| Age[1] | 1,00 | 7,00 | 6,12 | 1,39 |
| Size[2] | 1,00 | 9.000,00 | 60,41 | 431,49 |
| Absorptive capacity[3] | 0,00 | 100,00 | 20,53 | 27,17 |
| Face-to-Face[4] | 0,00 | 100,00 | 37,06 | 21,87 |
| ICT[5] | 0,00 | 100,00 | 43,87 | 21,37 |
| 'Knowledge workers' | -2,52 | 1,89 | 0,00 | 1,00 |
| 'Innovation' | -2,12 | 1,91 | 0,00 | 1,00 |
| 'R&D' | -1,53 | 3,95 | 0,00 | 1,00 |

[1]Number of *years* ago the establishment is founded, interval: 1=1, 2=2, 3=3, 4=4, 5=5, 6=6-10, 7=>10

[2]The number of *jobs* in the establishment (more than 12 hours a week)

[3]Percentage of jobs in *research* and *consulting* activities in total number of jobs in the establishment

[4]Percentage of personal physical contacts in total of communication forms of business relations

[5]Percentage of contacts by information and communication technology in total of communication forms of business relations

## 6. Empirical results

Controlling for firm specific characteristics we focus on locally bounded knowledge externalities in several model specifications. Table 5 presents the models for firm level productivity, for absolute productivity growth and c relative productivity growth. From the null-model for productivity level (a) we learn that approximately 3 % of a firm's productivity can be assigned to the firm's municipal context. An important learning thus is that 'internal firm characteristics' are by far more dominant for productivity, relatively to the spatial context.

Model 1a in Table 5 adds firm level variables to the null-model. The firm's size (number of employees) is significantly and positive related to productivity. This was hypothesised, because larger firms are more productive due to economies of scale and scope. The size of firms is on the micro level the most important element. Also of importance is the distinction in type of economic activities (sector). We included dummies for labour intensive, capital intensive and knowledge intensive manufacturing. Business services are the reference category (not included to avoid multicolliniarity problems). Especially firms belonging to the knowledge intensive manufacturing category have significant higher levels of productivity.

The firm's absorptive capacity (the number of knowledge intensive jobs in the total number of jobs), does not contribute to productivity. We expected a positive relationship; we do not find indications that a higher number knowledge absorptive jobs is correlated with higher firm productivity though. We tested for the possibility of a threshold influence (a certain amount of absorptive capacity is needed to grasp externalities, not just 'the more, the better'). But dummies for 'above average' or 'being in the top quarter' of the distribution of the absorptive capacity variable turn out to be not significant either. Focussing on the firm's communicative abilities we find a significant positive effect of the use of ICT in inter-firm relational communication for productivity. We do not find a positive relation of degree of face-to-face contact with productivity.

In the models 2a and 3a we add knowledge related contextual variables. The question is whether the knowledge intensity in the firm's region is profitable for firm's productivity. We especially find that an 'innovative' spatial context is an important factor for productivity on the firm level. This stresses the importance of 'entrepreneurial' skills in the field of industrial organization (marketing, organization, product and process innovation), not only on the micro level but also as externalities. The contribution of R&D externalities and 'knowledge workers' related externalities to firm’s productivity are not significant.

Knowing that there is a small contextual effect for firm's productivity and that firm internal characteristics are more important, the question is 'how much variance is explained?' In multilevel regression analysis the issue of modelled or explained variance is complex. It can be estimated by examining the residual error variances in a sequence of models where the null model is the baseline model. This must be issued level-by-level (see Hox 2002: p.63). For our models we see that the proportion of variance explained at the firm level is 11,4%. Model 1a shows that although no level 2 variables are added 44,8% of the municipal-level variance is explained by firm internal characteristics. If the proportion of for example size and sector are not exactly the same in all regions, the regions differ in their average number of firm's size or sector, and this variation can explain some of the regional level variance in average productivity between regions. Approximately 45% can be explained by unequal composition of firms and 55% is really due to regional differences in contextual conditions. In model 2a we see that adding the regional knowledge factors raises the R-square by 25%-points (to more than 75%). This means that especially a high innovative spatial context matters for firm's productivity by 0,75% (25% of 2,9% -the intra-class correlation-).

For the firm’s productivity growth models (table 5: models b and c) the main result is that there is a very limited spatial influence (a non-significant intra-class correlation). This means that in our models we do not find indications that firm's productivity growth is determined by the location and the heterogeneity on the level of municipalities. This is remarkable since we expected that controlling for firm characteristics, the location of the firm should contribute in enhancing productivity growth (as suggested in Kim 1997, Ciccone and Hall 1993, Moomaw 1981). Finally, we find a small effect of contextual innovation on productivity growth (model 3b and 3c).

A second conclusion based on table 6 is that, on the contrary to what we noticed with the productivity level estimation, for growth most of the measured internal factors are insignificant. Only the size of the establishment matters for relative productivity growth: the larger the establishment, the higher it's productivity growth. This result includes the control for the starting level of productivity. Normally firms with a high level of productivity in the beginning of the period analysed, have lower relative growth chance due to this head start. The size effect in the growth specifications can be related to efficiency advantages in larger firms (establishments) (see Evans 1986).

It should be remarked that the firm internal characteristics we added in our models do only explain a very small part of the variance of productivity growth. This means that productivity growth is likely to be related to real firm internal characteristics that have little to do with our knowledge-base related firm characteristics, for example organizational and management related factors. Because our focus was on the regional influence on firm performance we did not include similar indicators in our research.

Finally, model 4a specifies productivity growth with only contextual factors. This model shows that *not* controlling for firm internal characteristics, the influence of the spatial knowledge contexts is exaggerated. All three factors are positively significant, while they are not in the earlier models.

## Table 5 Productivity '05 and Productivity growth '00-'05

| | Productivity '05 | | | | | Absolute growth productivity '00-'05 | | | | Relative growth productivity '00-'05 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Null a | Model 1a | Model 2a | Model 3a | Model4a | Null b | Model 1b | Model 2b | Model 3b | Null c | Model 1c | Model 2c | Model 3c |
| Level 1: firm | | | | | | | | | | | | | |
| Constant | 0,001 | -0,034 | -0,049 | -0,082 | -0,018 | 0,001 | 0,004 | 0,012 | -0,161* | 0,001 | -0,001 | -0,002 | -0,065 |
| | (0,031) | (0,031) | (0,034) | (0,089) | (0,031) | (0,022) | (0,027) | (0,035) | (0,084) | (0,022) | (0,027) | (0,035) | (0,084 |
| Age | | 0,018 | 0,018 | 0,018 | - | | 0,034 | 0,033 | 0,034 | | 0,002 | 0,002 | 0,003 |
| | | (0,022) | (0,22) | (0,022) | | | (0,023) | (0,023) | (0,0230 | | (0,023) | (0,023) | (0,023) |
| Size | | 0,330*** | 0,324*** | 0,323*** | - | | 0,020 | 0,019 | 0,018 | | 0,051** | 0,047** | 0,046** |
| | | (0,022) | (0,022) | (0,022) | | | (0,023) | (0,023) | (0,023) | | (0,023) | (0,023) | (0,023) |
| Labour int. manuf. | | 0,060 | 0,050 | 0,042 | - | | -0,018 | -0,029 | -0,038 | | 0,027 | 0,022 | 0,018 |
| | | (0,066) | (0,067) | (0,067) | | | (0,071) | (0,072) | (0,072) | | (0,071) | (0,072) | (0,072) |
| Capital int. manuf. | | 0,158* | 0,154* | 0,150* | - | | 0,018 | 0,010 | 0,003 | | -0,023 | -0,024 | -0,026 |
| | | (0,085) | (0,086) | (0,086) | | | (0,091) | (0,092) | (0,092) | | (0,091) | (0,092) | (0,092) |
| Knowledge int. manuf. | | 0,157** | 0,146** | 0,142** | - | | -0,023 | -0,031 | -0,036 | | -0,009 | -0,011 | -0,013 |
| | | (0,066) | (0,067) | (0,067) | | | (0,071) | (0,072) | (0,072) | | (0,071) | (0,072) | (0,072) |
| Absorptive capacity | | 0,009 | 0,011 | 0,012 | - | | 0,034 | 0,036 | 0,038* | | 0,004 | 0,008 | 0,009 |
| | | (0,021) | (0,021) | (0,022) | | | (0,023) | (0,023) | (0,023) | | (0,023) | (0,023) | (0,023) |
| Face-to-Face | | 0,028 | 0,029 | 0,029 | - | | 0,001 | 0,001 | 0,002 | | 0,010 | 0,011 | 0,011 |
| | | (0,022) | (0,022) | (0,022) | | | (0,023) | (0,023) | (0,023) | | (0,023) | (0,023) | (0,023) |
| ICT | | 0,047** | 0,049** | 0,047** | - | | 0,038* | 0,038* | 0,037* | | 0,005 | 0,005 | 0,005 |
| | | (0,022) | (0,022) | (0,022) | | | (0,023) | (0,023) | (0,023) | | (0,023) | (0,023) | (0,023) |
| Productivity '00 | | | | | | | 0,004 | 0,001 | -0,002 | | -0,002 | -0,007 | -0,009 |
| | | | | | | | (0,022) | (0,023) | (0,023) | | (0,022) | (0,023) | (0,023) |
| Level 2: municipalities | | | | | | | | | | | | | |
| 'Knowledge workers' | | | -0,035 | -0,026 | -0,052** | | | -0,021 | -0,023 | | | 0,020 | -0,023 |
| | | | (0,025) | (0,028) | (0,026) | | | (0,025) | (0,026) | | | (0,024) | (0,026) |
| 'Innovation' | | | 0,108*** | 0,115*** | 0,153*** | | | 0,027 | 0,073* | | | 0,050* | 0,093** |
| | | | (0,028) | (0,040) | (0,030) | | | (0,027) | (0,040) | | | (0,027) | (0,040) |
| 'R&D' | | | 0,036 | 0,031 | 0,048* | | | 0,001 | -0,017 | | | -0,019 | -0,029 |
| | | | (0,023) | (0,029) | (0,025) | | | (0,022) | (0,027) | | | (0,022) | (0,027) |
| Fixed effects[1] | No | No | No | Yes | No | No | No | No | Yes | No | No | No | Yes |
| -2*loglikelihood | 5689,3 | 5425,8 | 5411,7 | 5406,8 | 5664,9 | 5700,3 | 5691,2 | 5689,6 | 5680,0 | 5700,3 | 5694,7 | 5688,2 | 5684,2 |
| $R_1^2$ | - | 0,114 | 0,113 | 0,115 | - | - | 0,001 | 0,001 | 0,001 | - | 0,002 | 0,002 | 0,002 |
| $R_2^2$ | - | 0,448 | 0,759 | 0,621 | 0,724 | - | - | - | - | - | - | - | - |
| $\sigma_{\mu0}^2/\left(\sigma_\varepsilon^2+\sigma_{\mu0}^2\right)$ | 2,9 % | | | | | n.s. | | | | n.s. | | | |

Standard deviation between parentheses, n*i* =2009, n*j*=136, *** significant at the 0.01 level, ** significant at the 0.05 level, * significant at the 0.10 level [1]We tested whether a location in one of the eight Daily Urbans Systems (DUS) has an extra contribution on performance by including regional dummies. The software MLwiN (Rasbash *et al*. 2000) was used for the estimation of the models. Because we have a strong interest in the random part of the model, the number of groups should be considerably large. The average number of individuals is round and about 15 and additional requirement is that the minimum number of firms in a region is more than 5. This structure by-passes the possible bias in the estimates of the second-level standard errors estimates, which can occur with a small sample size at level two: meaning a sample of 50 or less (Maas and Hox 2005). Multilevel models mostly use Maximum Likelihood (ML) estimation. Two ML functions are common: full ML (FML) and restricted ML (RML). The difference is that RML maximizes a likelihood function that is invariant for the fixed effects. Maas en Hox (2005), quote Raudenbusch and Bruyk (2002): since RML maximize takes the uncertainty in the fixed parameters into account when estimating the random parameters, it should in theory lead to better estimates of the variance components (especially when the number of groups is small).

Following on the analysis presented in table 5, it might be the case that a specific regional knowledge context is not necessarily effective with all firms, but only with certain types of firms. Do specific knowledge intense firms profit more? This question is a cross-level interaction issue. Cross-level interactions are defined as interactions between variables measured at different levels hierarchically structured data (see Kreft and de Leeuw 2004, Hox 2002). It is to be expected that some firms are differently affected by contextual externalities. Especially the more knowledge intensive firm's can profit form localized knowledge spillovers and therefore from a high knowledge intensity in it's surrounding. Also, only firms in certain industries might profit from a high specialization or from a diverse structure.

On the firm level we can distinguish three types of knowledge intensities in which firms differ. Firstly, by type of economic activity (measured by sector), secondly, by a firm’s absorptive capacity (number of knowledge intensive jobs in the total of the firm). And thirdly by the amount of face-to-face contacts in the communication with external sources. Our hypotheses are that only firms (a) in knowledge intense sectors (knowledge intensive manufacturing and knowledge services); (b) with a high absorptive capacity and (c) with a high amount of face-to-face contact, will profit (by higher productivity) from local external knowledge.

The first step to explore these kinds of cross-level interactions is by analyzing a random coefficient model in which the slope of any of the explanatory variables on the micro level has a significance variance component between the regions (see Hox 2002). When slope variances exist, we can add cross-level interactions between group level variables (our three types of knowledge intensities on the regional level, of the five specialization indicators) and those individual explanatory variables that had significant slope variation.

We did *not* find significance slope variance for the firm's type of economic activity (a distinction in 4 types of sectors), absorptive capacity and face-to-face contacts and their relations with productivity. Because of the lack of slope variance, also possible cross-interaction relations between these firm's knowledge indicators and the regional knowledge intensities do not exists. In other words: there are no indications that some firm specific knowledge or sector related characteristics give firms more potential to profit from localized knowledge spillovers.

## 7. Conclusions

The question whether localized knowledge spillovers are important and firms profit from a location in *proximity* to each other's knowledge stock, has a central place in a longstanding debate of economic geographers, spatial economists and in industrial organisation. Still, this issue has seldomly been researched by modelling individual firm characteristics and performances simultaneously with its higher-level economic geographical context. From a localized knowledge spillover view we are interested if a firm can benefit from knowledge intensities in it's spatial context. We applied multilevel analysis to address this issue. This modelling technique enables us to model firm level productivity (growth) simultaneously with firms' knowledge intensive geographical context. This context is defined as a latent concept of 'knowledge economy' in a broad sense, using three manifest (measurable) dimensions: 'research and development', the successful introduction of new products and services: 'innovation', and a 'softer side' containing the use of ICT, educational level of the workforce, communicative and creative skills: 'knowledge workers'. We expect that firms in these types of environments have a higher productivity (growth).

We find only a small spatial effect: the region contributes for three percent to the average firm level of productivity. We find that the innovation and R&D-dimensions are significantly attached to this context effect. Regions where businesses are more successful in the renewal of products and services, make individual firms profit in terms of having a higher productivity. The factors 'knowledge workers' (an intensity in the use of ICT and communicative skills), and 'R&D' do not contribute to the productivity of a firm. On the contrary firm-internal characteristics are dominant for productivity. We find positive results from size, sector, and ICT-use in communication with inter-firm relations (not for face-to-face contacts): explaining 12% of the firm's productivity. Overall our results suggest that the territorial dimension of localized knowledge externalities for firms should not be exaggerated. Especially since no (knowledge intensive) contextual effect for firm productivity *growth* is found.

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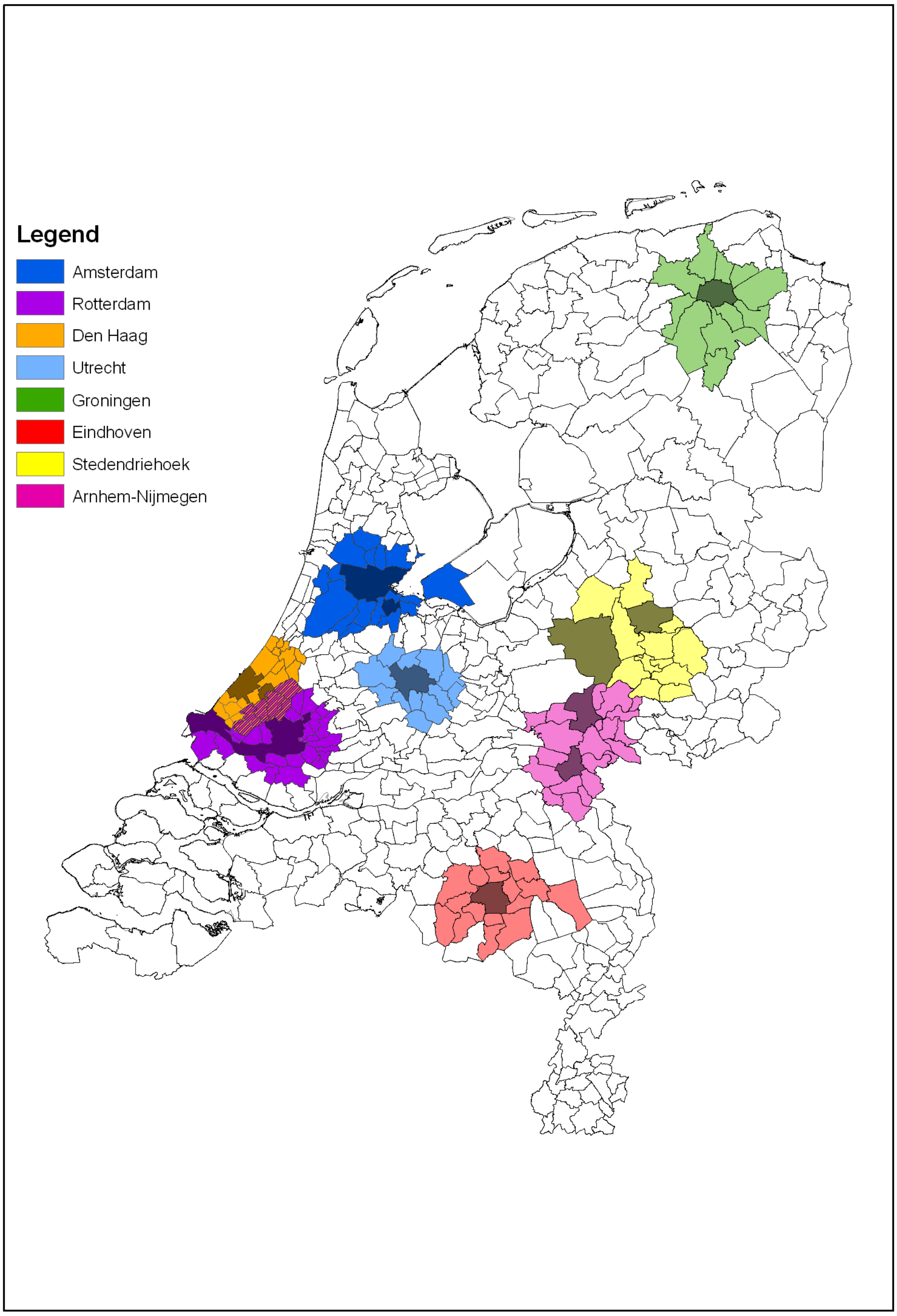
## Appendix 1: Spatial typology used in the study

Figure 2 Eight daily urban systems and central cities (municipalities, n=483)




Note: Central cities are marked dark. The Dutch Randstad consists of the regions Amsterdam, Rotterdam, Den Haag and Utrecht

**Appendix 2:**

Table 6 Correlation matrix of independent variables firm level

| | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. |
|---|---|---|---|---|---|---|---|---|---|
| 1. Dummy labour intensive manuf. | 1.0000 | | | | | | | | |
| 2. Dummy capital intensive manuf. | -0.1027 | 1.0000 | | | | | | | |
| 3. Dummy knowledge intensive manuf. | -0.1392 | -0.1015 | 1.0000 | | | | | | |
| 4. Dummy knowledge services | -0.5546 | -0.4045 | -0.5482 | 1.0000 | | | | | |
| 5. Size | -0.0105 | 0.0592 | 0.1156 | -0.1063 | 1.0000 | | | | |
| 6. Absorptive capacity | -0.1380 | -0.1425 | -0.0124 | 0.1847 | 0.0303 | 1.0000 | | | |
| 7. Face-to-face | 0.0218 | -0.0489 | -0.0923 | 0.0763 | -0.0610 | 0.0383 | 1.0000 | | |
| 8. ICT | -0.0869 | -0.0317 | 0.0617 | 0.0357 | 0.0148 | 0.0642 | -0.2565 | 1.0000 | |
| 9. Age | 0.1002 | 0.0626 | 0.0842 | -0.1645 | 0.2105 | -0.0712 | -0.0289 | -0.0229 | 1.0000 |

**Appendix 3**

Table 7 Sector and NACE-codes

| |
|---|
| SECTORS (based on 2 digit NACE-codes) |
| Labour intensive manufacturing |
| 17, 18, 19, 20, 28, 36, 37 |
| Capital intensive manufacturing |
| 15, 16, 21, 25, 26 |
| Knowledge intensive manufacturing |
| 23, 24, 27, 29, 30, 31, 32, 33, 34, 35 |
| Knowledge services |
| 22, 64, 65, 66, 67, 70, 71, 72, 73, 74 |