The knowledge economy and Dutch cities

Frank G. van Oort[1] & Otto Raspe

Paper prepared for the European Regional Science conference (ERSA), Amsterdam August 23-27, 2005.

Abstract

How can cities and metropolitan regions remain prosperous and competitive in a rapidly changing economy? The spatial-economic literature suggests that 'the knowledge economy' offers perspectives for growth and added value creation. This paper clarifies what causal elements of the urban knowledge economy related to growth can be distinguished, in which regions and cities in the Netherlands these have its most significant imprints and what statistical association there is between regional and urban knowledge conditions and good economic performance of firms. Contrary to earlier empirical research, we do not have to restrict our definition of the knowledge economy in order to construct indicators at low spatial levels. As a consequence of using indicators at the municipal level in the Netherlands (n=469), spatial dependence should be dealt with when answering our research questions. We use spatial lag and spatial regime estimation when constructing econometrical models that relate urban economic performance to knowledge indicators. The paper contributes to the urban knowledge economy discussion by (1) addressing interdependencies in spatial (urban) scales of analysis, (2) consistently constructing knowledge indicators as mentioned in the theoretical literature and (3) weighing indicators in relation to economic performance. Two opposite hypotheses on the relevant urban scale of analysis are tested: are central cities motors of economic growth, or does The Netherlands as a small country function as an urban field in which urban conditions are not localized? Both hypotheses are found to be too extreme to fit the Dutch situation. We also conclude that in all econometric specifications over regimes and spatial lag estimations, the locational attributes of non-industrial factors like 'knowledge workers' are much more significantly related to economic growth and added value than R&D-based innovation input factors. This questions Dutch policy initiatives that mainly focus on R&D as stimulator of the knowledge economy.

1 Introduction

"The Dutch government aims to invest in the urban economy and work on building strong innovative regions. Fundamental knowledge development should aim at an applicable and competitive knowledge economy, in which research and development (R&D)

[1] Corresponding author: Utrecht University, PO Box 80115, 3508 TC, Utrecht, The Netherlands, f.vanoort@geo.uu.nl & Netherlands Institute for Spatial Research, The Hague, The Netherlands, oort@rpb.nl. Tel.: (+31) 70 3288771.

investments are central. The Eindhoven region (South-East Brabant), because of its leading international position in R&D-investments, is therefore appointed as brainport – and the region will be supported by spatial-economic and infrastructural policy initiatives by the Dutch government" (Nota Ruimte 2004, p.80).

This quotation from the most recent policy document on spatial planning in the Netherlands summarises why we were motivated to apply a longstanding academic discussion on the role of knowledge to economic growth (Foray 2004) to the local and regional situation of the Netherlands. The choice of Eindhoven as central focal point for spatial-economic development in the Netherlands appears arbitrary. The central indicator being the amount of research and development (R&D), Eindhoven indeed ranks above all other Dutch municipalities because of the presence of many high-tech manufacturers (of which Philips is by far the largest) and the technical university. In this paper we agree that 'the knowledge economy' offers perspectives for growth and added value creation, but that it is rather unclear what elements the knowledge economy actually consists of, how it can be measured in statistical indicators and in which regions and cities in the Netherlands the knowledge economy has its most significant imprints. More important, it is not a priori clear what statistical (causal) association there is between knowledge embedded in regions and cities and relatively good economic performance of firms. The Dutch economy consists mainly of service- and distribution based specializations, and hence a focus on technical innovation (measured by R&D) does not seem to encompass al opportunities in the Dutch knowledge economy.

Also not unambiguously clear is the spatial scale of analysis that should be central when researching "the urban economy and innovative regions in the knowledge economy". In this paper we test two contrasting hypotheses often heard in the international and Dutch literature. The first focuses on the role of cities in the knowledge economy, the second on the absence of an urban determination in the pinning down of firm performance in the knowledge economy (the 'urban field' hypothesis). The current embedding of knowledge externalities in endogenous economic growth theory have led to important contributions that stress the urban character knowledge transmission in particular. The reasoning is that if knowledge spillovers and –externalities are important to growth and innovation, they should be more easily identified in cities where many people are concentrated into a relatively small geographic space so that knowledge can be transmitted between them more easily. Simultaneously, a large body of literature on the Dutch spatial configuration of innovation and high-technology firms predominantly stresses the supposed 'urban field' character of the Dutch case: location and agglomeration aspects do not seem to have a systematic impact on the distribution of innovative and growth inducing activities over space. As argued in this paper, many of these arguable 'stylised' conclusions depend heavily on the definitions of the knowledge economy, research population and hypothesised proximity- and functional relations over space. Much research sacrifices greater precision in the operational definition in order to tell the interesting story about the knowledge and information sector in metropolitan economies (Drennan 2002, p.18). Because we are able to measure knowledge economy indicators at the municipal level in the Netherlands (n=469) our analyses are not subject to these restrictions. At the same time it means that spatial dependence should be dealt with when answering our research questions, because spatial interdependences on this low spatial scale are obvious and should be controlled for when concluding on the relation knowledge factors – economic growth. We use data for the period 1996-2003 for testing. Good 'performances' of firms in relation to knowledge-economy indicators in one municipality are hypothesized to be related to performances in municipalities nearby (spatial lag estimation) or to performances in functionally related municipalities (spatial regime estimation, e.g. municipalities of the same urban size, municipalities in larger urban regions or in municipalities that are employment (central cities) or population (suburban) dominated).

Our aim in this paper is to test which aspects of knowledge intensity of enterprises is connected to economic growth, doing so by systematically applying spatial econometric modelling techniques. This contributes to the understanding of the relation between proximity, agglomeration and knowledge intensity in the Dutch case. But it also questions the relationship in other countries, as R&D investments as central indicator for spatial-economic development are central in most European and American policy views (OECD 2004). In short, we focus on three research questions. (1) Which causal aspects of the knowledge economy are mentioned in the literature as important for economic growth, and can all these be measured for the Dutch economy? (2) What spatial and sectoral overlap do these knowledge indicators have (is R&D indeed a good overall proxy?), and can they thus be reduced to (one or more) uncorrelated "pillars" (factors) of the knowledge economy? And (3), controlling for spatial proximity and spatial regime dependence, can the relationship between knowledge factors and economic performance on the urban level more precisely be pinned down for the Dutch case? This paper is build up around these three questions. Section 2 scans the literature for identifying knowledge economy indicators that are hypothesised to be connected to economic growth. Eight indicators are distinguished and mapped on the municipal level. Section 3 defines urban regimes and descriptively analyses the eight indicators over these regimes. Section 4 uses factor analysis to synthesise the eight indicators into three distinctive factors. Section 5 presents the results of spatial econometric models that link the three factors to economic (employment) growth and added value creation. Section 6 concludes and evaluates what insights are important for policy.

2 Knowledge economy and economic growth: definition and indicators

The recent attention paid to the knowledge economy is embedded in a longer tradition. During the sixties of the twentieth century the term "knowledge economy" was introduced in publications of Machlup (1962) and Drucker (1959). In 1999, the concept was introduced in the dictionary for the first time, being 'an economy in which the production factors labour and capital are aimed on the development and application of new technologies'. This definition seems to fail on two aspects. Firstly, it does not define knowledge, while we have to know what knowledge is before applying it to an economy. Second, the ultimate goal of the knowledge economy appears to be the application of new technologies. This conceptualization is very much influenced by OECD-definitions (Godin 2004). We think the goal should be economic (productivity) growth, and several knowledge-economic aspects can contribute to that. Meanwhile, the theoretical and empirical literature has broadened the concept. We will discuss this literature shortly now, and distill (measurable) indicators from it.

In analysing the possible spatial effects of knowledge of economic growth, it is necessary to have a closer look at the role of knowledge and knowledge transmission in organisations. Because activities in organisations have to be integrated, co-ordination of these tasks and functions is at the heart of the organisation's economic process. In general, co-ordination of tasks and functions induces costs. Knowledge about processes and products is hypothesised to make this co-ordination more efficient and less costly. ICT can play a role in this. Especially the potential reduction of ICT on time-, distance- and relational costs, leads to more efficient management. Time and physical distance become less stringent constraints for economic functioning and production chains of organisation potentially are reduced, either by internal vertical integration and/or external oriented vertical disintegration. The picture becomes more complex when the efficiency of tasks that depend on non-codified knowledge is related to the availability of knowledge. This is particularly valuable for the quality and innovation of production and where non-codified, tacit knowledge is important. It becomes necessary to look at the change from information towards knowledge. This does not mean that codified information and cost-efficiency are not important, but that the balance of relevant aspects changes. More emphasis on networks, facilitated by ICT, coincides with a growing importance of knowledge attached to human capital and for knowledge networks within and between organisations. The shift from substitution towards facilitating is strongly related to the development of the knowledge economy. The knowledge-based organisation differs substantially from the classical organisation. Knowledge is at the core of the enterprise and labour changes from a cost into an essential investment. Production processes aim at the creation of immaterial knowledge-structures. Consumer and business relations become part of more personalised networks in which interaction and face-to-face contacts prevail. These immaterial assets determine increasingly, and complementary to material assets, the value of an organisation.

In the above vision, knowledge transforms information and data into useful applications for businesses that lead to economic (productivity) growth. Most information people come across is still unstructured and chaotic. Knowledge concerns the structuring and application of information. Only with knowledge, information becomes meaningful. Knowledge can be obtained and trained by experience, familiarity, science or learning. Often knowledge is taken together with innovation: the commercial exploitation of knowledge. To encompass al these elements of knowledge conceptualisation, we propose a broad definition of knowledge economy. Knowledge is the adding up of abilities (capabilities, creativity and persistency) to recognise and solve problems, by collecting, selecting and interpreting information. 'Change' is an essential element in this. The knowledge economy then is the use of knowledge in interactive relations between market actors and others, while producing and using goods and services, from the first idea to final products. This definition does not focus solely on technological renewal as goal of a knowledge economy, but on productivity and employment growth of firms. Reading the (large) literature on this, we come across eight (measurable) indicators that connect knowledge economy and economic development. We will discuss them shortly. More information on the indicators and their respective theoretical background can be found in Raspe *et al*. (2004). See also table 1 for the sources of the data used.

The first aspect that is central in many studies is the role of education and professional capabilities. Many studies focus on these forms of human capital as crucial conditions for a knowledge-based economy (Lucas 1988, Mathur 1999). A capable and highly educated workforce has more opportunities to absorb and use information. Firms with such a workforce are more competitive, since search costs are lower. In spatial-economic terms it is good to have a highly educated and capable workforce in the surrounding of firm – a labour market characteristic. This is often the case in larger urban agglomerations. Recently, Florida (2002) replaced human capital as source of entrepreneurship and economic growth by creative capital. From spatial regression analysis becomes clear that creativity (measured by occupations rather than sectors) spatially coincides with positive urban growth potentials. The difference with human capital theory is that the creative class (as Florida labels knowledge workers and artists) not necessarily needs to have a high educational level in order to create more than average added value in and with their work. Besides direct productivity effects by hardworking knowledge workers, Florida distinguishes indirect, localised growth effects from consumptive power of the creative class, in amenity–rich urban environments in which they live. Because his research shows that creativity as motor for local economic potential can be considerable, we added the presence of creative industries (distinguished as Florida does in Dutch labour force data) in our analysis as second knowledge economy indicator.

Both creative and human capital theories measure person bounded and more communicative aspects of knowledge, stored in employees and entrepreneurs. The literature distinguishes two more conceptualisations that focus at the communicative aspects of knowledge and knowledge transfer. A large literature focuses on the growth potentials of firms due to an increased accessibility of information through information- and communication technologies (ICT) in their entrepreneurial operations, especially in urban areas (Drennan 2002). In theory, ICT as a general-purpose technology can accelerate organisational processes in terms of productivity. Contrary to other communicative indicators, ICT functions as an optimal vehicle of knowledge transfer when information is codified. We take this aspect (measured by computer usage per employee per 5-digit industry, localised in municipalities) as third indicator in our research. Fourth, much social-economical research focuses on social, cultural and communicative capital as sources for productivity gains in economic sectors (Cooke and Morgan 1998). This conceptualisation looks at trustworthy connections between economic actors as sources of social and economic networks. Especially communicative skills are required in that sense, and the ability to persuade and convince others. This not only requires capabilities of employees, but also from the quality of the (selection) environment in which they operate. An indicator based on communicative skills in network relations (first developed in McCloskey and Klamer 1995) is applied to the detailed municipal industry structure in the Netherlands, and functions as fourth indicator. We have to remark that, contrary to what the individual literatures try us to believe, theories on creative and human capital, communicative persuasiveness and ICT-sensitivity share a lot of common ground. We will come to this point later.

Our definition of the knowledge economy also addresses more technical and production oriented aspects of economic renewal that (endogenously) can lead to economic growth of firms. By tradition, the largest amount of literature focuses on these aspects (that are also central in the dictionary definition). The largest attention of governments and institutions is being paid to research and development (R&D) as sources of growth, because this input factor can be stimulated by subsidies (Foray 2004, Acs 2002). Although not all R&D-activities lead automatically to innovative output and growth (Black 2004), we use the number of R&D employees in firms as fifth indicator in our analysis. A special, and according to many independent indicator of R&D-activity, occurs when R&D-intensive firms cooperate in international networks, and their export is also technology driven. In those cases the literature speaks of high- and medium tech economic activities, which overrepresentation functions as source for internalising macro-economic growth Cortright and Mayer 2001). An indicator of relative overrepresentation of high- and medium tech industries is used as sixth indicator in our analyses. Innovation is generally regarded as the most import knowledge economic key source for economic growth. R&D is an input-indicator of innovation (intentions); it does not measure actual innovative output of firms. Several sources for innovative output exist (Jaffe and Trajtenberg 2002): patens and patent citations, copyrights, new product announcements and questionnaires in which firms are in great detail asked about their innovative behaviour (products and processes new for the market and new for the industry in which one operates). It is important to distinguish between technological and non-technological innovations. Both aspects are introduced in our analyses, by focussing on innovations in the third Community Innovation Survey (CIS3) of Statistics Netherlands and EUROSTAT. They are the seventh and eight' indicators in our analyses.

Most indicators measure the relative municipal employment specialization in the workplace of employees. We frequently use shift and share analysis to distribute regional data to the municipal level. Because of a large sectoral detail (we distinguish up to 728 industries) our indicators resemble actual municipal data to a large extent (Van Oort 2004). Table 1 gives descriptive statistics of the eight indicators used in our analysis. Individual maps of all indicators can be found in Raspe *et al*. (2004).

Table 1 Descriptive statistics of eight indicators of the knowledge economy

	Mean	Standard deviation	Minimum	Maximum
1. Education level[0]	1,92	0,08	1,76	2,21
2. Creative economy[2]	2,03	1,58	0,26	20,84
3. ICT-sensitivity[1]	0,75	0,11	0,53	1,27
4. Communicative skills[3]	0,53	0,08	0,33	0,80
5. R&D[5]	1,20	1,12	0,08	12,00
6. High-tech & Medium-tech[4]	7,70	4,69	0,00	27,00
7. Tech. Innovation[6]	50,44	9,71	20,88	81,95
8. Non-tech. Innovation[6]	61,06	7,67	39,38	83,11

N= 496 (Dutch municipalities)

[0] The education level is the weighted average (respectively with the weights: 1,2,3) of the educational levels: high (university –WO- and higher vocational education –HBO-), middle (intermediate vocational education –MBO-, higher general secondary education –HAVO- and pre-university education –VWO-) and low (lower general secondary education –MAVO- and lower vocational education –LBO-)

[1]The number of computers and terminal per sector (National Statistics; Computerization survey) is linked to the population firm establishments of on the level of municipalities (LISA database): the indicator measures the number of computers and terminals per employee on the level of a municipal.

[2] Based on: W. Manshanden, O. Raspe & P. Rutten (2004), The value of creative industry , *ESB*, 28-5-2004, jaargang 89 nr.4434

[3] Based on classification D. McCloskey & A.Klamer (1995), 'One Quarter of GDP is Persuasion', *American Economic Review*, vol. 85-2, p.191-1995

[4] High-tech and medium-tech firm are classified by their (detailed) SIC codes by their extend of research and export orientation, see OECD (2003), *Science, technology and industry scoreboard*. Paris.

[5] The R&D intensity per sector per Dutch province form the third Community Innovation Survey (CIS3, Statistics Netherlands) is redressed to municipalities (based on LISA database). See: Bruijn, P. de (2004), 'Mapping

innovation: regional dimensions of innovation and networking in the Netherlands', *Tijdschrift voor Economische en Sociale Geografie*, 95: 433-440.
[6] The innovation intensity per sector per Dutch province form the third Community Innovation Survey (CIS3, Statistics Netherlands) is redressed to municipalities (based on LISA database). See: Bruijn, P. de (2004). Innovation are registered as products and services, which are new in the market of sector.

3 Defining the urban dimension

Research and development, innovation and knowledge availability are unambiguously believed to be good for economic growth. The current embedding of knowledge externalities in endogenous economic growth theory leads to several important contributions that stress the *spatial* character of (urban) knowledge transmission in particular (Van Oort 2004). But despite its proclaimed importance, the relevance of proximity is one of the most controversially discussed topics in the context of innovative linkages and networks. A large and growing empirical literature has been built around testing this idea using data from cities. The reasoning is that if knowledge spillovers are important to growth and innovation, they should be more easily identified in cities where many people are concentrated into a relatively small geographic space so that knowledge can be transmitted between them more easily.

Indeed, the empirical literature recently finds a limited extent of spatial spillovers and a large degree of local clustering. Spatial proximity (clustering) is considered important by many for 'explaining' localised growth and value added created by knowledge-intensive industries (Audretsch and Feldman 1999). The marginal cost of transmitting tacit knowledge rises with distance. As tacit knowledge and human interaction become more valuable in the innovation process, geographical proximity becomes crucial to the innovation and growth process. The exchange of tacit knowledge may require a high degree of mutual trust and understanding. Most of the relevant empirical literature focuses on American states as the spatial unit of analysis. Some research, however, focuses on lower scales of analysis. Anselin *et al*. (2000), Wallsten (2001) and Black (2004), for instance, use metropolitan statistical areas in the US-context to analyse the spatial extent of R&D, innovation (patent) and growth externalities and find that local spatial externalities are present and important. Proximity matters in the transmission of innovation- and growth-based knowledge of dynamic firms, while distance decays tend to be rather steep (Jaffe *et al.* 1993). Similarly, a body of empirical literature on the Dutch spatial configuration of innovation and high-technology firms predominantly stresses the supposed 'urban field' character of the Dutch case: location and agglomeration aspects do not seem to have a systematic impact on the distribution of innovative and knowledge intensive activities over space (Kleinknecht & Poot 1992, Wever & Stam 1999). As hypothesized in this paper, many of these 'stylised conclusions' depend heavily on the definitions of innovation and knowledge intensity, on the research population and on the hypothesised functional relations over space.

The (geographic) literature also provides clues for non-contiguous (regime) types of spatial dependence. Quality of life aspects, regional labour markets, specialised urban networks and city size appear as significant locational considerations knowledge intensive firms (Van Oort 2004). The spatial structures of proximity (contiguous nearness at the municipal level) and heterogeneity (urban hierarchical and regional, not necessarily contiguous, spatial dependence) have been tested for in this study (and when appropriate been controlled for) by spatial dependence (spatial lag and spatial error) tests and spatial regimes respectively. When appropriate, the spatial coefficient in spatial lag estimation shows whether the dependent variable in a model (in our case localised firm growth or added value creation) is dependent on neighbouring values of this dependent variable. If so, conclusions can be reached on the significance and magnitude of this spatial dependence (Anselin 1988). Spatial heterogeneity on the other hand is modelled by spatial regimes, involving change-of-slope regression estimation over various types of locations that theoretically 'perform' differently. Three sets of spatial regimes are distinguished, each indicating aspects of urban structures at different spatial scales.

(1) On the macro-level, three national zoning regimes have been distinguished: the Randstad core region, the so-called intermediate zone and the national periphery (figure 1). Distinguishing between macro-economic zones in the Netherlands is based on a gravity model of total employment concerning data from 1996. The Randstad region in the Netherlands historically comprises the economic core provinces of Noord-Holland, Zuid-Holland and Utrecht, the intermediate zone mainly comprises the growth regions of Gelderland and Noord-Brabant, while the national periphery is built up by the northern and southern regions of the country. This zoning distinction is hypothesised as important in many studies on endogenous growth in the Netherlands, in the sense that the Randstad region traditionally has better economic potential for development (cf. Van Oort 2004).

(2) On the meso-level we distinguish a labour market induced connectedness regime from a non-connectedness regime (figure 2). This spatial regime concerns commuting based labour market relations. In the figure, core and suburban municipalities together comprise the connected regime, as opposed to the other types of locations that are characterised as non-connected. The three types of locations have been distinguished, initially based on municipal data for 1990-1999. The classification is based on the dependency of a municipality's population upon employment and services proximity and accessibility. Urban core areas have an important employment function. More than 15,000 persons commute into these municipalities (while living somewhere else) on a daily basis. Municipalities where more than 20 per cent of residents commute to central core locations are labelled suburban. The literature finds in general that urban

areas in the connected regime show higher economic growth and innovation rates than areas in the non-connected regime (e.g. Anselin *et al.* 2000). As becomes clear from figure 2, locations in the connected regime are not necessarily adjacent to each other.

(3) The third set of spatial regimes is constructed using the degree of urbanisation of municipalities (figure 3). Following Dutch standards of urbanisation, cut-off population thresholds of 200,000 and 45,000 inhabitants distinguish large and medium-sized cities in the Netherlands from small cities and rural municipalities.

In sum, these three aspects of spatial heterogeneity constitute three spatial levels of urban constellation: the urban level itself, the functional (commuting) region and the meso-level 'agglomerative fields' of the Randstad core region compared to its adjacent intermediate zone and the national periphery.

4 A synthesis of spatial knowledge indicators

In the previous section different aspects of the knowledge economy were introduced: the level of education of the working population, ICT-related employment, innovation (output), research and development (innovation input), the representation of high-technology sectors, and skills related to handling information and creativity. The spatial repercussion of the complex of indicators differs a lot (in this paper the individual maps of the eight indicators are not included, see Raspe *et al* (2004) for these maps). But a lot of indicators also showed spatial association. In this chapter we will distillate and describe the independent dimensions (factors) that form the underlying level of the eight indicators and that can be seen as independent pillars in the urban knowledge economy. All eight indicators were first standardised into z-scores, because we are interested in similarities in their spatial pattern, not in their individual contribution to the knowledge economy.

We first carried out a factor analysis with VARIMAX-rotation[2] to group the municipal scores of the eight indicators of the local knowledge economy into spatially independent underlying factors. Often, this also means sectoral (in)dependence. For example the spatial correlation between the level of education and the use of ICT seems obvious: highly educated employees often use computers in their business processes (on the sectoral level the correlation is 0.36). The spatial patterns show an even stronger correlation: an regional overrepresentation of highly educated employees coincides with strong specializations in ICT-use (on the regional level the correlation is 0.58). Of course, section 2 made clear there are also theoretical motives that clarify why the eight indicators are different.

[2] Factor analyses is a statistical technique to identify the underlying variables (named factors) in a dataset in which multiple characteristics are included, that simultaneously show mutual correlation. This technique is often used to remove the overlap between the different indicators and reduce the characteristics to independent factors: the similarity within a factor is high while low between the factors.

Table 2 Factor scores in the knowledge economy

Indicators:	***FACTORS:***		
	Factor 1 'Knowledge workers'	**Factor 2 'Innovation'**	**Factor 3 'R&D'**
ICT-sensitivity	**0.764**	0.369	0.233
Education level	**0.960**	0.120	0.037
Creative economy	**0.473**	0.114	-0.350
Communicative skills	**0.933**	-0.003	-0.070
High-tech and medium-tech	-0.169	0.239	**0.790**
Research and Development	0.176	0.102	**0.832**
Innovation (technological)	0.129	**0.899**	0.217
Innovation (non-technological)	0.155	**0.911**	0.071

The result of the factor analysis is a three-factor structure. Table 2 shows the factor scores: the correlation between the eight individual indicators and the three remaining factors. The three factors can relatively unambiguously be interpreted. The third factor, labelled 'R&D', is usually most identified with the knowledge economy. The factor is closely related to the indicators research and development and the relative presence of high-tech and medium-tech enterprises. Concerning their content, there is a large overlap between these two indicators. R&D is an input factor in knowledge processes. The factor labelled 'innovation' is build up by the indicators of innovation output, both technological and non-technological in character. Regions that have high scores on this factor contain relatively many enterprises that introduced new products or services to the market or carried out new business processes in the recent years. Remarkable is that the non-technological innovators are smaller in number of employees, but are spatially concentrated in the same regions as the technologically oriented innovators. The factor 'innovation' combines both types. Remarkably, the number of employees that carry out research and development is sectorally and spatially clearly a different indicator than the outcome of research, innovation. After all not every research leads to new products or services. The factor 'knowledge workers' finally, shows high scores on ICT-sensitivity, education level, employment specialized in communicative skills and the amount of creative economic sectors. As mentioned in section 2, this common conceptual ground did not come as a big surprise to us. Generally, this factor is characterized by employment specializations with a high degree of human capital. Locations with high factor-scores have relatively much employees with a high level of education, who use a lot of computers and possess skills that have to do with creativity, communication and persuasiveness. They are in the frontline of the ICT and information economy. These knowledge workers are important in the diffusion process of knowledge, not only codified knowledge but also the more difficult transferable tacit knowledge (Van Oort *et al*. 2003). Due to their skills, creativity and modern ICT-applications, knowledge workers guide the "throughput" in economic renewal and diffusion processes, especially in relation to business services. It is important to consider this (less 'hard' en therefore often neglected) dimension simultaneously with the (technical) industrial factors (R&D and technological innovation). After all they equally qualify as conditions or sources for innovation and hence embody economic renewal.

The spatial patterns of the factor scores are presented in figures 4, 5 and 6, and summarised for the spatial regimes in figure 7. We defined three statistically independent dimensions in the employment oriented knowledge economy - respectively the input ('R&D'), the throughput ('knowledge workers') and the output ('innovation') of economic renewal processes. Figure 4 shows the spatial pattern of the factor 'knowledge workers'. Figure 7 shows that there is a hierarchical structure on all three urban levels distinguished: the highest average factor scores are in central cities, in large cities and in the Randstad region. Figure 4 indeed emphasise larger cities and regions that are in the direct surroundings of these: the north wing of the Randstad region. Large cities like Amsterdam and Utrecht as well as their suburban surroundings have high scores on the factor 'knowledge workers'. Hilversum with the specialization on media activities has a top position. But also The Hague, Delft and Leiden have economies highly driven by knowledge workers. The logistic region Rotterdam has a position in the highest interval, but is lacking behind when compared to Amsterdam, The Hague and Utrecht. The suburban and surroundings of Rotterdam are also less oriented to knowledge workers. This region has a higher specialization in industrial activities, while knowledge workers (ICT using, high educated and communicative employees) are more directly bonded to business services. Also a number of medium-sized cities in the intermediate zone of the Netherlands, as Wageningen, Ede, Apeldoorn, Arnhem and medium-sized cities in the South like 's-Hertogenbosch, Eindhoven, Tilburg en Breda specialize in economies that are characterized by knowledge workers. The rural regions and de regions in de national periphery of the Netherlands are lagging behind in intensity of this employment.

The map of the second factor, 'innovation' (figure 5), shows a different spatial pattern than that of the knowledge workers. Especially regions in de western part (the Randstad), and the eastern part of the Netherlands show a higher degree of innovative businesses. The region Amsterdam, and the areas nearby this big city (Haarlemmermeer, Sassenheim en Velsen) are very innovative in character. Also Rotterdam forms the center of an innovative region. Compared to the pattern of knowledge workers we see a lager and more united spatial structure between the cities of The Hague and Rotterdam. Also several smaller cities and regions are connected to this structure, like Enschede and Deventer/Zwolle in the eastern part of the country. Also, the chemical industrial clusters like Sittard-Geleen (DSM) and Terneuzen (DOW Chemicals) form innovative hotspots. Remarkable is that the centrally located Utrecht region lacks relatively innovative businesses. Although the actual distribution over municipalities differs considerably from that of the factor knowledge workers, on average there still exists a hierarchy over all three urban levels of spatial regimes (figure 7). Municipalities in the Randstad region, larger cities and central areas of urban agglomerations still come to the fore as the foci of innovative activities. The hierarchy is less distinctive as in the knowledge workers variable.

Also the spatial pattern of the third factor, 'R&D' (figure 6), differs form the knowledge workers and innovating regional patterns. The regions in the western part of the Netherlands, which showed strong orientations to the knowledge workers and innovators dimensions, are characterized by relatively low degrees of R&D activities. Not the (largest) cities and the most dense economic parts of the Netherlands, but the regions in the southern and eastern national periphery are in front of (relative) R&D-employment specialization. These are the regions that have a stronger industrial orientation, the regions that functioned as an overflow area for the industrial activities that left the Randstad and other dense parts (Van Oort 2004). The Eindhoven region (with Philips and ASML), Tilburg, Wageningen, De Bilt, Delft, Zijpe (with their universities and research institutes) and Gilze-Rijen, Emmen and Terneuzen (with technologically oriented multinational firms) are the R&D hotspots in the Netherlands. From figure 7 it becomes clear that on average urban hierarchy does not apply to the R&D-factor. Municipalities in the Randstad region, in the largest cities and in central areas of cities have the lowest average scores on the R&D-factor. Instead, the municipalities in the intermediate zone of the country, medium-sized cities and the non-urban areas in terms of labour market connectedness have economic structures that best link to the R&D-factor.

5 Spatial econometric analyses on growth and value added

In tables 3 and 4, the econometric models that we ran are summarised. Below the tables technical explanation on the models is provided. The models are numbered over the two tables – models (1) to (5) on employment growth in the period 1996-2002 in table 3 and models (6) and (10) on added value patterns per squared kilometre (log) in table 4. In order to correct for high growth rates when growing from a low base, employment growth is defined as the growth in employment from 1996 till 2002 relative to the average potential labour force (people in the range 15-65 in age) in municipalities. For the same reason, value added is measured relative to municipalities' physical sizes (relative to employment density gave the same model results). The three factors 'knowledge workers', 'innovation' and 'R&D' are introduced according to the definitions given in section 4. The three factors are uncorrelated to each other, what therefore immediately solves possible multicollinearity problems. Five remarks should be made beforehand. First, the three factors are measured in standardised values (z-scores with average 0 and standard deviation 1). We are interested in which knowledge economy factors are *relatively* more profoundly attached to economic growth and value added. We do not want to disentangle the absolute contribution of the three factors to employment growth and value added, but we want to investigate whether other than R&D-based aspects have a relation with economic performance in cities and regions. The inclusion of a constant in all models gives an indication of the level of average growth and value added without any other explanatory variables. Second, and in line with the first remark, the weighing of different factors in terms of policy measures is not up to us researchers. That is interesting for policy makers. We treat all three factors equally in the models in order to determine their simultaneous relationship with growth and value added. Third, many control variables influencing employment growth and value added should ideally be included, like size and specializations of a region's and municipalities' economy, agglomeration factors and accessibility factors (Van Oort 2004). But, indirectly these factors are already present in the eight indicators that form the basis of the three knowledge economy factors. There, the size and specializations of all industries are weighed in their build-up of ICT-usage, innovation-intensity, educational level of the employees, etc. Fourth, all models turned out to be best fit by spatial models using w_2 (distance squared) spatial weight model, in which distances are measured by kilometres (all models were tested for w_1 and w_3 distance weights relevance). This already leads us to conclude that the indicators of economic performance are clustered, but in a very localised way (very proximate to each other). Fifth, the structure of the models respects spatial dependence, but only within the Netherlands. Spillover effects to international headquarters or large corporations outside the Netherlands are plausible, but not measured in our analyses. Since we focus on localised policy measures that are regionally defined, this still serves our research questions well.

Table 3 Econometric models on employment growth (1996-2002) in municipalities in the Netherlands (n=496, t-values in parentheses)

Explanatory variables:	(1) Basic model (OLS)	(2) Spatial lag model	(3) Spatial lag model with urban size regimes			(4) Spatial lag model with national zoning regimes			(5) Spatial lag model with labour market regimes		
			Large	Medium	Small	Randstad	Interm. zone	Nat. periphery	Central city	Suburban	Other
Constant	89.819	50.586	136.686	119.789	45.677	70.842	54.220	52.518	97.644	47.318	53.531
	(30.311)	**(4.701)**	(0.637)*	**(6.058)***	**(5.185)***	**(4.761)**	**(5.253)**	**(5.749)**	**(2.456)**	**(4.971)**	**(5.744)**
Factor 1:	14.737	13.634	-5.395	-21.527	10.674	2.471	14.342	15.665	0.077	8.735	20.014
Knowledge workers	**(4.968)**	**(4.700)**	(-0.065)*	(-1.937)*	**(3.107)***	(0.441)	**(2.943)**	**(3.052)**	(0.004)	(1.945)	**(3.894)**
Factor 2:	15.431	13.504	-81.096	8.398	10.638	20.827	13.242	9.633	-10.910	16.825	12.869
Innovation-output	**(5.206)**	**(4.613)**	(-0.516)	(0.905)	**(3.392)**	**(2.569)**	**(2.165)**	**(2.300)**	(-0.730)	**(3.915)**	**(2.969)**
Factor 3:	-0.801	0.076	-60.091	24.834	2.325	-8.835	9.045	-3.225	-9.990	1.814	-2.633
R&D	(-0.270)	(0.026)	(-0.475)*	**(3.058)***	(0.754)*	(-1.227)*	**(1.986)***	(-0.688)*	(-0.905)	(0.359)	(-0.665)
Spatial coefficient (ρ)	-	0.430		0.445			0.356			0.442	
		(4.701)		**(4.950)**			**(3.688)**			**(4.815)**	
Test statistics:											
R^2	0.095	0.118		0.157			0.156			0.131	
Max. likelihood	-2779.80	-2769.37		-2757.78			-2759.77			-2765.52	
LM (BP)	8.28	6.84		6.07			5.27			5.81	
	(0.004)	(0.077)		(0.087)			(0.093)			(0.071)	
LM (ρ)	30.284	-		-			-			-	
	(0.000)										
LM (λ)	26.225	0.139		-			-			-	
	(0.000)	(0.708)									
LR (ρ)	-	20.865		22.876			12.489			21.741	
		(0.000)		(0.000)			(0.000)			(0.000)	
Chow-Wald	-	-		23.755			19.116			7.756	
				(0.003)			(0.014)			(0.457)	

Technical explanation table 3:
Values of log-likelihood are not comparable over populations of all and old establishments. Following Anselin *et al*. (1995), LM (ρ) and LM (λ) are statistics for the presence of a spatial lag in the dependent variable and in the residual respectively, with a critical value of 3.84 at the 5 per cent level of significance (marked +). LM (BP) tests for homoscedasticity of regression errors using the Breusch-Pagan Lagrange multiplier test for normal distributed errors. The spatial weight matrix used is w_2 (row standardised, distance-squared), probability levels (p-values) are presented in the tables. Significant p-levels are printed in bold. Models with w_1 (single) distance weight matrices and w_3 (triple) distance weight matrices have a less significant model fit. The spatial Chow-Wald test is distributed as an F-variate and tests for structural instability of the regression coefficients over regimes (Anselin 1995, p.32). Significant results (95 per cent confidence interval) of the spatial Chow-Wald in general and on individual coefficients (rejection of H_0 of joint equality of coefficients over regimes) are marked (*). All variables are log transformed and corrected for extreme values.

Table 4 Econometric models on added value per km^2 (2002, log) in municipalities in the Netherlands (n=496, t-values in parentheses)

Explanatory variables:	(6) Basic model (OLS)	(7) Spatial lag model	(8) Spatial lag model with urban size regimes			(9) Spatial lag model with national zoning regimes			(10) Spatial lag model with labour market regimes		
			Large	Medium	Small	Randstad	Interm. zone	Nat. Periphery	Central city	Suburban	Other
Constant	0.031	1.079	-0.435	2.524	3.929	2.981	1.252	1.336	2.892	0.625	0.649
	(-0.001)	**(6.486)**	(-0.902)*	**(6.038)***	**(2.816)***	**(8.463)**	**(6.006)**	**(6.767)**	**(2.819)**	**(3.238)**	**(3.956)**
Factor 1:	1.364	1.285	0.497	0.846	1.194	2.169	0.909	1.133	2.190	0.784	0.907
Knowledgeworkers	**(15.693)**	**(14.399)**	**(2.200)***	**(7.977)***	**(6.166)***	**(13.337)***	**(6.399)***	**(7.885)***	**(2.318)***	**(6.423)***	**(6.733)***
Factor 2:	0.793	0.682	0.463	0.068	1.534	0.681	0.708	0.529	-0.285	0.639	0.386
Innovation-output	**(9.134)**	**(7.757)**	(1.305)	(0.327)	**(4.892)**	**(3.086)**	**(3.968)**	**(4.378)**	(-0.729)*	**(5.622)***	**(3.388)***
Factor 3:	0.002	0.066	0.325	-0.093	1.352	0.144	0.415	-0.156	-0.254	0.212	0.016
R&D	(0.028)	(0.769)	(-1.138)	(-0.512)	(1.926)	(0.740)*	**(3.207)***	(-1.197)*	(-0.880)	(1.595)	(0.161)
Spatial	-	0.340		0.445			0.372			0.460	
Coefficient (ρ, λ)		**(4.216)**		**(6.315)**			**(3.714)**			**(5.824)**	
Test statistics:											
R^2	0.401	(0.417)		(0.669)			(0.590)			(0.539)	
Max. likelihood	-9023.46	-9014.39		-8871.93			-8969.38			-8953.86	
LM (BP)	3.998	2.15		1.83			1.604			1.60	
	(0.000)	(0.200)		(0.093)			(0.063)			(0.081)	
LM (ρ)	43.277	-		-			19.532			-	
	(0.000)						(0.202)				
LM (λ)	22.811	1.682		-			-			-	
	(0.000)	(0.194)									
LR (ρ)	-	18.152		45.784			14.543			35.506	
		(0.000)		(0.000)			(0.000)			(0.000)	
Chow-Wald	-	-		86.061			87.108			137.688	
				(0.003)			(0.000)			(0.000)	

Technical explanation table 4:
See below table 3. Following the outcome of the LM-test for spatial dependence is spatial model (4) with national zoning regimes estimated as a sptial-error model.

The Ordinary Least Squares model for employment growth (column (1) in table 3) shows the significance of the factors 'knowledge workers' and 'innovation'. The third knowledge economy factor ('R&D') turns out to be not significantly attached to local economic performances. Interestingly, this result does not provide support for a regional or local policy focussing on growth from R&D-intensive clusters. The results presented are much of interest from the broader perspective of those concerned with the location tendencies of knowledge-intensive growth. The test statistics of LM(ρ) and LM(λ) in Column (1) reveal the presence of spatial autocorelation dependency of the model (using w_2 distance weights). In column (2) in table 3, therefore, the model is estimated using a spatial lag specification. Spatial lag models make use of maximum likelihood estimation techniques, in which the explained variance is no longer an adequate measure for model fitting. The spatial coefficient indeed turns out to be significant. Introducing spatial dependency in the model alters the coefficients slightly when compared to the OLS base model (the constant changes considerably in magnitude and significance). Relative high values of R&D-specialisation in particular hampers growth dynamics, while high values of innovation and knowledge workers characteristics remain unambiguously connected to employment growth. The likelihood based measure (*ML* in the summary statistics of the tables) can be used to compare the model fit with that of the basic OLS model. It turns out that for the employment growth model, the fit considerably improves when the spatial lag is added to the model, as indicated by an increase in the log likelihood. Heteroscedasticity emerges as a problem in the OLS-model, but less so in the spatial lag models (see the LM[BP] statistics in the table). The interpretation of the model outcomes does not change when the spatial lag specification is applied. Columns (3a-c), (4a-c) and (5a-c) give spatial lag estimation, but with the allowance of structural change of coefficient estimates between spatial regimes. Column (3) shows that the 'knowledge workers' and 'innovation' dimension works out more favourably in connection with employment growth in small municipalities, as opposed to large and medium sized ones. Remarkably, in the medium-sized city dimension, the R&D-factor shows a positive relationship with employment growth, corrected for spatial proximity. The model fit again improves when compared to the OLS and spatial lag model without the urbanisation regimes., and the Spatial Chow-Wald test confirms the significance of the spatial regimes (especially because of the different signs and levels of significance of the 'knowledge workers' dimension and the constant (the latter is not significantly attached to employment growth in the largest cities regime). The relations found thus work out most profoundly in medium-sized and smaller urban environments. This conclusion questions the large-city urban focus of Dutch policy: highest potentials for growth connected to the knowledge economy are in smaller cities (that theoretically do not suffer from congestion). Column (4) in table 3 shows that the intermediate zone region most notably ‘exhibits’ the significant set of knowledge economy factors related to growth, as opposed to the Randstad region and (to a much lesser extent) the national periphery. This is remarkable, since most agglomeration indicators are attached to the Randstad region (Van Oort 2004). The model fit is slightly less than in the urban regimes model, but still considerably better than the OLS and spatial lag (sec) model. The regime of macro-economic zoning is significant, especially due to diverging scores on the R&D-factor. Column (5a-c) shows the significance of the connected spatial regimes (central cities and suburbs), as opposed to the unconnected regime. Central cities in the Netherlands are, as opposed to the theoretical literature, not the central foci of knowledge economy circumstances that are related to employment growth. Suburban municipalities in general have better cards to play in this respect. Remarkably, the labour market regimes of connectedness do differentiate over the R&D-factor, which is insignificant in all three regimes.

Table 4 shows the results of the econometric models made for (log) added value per square kilometre. The results are in magnitude and significance comparable to the employment growth models, except for the ‘knowledge workers’ dimension. In table 4, this factor shows considerably more significant attachment to the explained variable than in that of table 3. Large and medium-sized cities, the Randstad municipalities and central city and suburban municipalities now all have significant positive signs for the ‘knowledge workers’ variable. When value added is a policy goal alongside employment creation and growth, the attention shifts more to larger cities as potential investment areas for knowledge-intensive economic activities. The factor ‘knowledge workers’, attached to the service economy of larger metropolitan area, come to the fore as good ‘predictors’ of localised growth and value added concentrations in the Netherlands. Regions and locations with R&D-overrepresentation though are little attached to good economic performances, even when corrected for spatial dependency. This might also be the case in other small-scale West-European countries. The analyses show that urbanisation matters for employment growth in relation to knowledge economy characteristics in all different scales of urban analyses in the Netherlands, both defined by contiguous proximity (as envisaged by the spatial lag significance) and by the spatial heterogeneous regimes. No large city paradigm emerges, neither does an urban field conceptualisation hold true. This extends considerably the current debate on urbanisation and localisation externalities in relation to the knowledge economy, which focuses mainly on proximity based spillovers and knowledge transfer in R&D-intensive sectors.

6 Conclusions

The Dutch government has indicated that it wants to stimulate urban economies by focussing on knowledge economy potentials of metropolitan regions, especially indicated by R&D-intensity. We focused on three research questions. The first asked which causal aspects of the knowledge economy are important for economic growth, and can all these be measured for the Dutch economy? In the paper we introduced eight indicators of the knowledge economy on the municipal level of the Netherlands (n=469) that the literature indicated to be related to good (urban) economic performances: (1) innovative industrial firms, (2) innovative non-industrial firms, (3) employment in research and development, (4) representation of high- and medium-tech industries, (5) educational level of the working population, (6) ICT-adaptation in firms and industries, (7) an industry-specific indicator for communicative skills and (8) an indicator for the creative labour force. The second question asked what spatial and sectoral overlap these knowledge indicators have (is R&D indeed a good overall proxy?), and whether can they can be reduced to (one or more) uncorrelated "pillars" (factors) of the knowledge economy? We mapped the eight indicators and applied a factor analysis to determine statistically independent components. Three good interpretable factors remained: 'knowledge workers', 'innovation input (R&D)' and 'innovation output'. Descriptive analysis brought to the fore that regions specialised in R&D are not necessarily the one that inhabit industries and firms with larges innovations, e.g. new to the marker products or new to the industry production processes. Instead, the factor 'knowledge workers' is most profoundly attached to urban locations. The third question was whether these urban conditions coincide with good economic performances, even controlling for spatial proximity and spatial regime dependence. Can the relationship between knowledge factors and economic performance on the urban level more precisely be pinned down for the Dutch case? Table 5 shows the main results of the econometric models we presented.

Indeed, the 'knowledge worker' dimension turns out to be positively attached to urban economic growth and value added, much more than R&D-intensity does (the indicator central governments frequently apply). We conclude mixed on the urban and 'urban field' hypotheses. Regarding the urban hypothesis, the fact that a distance squared distance weight matrix fits the data best indicates that spatial relations are limited and urban fixed. The significance of the 'knowledge workers' dimension in practically all urban environments in the Netherlands indicates (employment) growth and added value potential for larger agglomerations. This questions Dutch policy initiatives that mainly focus on R&D as indicator of the urban knowledge economy. But the significance of several other spatial regimes though (especially those of the so-called intermediate zone and medium-sized and smaller cities) indicates that the urban structure related to the knowledge economy and economic performance is not straightforward hierarchical (largest cities are not always most attached to the knowledge economy). Both hypotheses (urban and non-urban) are too extreme to fit the Dutch situation.

Table 5 Summary of the spatial regression results

Explanatory variables: employment growth (1996-2002) and added value per km² (2002)		Constant	'Knowledge workers'	'Innovation'	'R&D'
Basic OLS		+	++	++	0
Spatial lag model with urban size regimes	Large	0	+	0	0
	Medium	++	+	0	+
	Small	++	++	++	0
Spatial lag model with national zoning regimes	Randstad	++	+	+	0
	Interm. zone	++	++	++	+
	Nat. Periphery	++	++	++	0
Spatial lag model with labour market regimes	Central	+	+	0	0
	Suburban	++	+	++	0
	Other	++	++	+	0

Technical explanation: This table is a compound of table 3 and 4. The regression values for employment growth and added value per km^2 are converted in 1 value, expressed in plusses and zeros. The following criteria are used: t-values < 1,96 are 0, t-values between 1,96 en 3,92 are '+' en t-values > 3,92 are '++'. When the scores differ between employment growth and added value per km^2 a compounded score is made. Combinations are: ['0' en '+' are together '+'], ['+' en '++' are together '++'], ['0' en '++' are together '+']

References

Acs, Z.J. (2002), *Innovation and the growth of cities*. Cheltenham: Edward Elgar.

Anselin, L. (1988), *Spatial econometrics: methods and models*. Dordrecht: Kluwer.

Anselin, L., A. Varga and Z.J. Acs (2000), Geographical and sectoral characteristics of academic knowledge externalities. *Papers in Regional Science* 79, pp.435-443.

Audretsch, D.B. and M.P. Feldman (1996), R&D spillovers and the geography of innovation and production. *The American Economic Review* 86, pp.630-640.

Black, G. (2004), *The geography of small firm innovation*. Dordrecht: Kluwer.

Cooke, P. and K. Morgan (1998), *The associational economy. Firms, regions and innovation*. Oxford: University Press.

Cortright, J. and H. Mayer (2001), High-tech specialization: a comparison of high-tech centres. *The Brookings Survey papers*, pp.1-18

Drennan, M.P. (2002), *The information economy and American cities*. Baltimore: The Johns Hopkins University Press.

Drucker (1959), P. *Landmarks of tomorrow: a report on the new post-modern world.* New York: Harper.

Florida, R. (2002), *The rise of the creative class.* New York: Basic Books.

Foray, D. (2004), *The economics of knowledge*. Cambridge Mass.: The MIT Press.

Godin, B. (2004), The new economy: what the concept owes to the OECD. *Research Policy* 23, pp.679-690.

Jaffe, A.B., M. Trajtenberg and R. Henderson (1993), Geographic localization of knowledge spillovers as evidenced by patent citations. *The Quarterly Journal of Economics* 36, pp.577-598.

Jaffe, A. and M. Trajtenberg (2002), *Patents, citations and innovation. A window on the knowledge economy.* Cambridge Mass.: The MIT Press.

Kleinknecht, A. and T.P. Poot (1992), Do regions matter for R&D? *Regional Studies* 26, pp.221-232.

Lucas, R.E. (1988) On the mechanism of economic development, *Journal of Monetary Economics* XXII, pp. 3–42.

Machlup, F. (1962), *The production and distribution of knowledge in the United States.* Princeton: University Press

Mathur (1999), V.K. Human-capital-based strategy for regional economic development, *Economic Development Quarterly* XIII, pp. 203–216

McCloskey, D.N. and A, Klamer (1995), One quarter of GDP is persuasion. *American Economic Review* 85, pp.191-195.

Nota Ruimte (2004), *Nota Ruimte – Ruimte voor Ontwikkeling.* Ministry of Housing, Spatial Planning and the Environment, The Hague (in Dutch).

OECD (2004), *Global knowledge flows and economic development*. Paris: OECD.

Van Oort, F.G., A. Weterings and H. Verlinde (2003), Residential amenities of knowledge workers and the location of ICT-firms in the Netherlands. *Journal of Economic and Social Geography (TESG)* 94, pp. 516-523.

Van Oort, F.G. (2004), *Urban growth and innovation*. Aldershot: Ashgate.

Raspe, O., F.G. van Oort and P. de Bruijn (2004), *Spatial patterns in the Dutch knowledge economy.* Rotterdam: Nai Publishers (in Dutch).

Wallsten, S.J. (2001), An empirical test of geographic knowledge spillovers using geographic information systems and firm-level data. *Regional Science and Urban Economics* 31, pp.571-599.

Wever, E. and E. Stam (1999), Clusters of high-technology SME's: the Dutch case. *Regional Studies* 33, pp.391-400.

Figure 1 National zoning spatial regimes

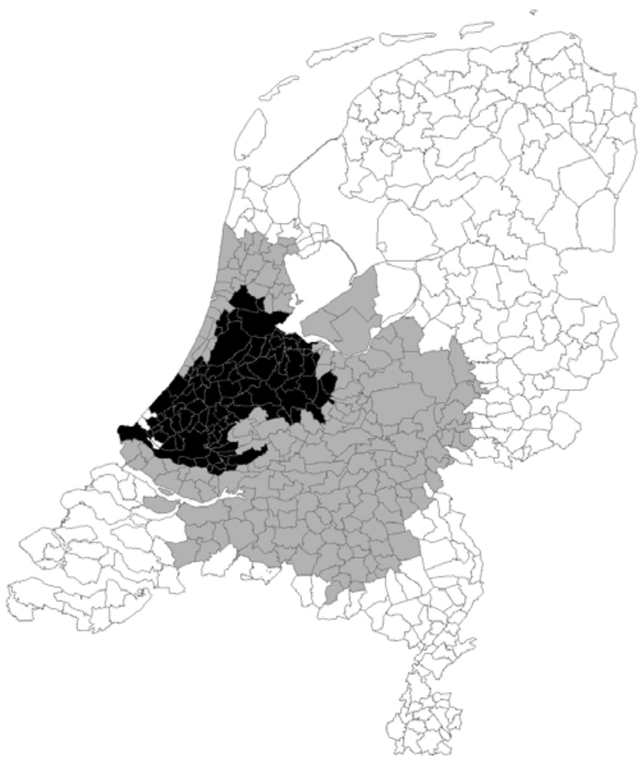

Figure 2 The labour market spatial regimes

Figure 3 Urban size (municipal) spatial regimes

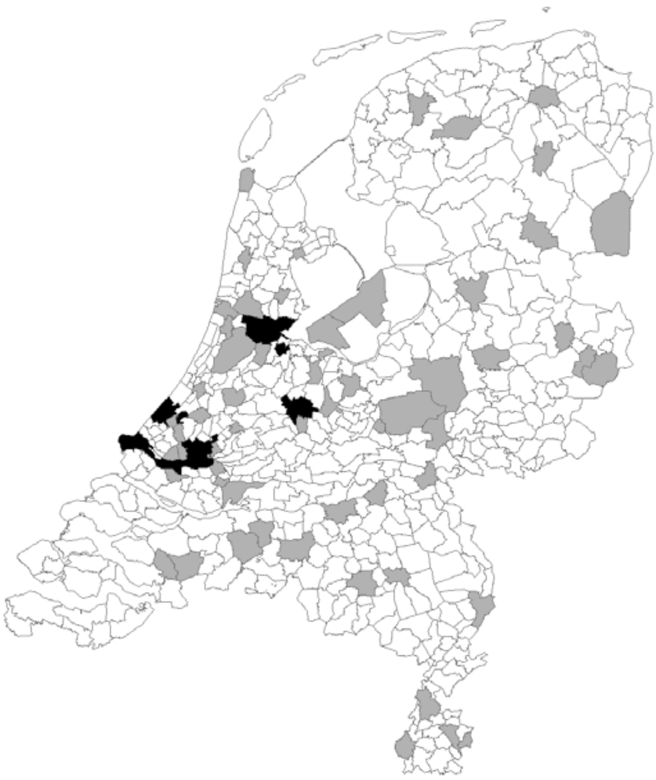

Figure 4 The 'Knowledge workers' dimension (factor 1)

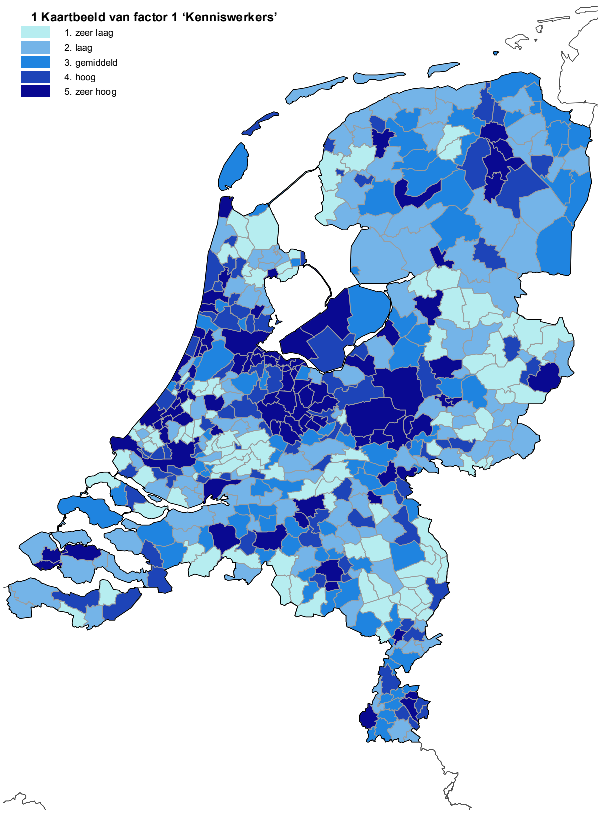

Figure 5 The 'Innovation' dimension (factor 2)

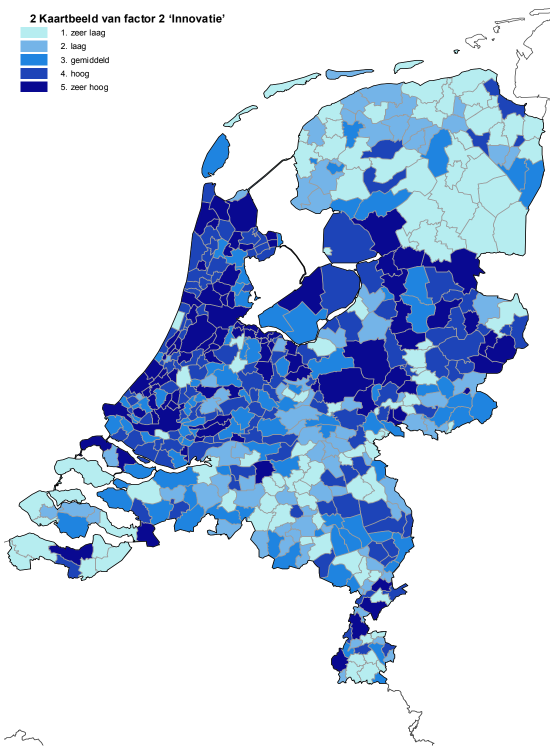

Figure 6 The 'R&D' dimension (factor 3)

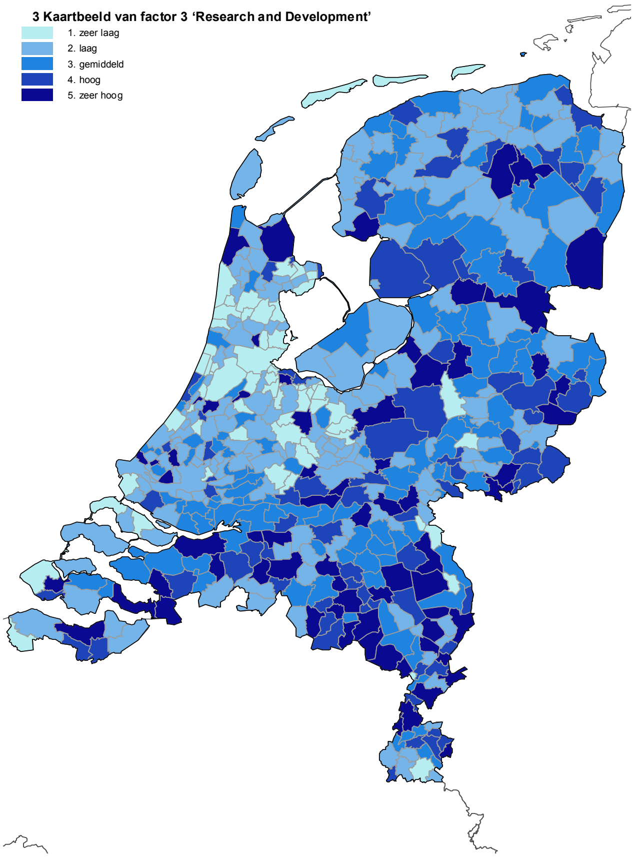

Figure 7 Independent factors of the knowledge economy in urban regimes