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Abstract

In this paper we contribute to the longstanding discussion on the role of knowledge to economic growth in a spatial context. We observe that in adopting the European policy strategy towards a competitive knowledge economy, The Netherlands is – as most European countries - mainly oriented towards industrial, technological factors. The policy focus is on R&D specialized regions in their spatial economic strategies. We place the knowledge economy in a broader perspective. Based on the knowledge economy literature, we value complementary indicators: the successful introduction of new products and services to the market ('innovation') and indicators of skills of employees ('knowledge workers'). Using econometric analysis, we relate the three factors 'R&D', 'innovation' and 'knowledge workers' to regional economic growth. We conclude that the factors 'innovation' and 'knowledge workers' are more profoundly related to urban employment and productivity growth than the R&D-factor. Preferably, urban research and policymakers should therefore take all three knowledge factors into account when determining economic potentials of cities.

Introduction

The concept of the *knowledge economy* is the central focus point of the European Union's socio-economic agenda. Five years ago the European Union launched an ambitious agenda for reform to set itself a new strategic goal for the next decade: to become the most competitive and dynamic knowledge-based economy in the world - capable of sustainable economic growth with more and better jobs and more social cohesion (EU 2000). But since, productivity has grown faster outside Europe and investments in research and development have not caught up with Asian and American levels. A recent report form the High Level Group in November 2004 advises that Europe needs to improve its productivity and employ more people by streamlining the Lisbon strategy even more to the direction of increasing and improving investment in Research and Development (R&D), ICT and a strong industrial base (EU 2005).

Also in the (economic) literature of the recent years the 'knowledge economy' has a great deal of attention: 'knowledge' is considered to play a crucial role as a powerful engine for growth. Despite this attention in policy documents and the literature it is not unambiguously clear what is meant by the 'knowledge economy'. Europe's strong focus on technological development and R&D is remarkable, but for good reason. R&D and high-tech economic activities have an overwhelmingly dominant share in the common statistics and indicators used. These data mostly stem from the OECD - an important promoter of the 'knowledge economy' -, which collects nearly sixty indicators aiming at measuring the knowledge-based economy (Godin 2004).

In this paper we wonder whether 'R&D' statistics as central indicators of the knowledge economy give sufficient insight in how the knowledge economy functions. This is especially important in relation to the economic growth potential of the knowledge economy. Besides a clear definition of knowledge economy, the spatial consequences of a knowledge economy are not unambiguously clear either. In this paper we therefore also focus on spatial patterns and differences in the knowledge economy in the Netherlands as a European example. Like most West-European national governments, the Dutch government has recently formulated a spatial vision on triggering the knowledge economy:

> "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) 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 summarizes why we were motivated to apply a longstanding academic discussion on the role of knowledge to economic growth (Foray 2004, Acs *et al.* 2002) to the local and regional situation of the Netherlands. In this discussion, the role of innovation clusters and agglomeration economies is an important element (see Rosenthal and Strange (2006) for an overview). Starting in the early nineties of the last century, a vast quantity of empirical research has accumulated on the issue of agglomeration externalities. Models especially focus on the issue of isolating localized intra-industry (specialization) and inter-industry (variety) externalities contexts (Frenken *et al*. 2006). A problem in determining the exact nature and extent of local advantages of agglomeration is that they are context dependent on at least three dimensions: geographical, temporal, and sectoral.

First, it is likely that local agglomeration externalities vary over countries, as factors affecting agglomeration forces, like labour mobility and spatial and economic policies, are different from one country to another. Second, it is plausible that the time frame matters. Agglomeration externalities will differ sharply between periods of economic growth and periods of decline. A third relevant aspect is the industrial context: firms in some industries benefit more from geographical concentration than their counterparts in other industries (Combes *et al*. 2004, Henderson 2003). Relatively few empirical studies have satisfyingly focused on all three contexts simultaneously. Besides, a drawback of this literature is that it tests for the existence of statistically significant relations between indicators of agglomeration on the one hand, and industrial productivity and growth on the other. Whereas each of the different kinds of agglomeration benefits are embedded in mechanisms like spillovers and a range of cost savings due to concentration, none of these mechanisms is empirically modeled. This methodology, in fact, leaves the concept of agglomeration economies as a black box. This limits its usefulness for economic policy. This paper does not open the entire black box of agglomeration economies – but contributes to the discussion by determining different kinds of localized knowledge densities within economic growth clusters (each with distinctive causal relationships).

In this light, the choice of Eindhoven as central focal point for spatial-economic development in the Netherlands appears arbitrary. The central indicator being research and development investments, 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 a technical university. But do all agglomeration circumstances related to knowledge externalities fit best in the Eindhoven region? The Dutch economy consists mainly of service- and distribution based sectoral specializations, and hence a focus on technical innovation (measured by R&D) does not seem to encompass al opportunities in the Dutch knowledge economy. In this paper we agree that 'the knowledge economy' offers perspectives for economic growth, but that it is rather unclear what elements the knowledge economy actually consists of, how it can be fully measured in statistical indicators and in which regions and cities in the Netherlands the knowledge economy has its most significant imprints. One step further, the association of these imprints with employment and productivity growth on urban spatial scales is often difficult to measure because of data limitations (Drennan 2002). This paper focuses on these caveats in prior research. Indeed, many of the arguable 'stylised' conclusions on the spatial knowledge economy depend heavily on the definitions of such an economy, the research population and the spatial level of analysis. Because we are able to measure knowledge economy indicators at the municipal level in the Netherlands (n=469) our analyses are not subject to many of these restrictions. We use data for the period 1996-2003 for testing.

In short, we focus on three research questions. (1) Which causal aspects of the knowledge economy are discussed in the literature as important for urban-economic growth, and can all these be measured for the Dutch economy? (2) What spatial and sectoral overlap do these knowledge indicators have, and can they be reduced to uncorrelated "pillars" (factors) of the knowledge economy? And (3) can a relationship between knowledge factors and economic growth on the urban cluster level be found for the Dutch case?

This paper is further organised as follows. The next section scans the literature for identifying knowledge economy indicators that are hypothesized to be related to economic growth. Eight indicators are distinguished and discussed on the municipal level. The third section uses factor analysis to synthesize the eight indicators into three distinctive factors. The fourth section presents the results of econometric models that link the three factors to employment and productivity growth on the cluster (urban) level in the Netherlands. The last section concludes and evaluates what insights are important for urban-economic policy.

Knowledge economy: definition and indicators

The recent attention paid to the knowledge economy is embedded in a longer tradition. During the 1960'ies 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 labor 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). As economists agree that the ultimate goal should be economic (employment and/or productivity) growth, there is debate on which knowledge-economic aspects best contribute to that. Because of this discussion, the theoretical and empirical literature has broadened the concept, from technological to also social and informational dimensions. We will discuss this literature shortly below, and distill (measurable) indicators from it. We start with the embedding of knowledge in organizations, filtering down into a definition of knowledge and knowledge economy, then followed by a discussion of the indicators that are related to urban-economic growth.

In analyzing 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 organizations. Because activities in organizations have to be integrated, co-ordination of these tasks and functions is at the heart of the organization's economic process. In general, co-ordination of tasks and functions induces costs. Knowledge about processes and products makes this co-ordination more efficient and less costly. The knowledge economy, especially the information density because of ICT's, can make time and physical distance less stringent constraints for economic functioning and production chains of organization 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 transformation of information into 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 knowledge networks coincides with a growing importance of knowledge attached to human capital and transactional relations within and between organizations. The knowledge-based organization differs substantially from the classical organization. Knowledge is at the core of the enterprise and labor 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 personalized networks in which interaction and face-to-face contacts prevail. These immaterial assets determine increasingly, and complementary to material assets, the value of an organization.

In the above vision, knowledge transforms information and data into useful applications for businesses that lead to economic (productivity) growth. Most information that 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 conceptualization, we propose a broad definition of knowledge economy. *Knowledge* then is the adding up of abilities (capabilities, creativity and persistency) to recognize 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 (and appendix 1) for the sources of the empirical indicators (translated from the literature) 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 firms – a labor 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. 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, localized growth effects from consumptive power of the creative class, in amenity–rich urban environments in which they live. Because his research shows (although not unambiguously accepted) that creativity as motor for local economic potential can be considerable, we added the presence of creative industries (distinguished by the Florida-definition in Dutch labor 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 conceptualizations 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 organizational 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, localized 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 conceptualization 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 (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 internalizing 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.

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]	2,81	1,09	1,00	5,00
6. High-tech & Medium-tech[4]	7,70	4,69	0,00	27,00
7. Tech. Innovation[6]	3,00	1,40	1,00	5,00
8. Non-tech. Innovation[6]	3,00	1,38	1,00	5,00

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 Manshanden *et al.* (2004).
[3] Based on classification by McCloskey & Klamer (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).
[5] The original indicator of 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: De Bruijn (2004) In this paper we constructed an interval variable based on map 13 (p. 73) in Raspe *et al*. (2004)
[6] Based on Raspe *et al*. (2004). The original indicator of 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: De Bruijn (2004). Innovation are registered as products and services, which are new in the market of sector. In this paper we constructed an interval variable based on map 14 (p. 75) and 15 (p. 77) in Raspe *et al*. (2004)

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).

In our paper we agree with Acs *et al.* (2002), who indicate that in order to understand the exact role that knowledge and, therefore, innovation plays in the economy, the measurement of knowledge inputs (as R&D expenditures), intermediate output (such as the number of inventions which have been patented) and knowledge outputs (such as new product sections) is critical. The valorisation phase of innovation processes should be included in studying localized economic dynamics. In this valorisation, it is important to distinguish between technological and non-technological innovations. Both aspects are introduced in our analyses, by focusing on successful innovations as reported in the third Community Innovation Survey (CIS3) of Statistics Netherlands and EUROSTAT. They are the seventh and eight' indicator 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 appendix 1.

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 this complex of indicators differs a lot. But a lot of indicators also showed spatial association. In this chapter we will distillate and describe 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 standardized. We first carried out a factor analysis with VARIMAX-rotation [1] 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 more often use computers in their business processes - on the sectoral level the correlation is 0.36 (the spatial patterns show an even stronger correlation: 0.58). Of course, section 2 made clear there are also theoretical motives that clarify why the eight indicators are different.

Table 2 Factor scores in the 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

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, labeled '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 labeled 'innovation' is build up by the indicators of innovation output, both technological and non-technological in character. Locations 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. Generally, this factor is characterized by employment specializations with a high degree of human capital. Locations with high factor-scores 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 in economic renewal and diffusion processes especially in relation to business services. It is important to consider this (less 'hard' and therefore often neglected) dimension simultaneously with the (technical) industrial factors - R&D and technological innovation. After all might equally qualify as conditions or sources for economic renewal.

The spatial patterns of the factor scores are presented in figures 1, 2 and 3. Figure 1 shows the spatial pattern of the factor 'knowledge workers'. In this pattern we see a hierarchical structure on levels of urbanity: the highest average factor scores are in cities and in the Randstad region. Large cities like Amsterdam and Utrecht as well as their suburban surroundings have relatively high scores on this factor'. 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 oriented firms. The logistic region Rotterdam has a position in the highest interval, but is lacking behind when compared to Amsterdam, The Hague and Utrecht. Also a number of medium-sized cities in the intermediate zone of the Netherlands (the region adjacent the Randstad region) specialize in economies that are characterized by knowledge workers. The rural regions and the regions in the national periphery of the Netherlands are lagging behind in intensity of this employment.

The map of the second factor, 'innovation' (figure 2), shows a different spatial pattern than that of the knowledge workers specialization. Especially regions in the 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 city are relatively innovative in character. Also Rotterdam forms the center of an innovative region. Some clear-cut chemical industrial clusters like Sittard-Geleen (DSM) and Terneuzen (DOW Chemicals) form innovative hotspots. Remarkable is that the centrally located Utrecht region relatively lags behind in the representation of 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 urban levels: cities and urban parts of the Netherlands have on average high scores. 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.

The spatial pattern of the third 'R&D' factor (figure 3) again 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 densest economic parts of the Netherlands, but the regions in the southern and eastern part of the country 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) and several other cities containing technologically oriented multinational firms and technical universities (like Tilburg, Wageningen, Delft and Terneuzen) are R&D hotspots in the Netherlands. On average an 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 labor market connectedness have economic structures that best link to the R&D-factor.

To summarize - we distinguished 8 indicators of the knowledge economy that can be reduced to three independent pillars of sectoral typologies of firms with different spatial imprints: 'knowledge workers', 'innovation' and 'research & development'. In the next paragraph we now turn to the relation between these three knowledge factors and economic growth.

Econometric analyses on employment and productivity growth

To test the relation between the knowledge intensity of businesses and their economic performance we link the knowledge factors to two dynamic economic performance indicators in an OLS-framework of analyses, controlling for other agglomeration variables: employment growth and productivity growth. Both growth indicators refer to municipal data (n=496) for the period 1996-2003. Productivity is measured as labor productivity: the gross added value per employee (in full time equivalents). Both employment and productivity growth are defined as the log (level 2003 / level 1996). Figures 4 and 5 show the spatial patterns of both dynamic performance indicators. In general, large and medium sized cities have a higher gross added value, but also show higher productivity levels. Labor productivity is highest in the western part of the Netherlands (the Randstad region) in which the four big cities Amsterdam, Rotterdam, The Hague and Utrecht are located. Employment growth in 1996-2003 was the highest in this Randstad region and in medium-sized cities outside this region. Suburban regions show high growth figures as well. For productivity growth the catching-up effect of rural and regions in the national periphery appears substantial (in the most productive regions it is more difficult to grow the same rate as regions that grow from a relative small base).

Table 3 shows the descriptive statistics of all variables used in the analyses in this section. In testing the relationship between knowledge intensities and economic performance we introduce relevant control variables for agglomeration attributes other than the localized knowledge indicators (Van Oort 2004). A Dutch municipal data set on sectoral employment structures is used to construct control variables of various types of agglomeration economies - as hypothesized in the second section. Those indicators are as reminiscent as possible to those used in prior studies (Henderson 2003). Economic growth is determined by both local and national circumstances. The Netherlands is relatively urbanised with a population density of over 450 inhabitants per km^2 - this is of interest because it is small enough to offer a natural control for location-specific cultural attributes. Within the country, cultural and economic differences between locations are simply less important and more easily controlled than they would be between the major U.S. cities considered in previous studies. Still, the local or regional determinants influencing the productivity of firms embody external and agglomeration factors (localisation and urbanisation economies). We want to test whether initial spatial circumstances are connected to subsequent agglomeration processes (a ‘sources of growth’ analysis). Therefore, explanatory variables are constructed using data from the base year (1996) to reduce problems of simultaneity as much as possible [2]. Theories on clustering and intrasectoral knowledge spillovers contend that knowledge is predominantly sector-specific and hence that regional specialisation will foster growth. *CONCENTRATION (LQ)* is defined as a location quotient showing the percentage of employment accounted for by an industry in a municipality relative to that percentage nationally. It is calculated for three broad basic sectors: for industrial, distribution and business service activities. This indicator in particular comprises (intra-industry) localization or specialization economies. Alternatively, an opposing body of literature contends that regional diversity in economic activity will result in higher growth rates as many ideas developed by one sector can also be fruitfully applied in other sectors. In accordance to the literature, economic diversity is introduced by means of a Hirschman-Herfindahl-index of employment distributions over 49 sectors in all 469 municipalities – actually measuring the *lack* of diversity. We further introduce initial conditions of indicators that account for local-economic particularities present in certain spatial units that work out (positively or negatively) for all firms in different industries in the same manner. *EMPLOYMENT LEVEL* and *PRODUCTIVITY LEVEL* measure absolute employment and productivity values per municipality, and control for localized start-of-period development bases. Industry differences in wages are controlled using *WAGE LEVEL*, measuring the industry wage rate in 1996 at the regional level. The initial wage level and the initial employment level[3] and productivity level are hypothesised to have a negative relation with growth performances. Population density is used as a proximate indicator of urbanisation externalities stemming from a large concentration of economic activity *per se*, irrespective of its composition.

Table 3 Descriptive statistics of performance and control variables

	Minimum	Maximum	Mean	Standard deviation
Employment growth (1996-2003)	-2,62	5,84	0,06	1,12
Productivity growth 1996-2003 [log]	-0,09	0,36	0,08	0,04
'Knowledge workers' [factor 1]	-2,23	3,89	0,00	1
'Innovation' [factor 2]	-2,11	2,14	0,00	1
'Research & Development' [factor 3]	-1,91	3,95	0,00	1
Specialization industrial activities [log]	-1,56	0,58	-0,038	0,324
Specialization distribution activities [log]	-0,57	0,42	0,04	0,17
Spec. producer services [log]	-0,72	0,43	-0,16	0,19
Variety 1996 (HHI, n=49) [log]	-2,98	-0,86	-2,41	0,29
Population density [log]	1,42	3,81	2,63	0,45
Investment level [log]	3,96	4,45	4,11	0,06
Wage level [log]	4,19	4,65	4,39	0,07
Supply business areas growth [log]	-0,48	0,82	0,09	0,16
Employment level 1996 [log]	-2,75	3,84	0,028	1,04
Productivity level 1996 [log]	4,48	5,02	4,701	0,06

n= 496 (Dutch municipalities)

Sources: see table 1, Frenken *et al*. (2006), Raspe *et al*. (2004) and Van Oort (2004).

The main component of urbanization economies is the benefits from market size. *INVESTMENT LEVEL* concerns investments in immobile capital goods, excluding houses. The indicator is computed per fte, and data are taken from Statistics Netherlands (CBS). Newly built business premises attract economic activity that previously was not present in that location. To control for these potential causes for extreme high differential employment growth we included the growth in business sites in hectares (average 1996-2002) from the IBIS-database (see Van Oort 2004). Because border regions may have different economic growth figures due to (unmeasured) foreign economic concentrations (like the Ruhr-region in Germany of the Antwerp region in Belgium), a dummy variable was constructer for border municipalities.

Table 4 shows the results of the econometric models on the municipal level (n=496) of employment and productivity growth. For multicollinearity reasons we do no include highly correlated variables (see correlation table in appendix 2). The three knowledge-economy factors by definition (because of the VARIMAX-rotation in the factor analysis) are statistically independent. Regarding endogeneity, an unobserved characteristic of a municipality may affect patterns of economic location, which feeds back through establishment behaviour to affect the level of agglomeration. This problem is especially troublesome when measuring employment growth. One option is to instrument for the agglomeration variables – but because it is unclear how these instruments are appropriately constructed we took another (and simpler) approach. So as to minimize the importance of location-specific factors, it is tested whether dummy variables (fixed effects or random effects) should be included in the employment growth models for each of the 40 NUT3-regions represented in the data (as in Henderson 2003). The NUTS-3 regional level is of key important for investment-, export-, wage- and labour market characteristics (Frenken *et al.* 2006). The first (LSDV) model, introducing only the three knowledge economy factors, proved to be better specified when introducing fixed effects (using a Hausman test on random versus fixed effects). Test statistics of spatial (municipality) dependence reveal that no spurious spatial autocorrelation is present when using fixed effects estimation. The second (OLS) model introduces all control variables as well. From the Hausman test it becomes clear that fixed effects estimation is not superior to random effects estimation. Subsequently, from the LM(BP) test it turns out that region-specific random effects are not superior to OLS-estimation, because of a lack of a form of heteroskedasticity. We therefore used OLS-estimation. In this case, spatial autocorrelation remains an issue in the estimation. Therefore, the third model estimates a spatial error model. The spatial coefficient turns out to be significantly positive. In the productivity growth models, NUTS-3 regional random effects are introduced (after performing a Hausman test on random versus fixed effects) in the fourth model in table 4 with only the knowledge indicators as explanatory variables. The explanatory power of this FGLS-model is extremely low. The fifth model introduces the control variables. Again, FGLS-estimation appears optimal. In both models 4 and 5, no signs of spatial autocorrelation are found.

From table 4 it becomes clear that there is a significant (positive) spatial relation between the ‘knowledge workers’ factor and the ‘innovation’ factor and localized employment growth. R&D intensities are not significantly related to employment growth on the municipal level. This robust outcome holds also after controlling for all other variables, fixed-effects and spatial autocorrelation. Most controlling variables perform as expected: local specializations in producer service activities are positively related to employment growth; as are the investment and employment levels in the base year. Negatively related to localized employment growth are the initial wage level and sectoral variety (and to a lesser extend population density). In the productivity growth models, coefficients of the ‘knowledge workers’ dimension, the ‘innovation’ dimension, and localized specializations in industrial and distribution activities are positive. Negatively related to productivity growth are the initial productivity level, sectoral variety and the ‘R&D’ dimension. The sum of these outcomes indicate that specialization- and (employment) density based hypotheses of local economic growth are more relevant for the Dutch municipal data than variety-based hypotheses (compare Van Oort 2004). As a central economic indicator of economic performance, productivity (the amount of added value per full time equivalent employee) plays a important role in regional economic policy. We observe that the intensity of ‘knowledge workers’ and ‘innovation’ co-locates with productivity growth – but ‘R&D’ is not. R&D even appears to have a negative effect on productivity growth at the local level. This surprising result might have technical reasons (recall that R&D is measured in 2002 instead of the base-year 1996) or theoretical reasons. For instance, due to the fact that that not every R&D effort results in a productivity gain as the outcome of the 'trail and error' process of R&D and its valorization in new products. Also, the valorization of R&D investments can be in other countries in the case of multinationals, like Philips (Van Leeuwen & Van de Wiel 2003). Still, it is not certain that these aspects are exhaustive explanations for the negative coefficient in the models. Further (micro-level) research should be headed to this.

Table 4 OLS models on employment and productivity growth in municipalities in the Netherlands (n=496, t-values in parentheses)

	Employment growth 1996-2003 (log)			Productivity growth 1996-2003 (log)	
	LSDV	OLS	Spatial error	FGLS	FGLS
Constant	-0,714 (-1,01)	0,164 (0,926)	0,052 (0,23)	-0,001 (-.01)	0,018 (0,39)
Fac1 'Knowledge workers'	0,427 (7,88)**	0,218 (2,48)**	0,277 (2,99)**	0,056 (1,19)	0,315 (4,08)**
Fac2 'Innovation'	0,258 (4,33)**	0,099 (1,87)*	0,162 (2,89)**	0,056 (0,17)	0,109 (2,29)**
Fac3 'R&D'	-0,002 (-0,04)	0,059 (1,10)	0,051 (0,91)	-0,139 (-2,99)**	-0,130 (-2,54)**
LQ industrial activities (log)	-	0,077 (1,01)	0,053 (0.69)	-	0,168 (2,34)**
LQ distribution (log)	-	0,093 (1,56)	0,093 (1,56)	-	0,115 (2,10)**
LQ producer services (log)	-	0.175 (2,95)**	0.196 (3,23)**	-	-0,069 (-1,23)
Herfendahl index (log)	-	0,250 (4,15)**	0,276 (4,52)**	-	0,148 (2,65)**
Population density (log)	-	-0,112 (-1,71)*	-0,129 (-1,89)*	-	-0,043 (-0,74)
Investment level (log)	-	0,098 (2,08)**	0,117 (2,49)**	-	0,009 (0,25)
Wage level (log)	-	-0,106 (-2,19)**	-0,089 (-1,75)*	-	0,008 (0,18)
Supply business areas (log)	-	0,014 (0,31)	0,021 (0,469)	-	0,048 (1,16)
Dummy border regions	-	-0,229 (-1,75)*	-0,229 (-1,57)	-	0,094 (0,79)
Employment level (log)	-	0,414 (5,95)**	0,376 (5,26)**	-	-
Productivity level (log)	-	-	-	-	-0,307 (-6,35)**
Lambda (spatial coefficient)	-	-	0,799 (5,98)**	-	-
Regional fixed effects	Yes	No	No	No	No
Regional random effects	No	No	No	Yes	Yes
R^2	0,276	0,246	-	0,031	0,135
LIK	-681,75	-699,03	-690,12	-	-
Hausman	15,97 (0,001)	9,40 (0,742)	-	0,62 (0,892)	16,31 (0, 233)
LM (BP)	-	3,75 (0,053)	-	13.06 (0,000)	30.90 (0,000)
LM (ρ, w_1)	0.818 (0,366)	2,826 (0,092)	-	2,309 (0,128)	0,349 (0,554)
LM (λ, w_1)	2,077 (0.149)	10.890 (0,000)	-	2,490 (0,114)	0,573 (0,449)
LR (λ)	-	-	7,822 (0,005)	-	-
LM ρ (λ)	-	-	0,042 (0,837)	-	-

** significant at 0.05, * significant at 0.10. OLS-models with fixed effects are usually referred to as Least Squares Dummy Variables (LSDV) Models (Greene 2000, p.560). FGLS (Feasible Generalized Least Squares) reports for regional random-effects models. Hausman reports on the Hausman tests of random versus fixed effects (p-value). LM (BP) reports on the Breusch-Pagan Lagrange Multiplier test of significance of random regional effects (p-value). LM (ρ) and LM (λ) are statistics for the presence of a spatial lag in the dependent variable and in the residual respectively, following Anselin *et al*. (1996), (p-values). LR(λ) tests for the significance of the spatial dependence coefficient (p-values). The spatial weight matrix used is that of the (row-standardized) inverse distance weights w_1 (row standardised). Additional tests have been performed with inverse distance squared (w_2) and tripled (w_3) weight matrices. LQ stands for location quotient, LIK for log likelihood.

The overall conclusion is that high R&D-levels are not a sufficient growth condition for economic growth in urban clusters - the ‘knowledge workers’ and ‘innovation’ dimensions are significantly better linked to localized economic growth in the Netherlands. This questions the recent stress on R&D as knowledge-economic trigger by Dutch (and other European) governments. The way firms innovate (introduce new products and services to the market) and how knowledge workers act in economic processes (by a high level of ICT usage, a high level of education and a high level of communicative skills) is more connected to the ‘soft’ side of the knowledge economy as opposed to the ‘hard’ technological side. The coefficients on the specialization and diversity variables indicate that locally specialized contexts are related to economic growth. A localized production structure with relatively more than average producer services enhances employment growth, while overrepresentation of industrial and distribution activities fosters average productivity growth. Diversity retards growth. Urban growth in clusters is more generally fed by the presence of innovative and flexible firms that specialize in knowledge workers characteristics.

5 Conclusions

In this paper we contributed to the longstanding discussion on the role of knowledge to economic growth in a spatial context. We observe that in adopting the European policy strategy towards a competitive knowledge economy, The Netherlands is – as most European countries - mainly oriented towards industrial, technological factors. The policy focus is on R&D specialized regions in their spatial economic strategies. We placed the knowledge economy in a broader perspective. Based on the knowledge economy literature, we valued complementary indicators: the successful introduction of new products and services to the market (innovation) and indicators of skills of employees: ‘knowledge workers’. Using econometric analysis, we related the three factors ‘R&D’, ‘innovation’ and ‘knowledge workers’ to regional economic growth. We conclude that the factors ‘innovation’ and ‘knowledge workers’ are more profoundly related to urban employment and productivity growth than the R&D-factor. Focusing on other agglomeration factors, localized clusters of producer services (for employment growth) and of industrial and distribution activities (for productivity growth) contribute to economic performance of cities. Sectoral diversity instead, is negatively related to urban economic growth. Finally, we suggest that urban research and policymakers should preferably take all three knowledge economic factors (knowledge workers, innovation and R&D) into account when determining economic potentials of cities.

Acknowledgement

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Notes

1. Factor analysis 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.

2. The 'Innovation' and 'R&D' indicators are measured in 2002, but reflect the CIS questionnaire in which is asked about the renewal in products, services and process over the previous two years. Data on R&D and innovation before 2002 are incomparable for analysis. Compared to the other variables used in the models, this implies a time lag in the variables of innovation and R&D, what might induce endogeneity Jaffe (1989) shows in a knowledge production function setting in the US that *spatial* patterns of innovation indicators are to a large degree stable over time.

3. Combes (2000) shows that including the level of the local *sectoral* employment in the analysis strongly changes the interpretation of the specialisation variable and leads to an overestimation of the localisation economies. Actually, the impact of the share of the sectoral employment in total employment, holding the level of the sectoral employment constant, is simply the inverse of the effect of the total employment. Thus, it cannot be interpreted as intrasectoral local externalities. The correct interpretation is obtained if the level of the sectoral employment is replaced by the level of the *total* employment in control variables – what is done in our analysis.

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

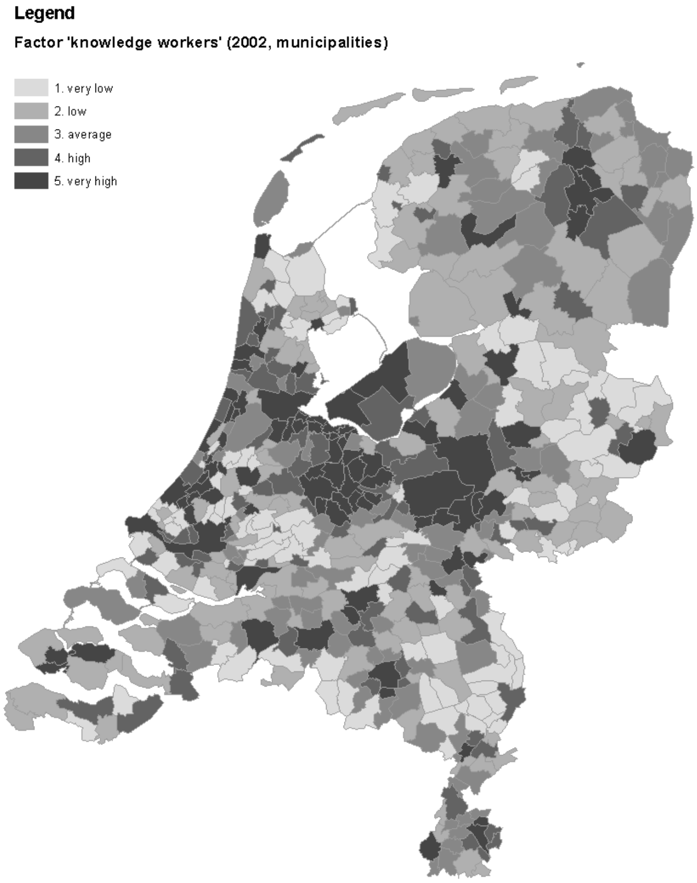


Figure 2 The 'Innovation' dimension (factor 2)

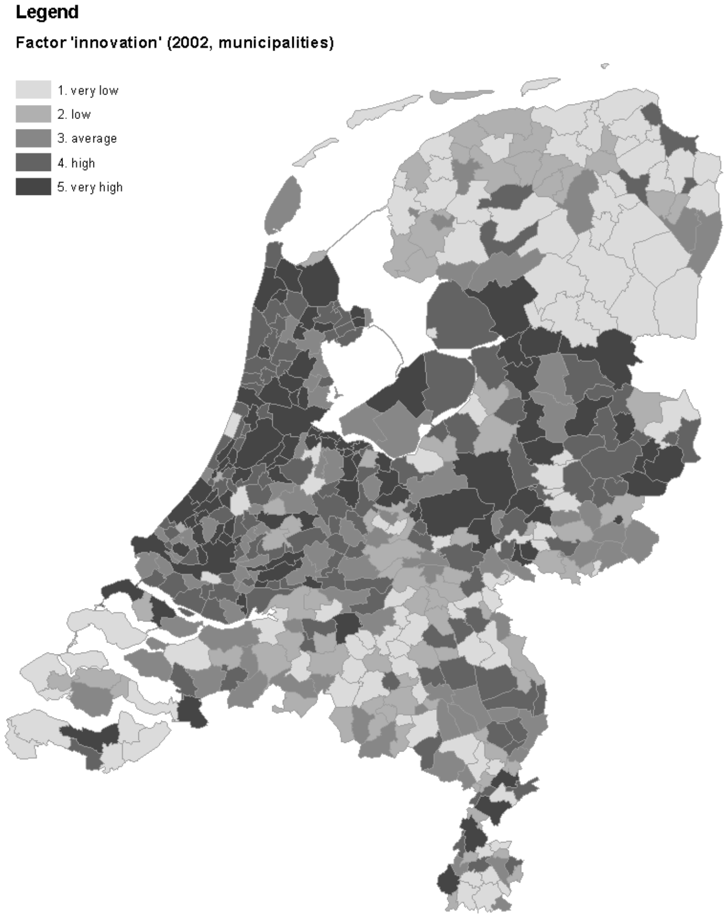


Figure 3 The 'R&D' dimension (factor 3)

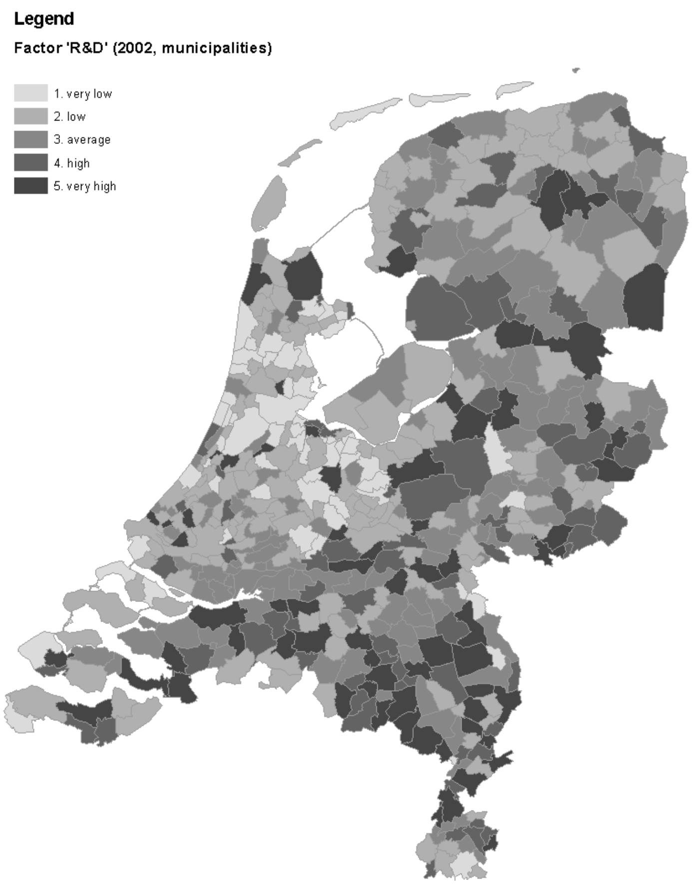


Figure 4 Employment growth 1996-2003 (log)

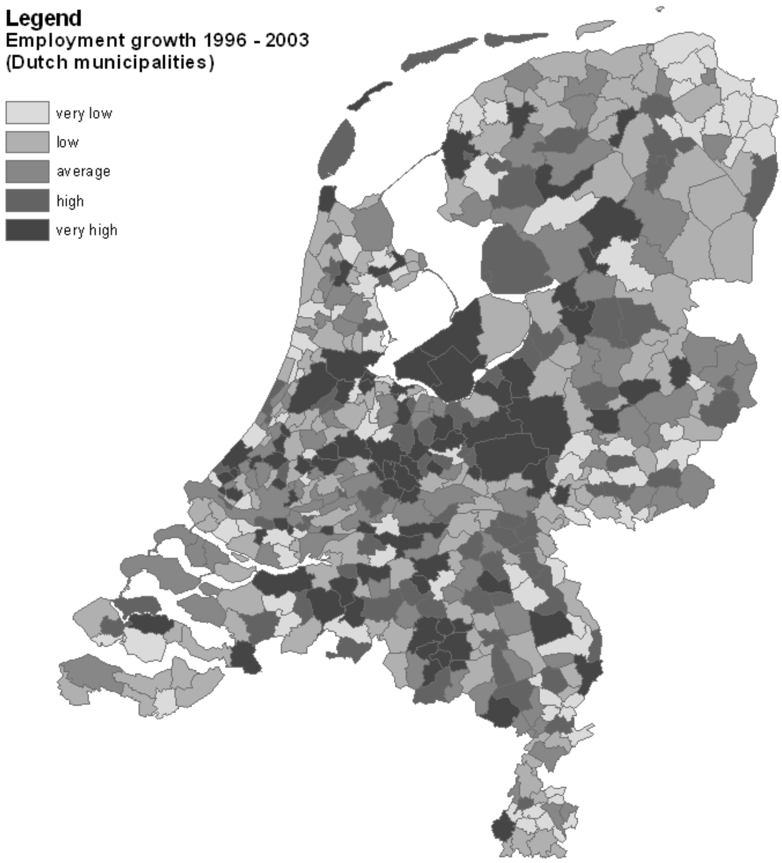
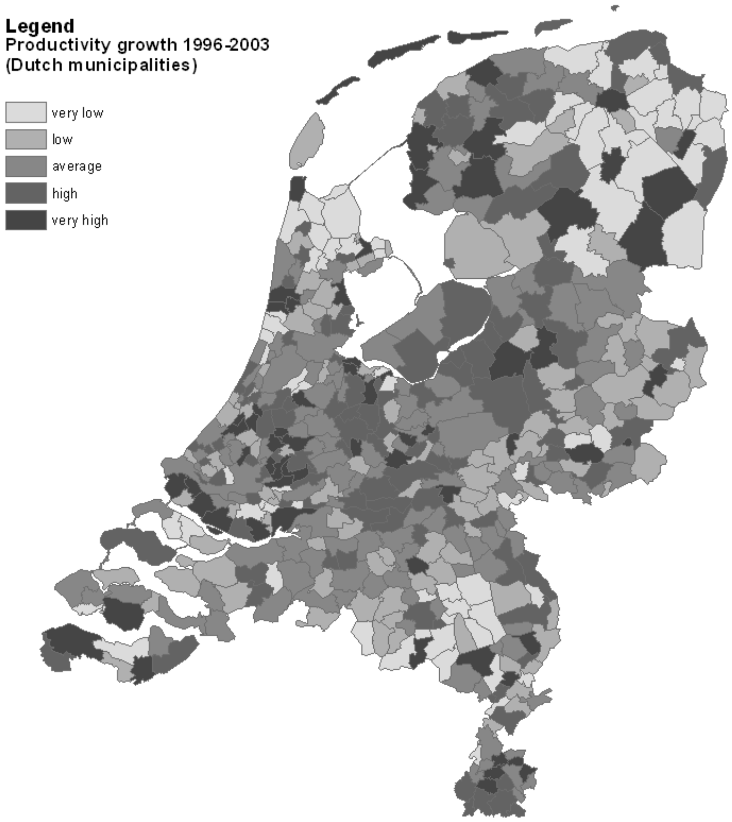


Figure 5 Productivity growth 1996-2003 (log)



Appendix 1 Indicators of the Dutch knowledge economy

In this paper we introduce eight indicators of the Dutch knowledge economy (Raspe *et al* 2004). All indicators are related to the location of firms (establishments). An important source of data is the LISA database (Landelijk Informatiesysteem Arbeidsplaatsen) that contains for 1996-2003 all establishments in the Netherlands (over 800,000), the type of economic activity (by NACE codes) and the number of employed persons. This dataset is the basis of our analysis of the regional economic structure of regions (aggregated to the level of municipalities). To construct the local indicators of the knowledge economy, we use statistics (national and regional, for instance on the level of provinces) that have a large sectoral detail that we use to regionalize the data. This appendix provides an empirical explanation of the eight indicators on the municipal level (n=496). All standardized indicators are visualized as standardized scores in figure 6, with mapping boundaries < -0.85, -0.85_-0.25, -0.25_+0.25, +0.25_+0.85, > +0.85).

Educational level

The average educational level of employment is calculated as the weighted sum of three levels of education: high (university and higher vocational education), middle (intermediate vocational education, higher general secondary education and pre-university education) and low (lower general secondary education and lower vocational education), respectively with the weights 3, 2 and 1. The three levels are measured as the total employment of an educational level in a sector (two digit NACE code). For every sector an average educational level, varying between 1 and 3, is estimated. To calculate the regional educational level we multiplied the average educational level per sector with the number of jobs in that sector, divided by the total number of jobs in the region (municipalities n = 496).

ICT-sensitivity

The indicator of ICT-sensitivity is the number of computers (and terminals) per job in industries in a municipality. First we computed the number of computers and terminals on the level of sectors (two digit NACE code, Automation Statistics Survey, Statistics Netherlands). Then we constructed an ICT-index per sector by dividing the number of computers and terminals by the number of jobs in a sector. In a third step the ICT-index is linked to the sectoral structure of the employment of the regions (municipalities, based on the LISA database).

Figure 6   Spatial pattern of 8 knowledge indicators in the Netherlands

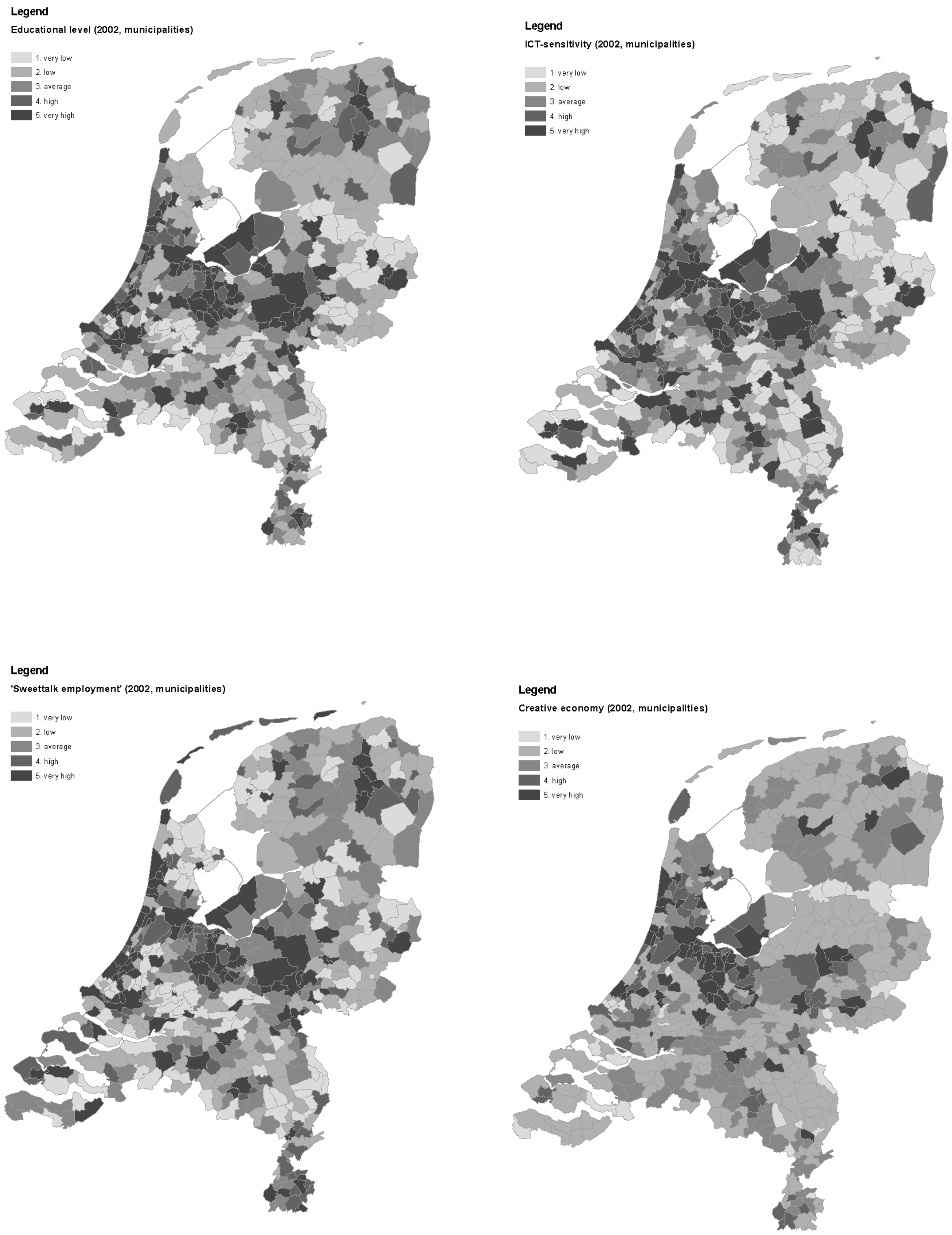
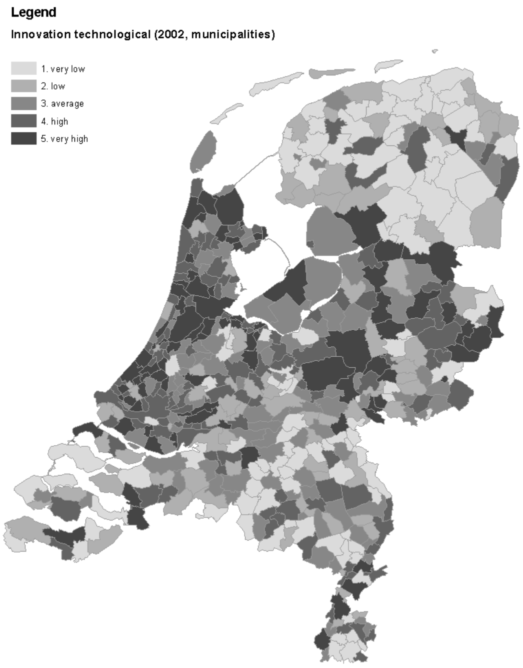
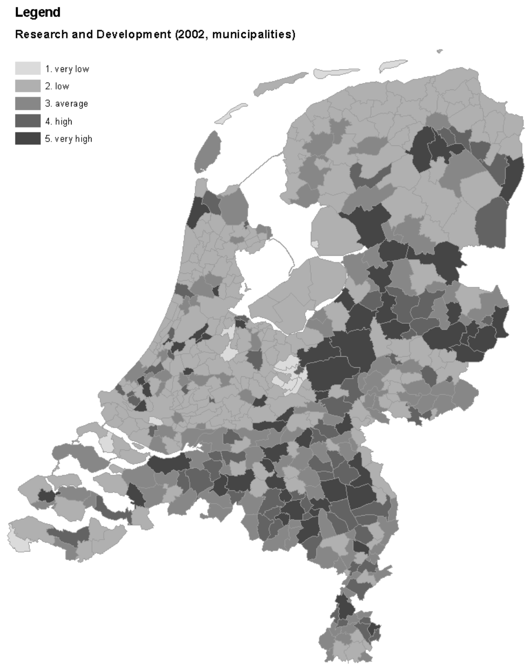
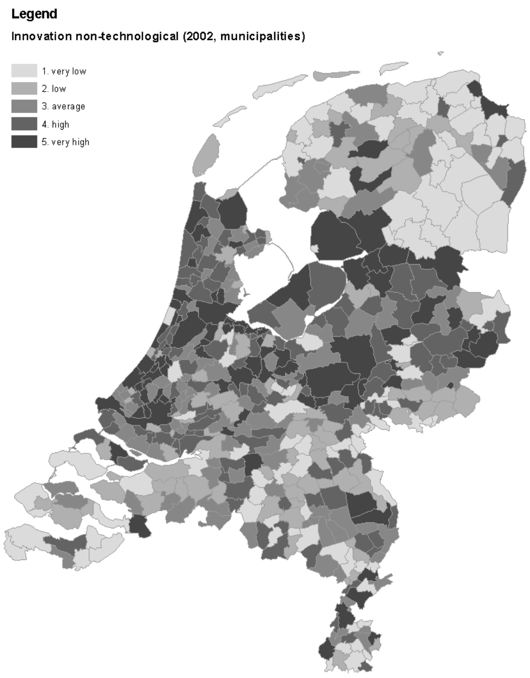
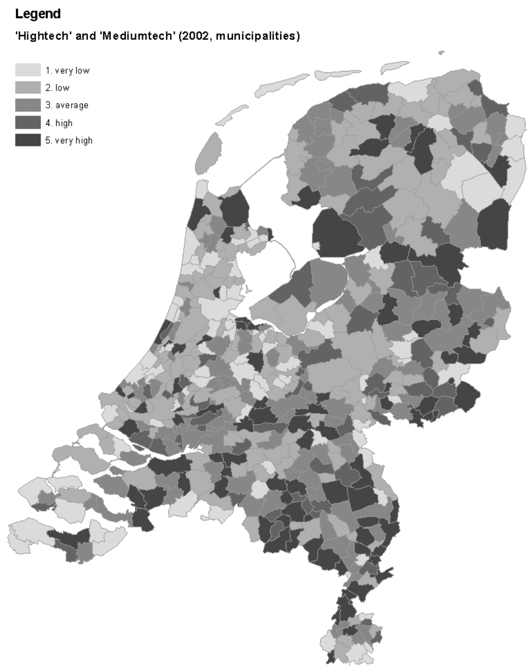


Figure 6 (continued)









Communicative skills

Based on Van der Laan (2000), we use as an indicator for social capital the relative overrepresentation of the number of employees specialized in communicative and information processing skills. The basic theoretical focus for this indicator stems from the 'model of persuasion' by McCloskey & Klamer (1995), in which economic transactions are not only based on market prizes and forces but also on persuasion and information judgment as well. In a growing number of jobs the importance of intense communication with others is fundamental in the persuasion of ideas or points of view. Especially concerning knowledge intensive jobs in science and consultancy. Maintaining and extending the position of trust in the relationship between the selling party and their customers plays a crucial role. Of all 1211 types of jobs (occupations) in the Standardized Jobs Classification (SBC'92, Statistics Netherlands) an inventory of specific skills based on a list of function descriptions (ARVO, 1989) is made. Eleven job qualifications resulted as clusters of skills. Five skills are selected as mainly based on persuasion: [1] management, which contains policymaking, [2] verbal activities, which needs skills of oral and written reproduction of thoughts and feelings, [3] artificial activities, which demands expressive and aesthetic design, [4] service related activities, aimed at service to persons, and [5] activities that needs persuasion power in direct contacts. These five skills are linked to industrial composition. In a first step all occupations were scored in the matter they use one of the defined skills. An index is per sector is calculated, between zero and one. A score of zero means that no single person in a sector works in persuasive occupations. A score of 1 means everybody in a sector works in persuasive occupations. The scores per sector are linked to the LISA database (all individual establishment by sector and size of the employment in the Netherlands).

Creative economy

The indicator creative economy is the amount of creative jobs in the total jobs of a region. The selection of creative jobs is based on the symbolic meaning of the products and services (Manshanden *et al.* 2004), resulting in a list of creative sectors (4 digit NACE codes, Rev. 1.1, 2002). The focus is on the creation and production of creative goods and services, reproduction and distribution (see table 5):

Table 5 Creative economy by NACE codes

Arts		Cultural Industries		Applied creative production	
92.31	Artistic and literary creation and interpretation	22.11	Publishing of books	74.20	Architectural and engineering activities and related technical consultancy (Excl technical design civil engineering, electro. technical, machinery)
92.32	Operation of arts facilities (excl Theaters etc and event halls)	22.12	Publishing of newspapers	74.40	Advertising
92.52	Museums activities and preservation of historical sites and buildings (excl preservation of national monuments and historic buildings)	22.13	Publishing of journals and periodicals	74.87	Interior, mode design
		22.14	Publishing of sound recordings		
		22.15	Other publishing		
		92.40	News agency activities		
		92.34	Other entertainment activities n.e.c.		
		74.81	Photographic activities		
		92.11	Motion picture and video production		
		92.20	Radio and television activities		
		92.13	Motion picture projection		

Innovation (technological and non-technological) and Research & Development

The innovation indicators are constructed as the number of employment of innovative firms in the total employment in a region (see De Bruijn 2004). This indicator is based on the European Community Information Survey (CIS '02), which is in the Netherlands carried out by Statistics Netherlands. Innovation is the result of innovation processes: the successful introduction of a new good or service on the market. We make a distinction in technological innovation: renewal of products and services or processes due to the development or application of new (to a firm) or recent technologies, and non-technological innovation: renewal not necessarily based on technological knowledge (for instance management, marketing or organizational renewal). The results of CIS '02 are on the level of provinces and 3 digit NACE codes, which are spatially redistributed by the LISA database (all individual establishment by sector and size of the employment in the Netherlands).

The R&D-indicator is the number of employment in R&D-jobs in the total employment in the region. This indicator is also based on the European Community Information Survey (CIS '02).

Hightech and mediumtech employment

The indicator high- and medium-tech is the amount of employment in a selection of high and medium-tech sectors in the total employment of a region. The selection of sectors is based on OECD (2003).

Appendix 2: correlation matrix of independent variables

	1. Fac1 'Knowledge workers'	2. Fac2 'Innovation'	3. Fac3 'R&D'	4. LQ industrial activities (log)	5. LQ distribution (log)	6. LQ producer services (log)	7. Herfindahl index (log)	8. Population density (LOG)	9. Investment level (LOG)	10. Wage level (LOG)	11. Supply business areas growth (LOG)	12. Dummy border regions	13. Employment level 1996 (LOG)	14. Productivity level 1996 (LOG)
1.	1	,000	,000	-,454(**)	-,508(**)	,451(**)	,136(**)	,526(**)	-,159(**)	-,091(*)	-,178(**)	-,117(**)	,521(**)	,241(**)
2.	,000	1	,000	,101(*)	,024	,213(**)	-,005	,347(**)	-,095(*)	-,047	,002	-,129(**)	,311(**)	,200(**)
3.	,000	,000	1	,469(**)	-,174(**)	-,052	-,286(**)	,093(*)	-,056	,106(*)	,003	,147(**)	,284(**)	,056
4.	-,454(**)	,101(*)	,469(**)	1	,054	-,344(**)	-,524(**)	-,068	,055	,150(**)	,090(*)	,207(**)	,088	,063
5.	-,508(**)	,024	-,174(**)	,054	1	,019	-,146(**)	-,155(**)	,158(**)	,098(*)	,079	-,190(**)	-,232(**)	-,018
6.	,451(**)	,213(**)	-,052	-,344(**)	,019	1	-,126(**)	,365(**)	,051	,063	-,124(**)	-,206(**)	,322(**)	,240(**)
7.	,136(**)	-,005	-,286(**)	-,524(**)	-,146(**)	-,126(**)	1	-,031	-,109(*)	-,134(**)	-,026	-,090(*)	-,248(**)	-,157(**)
8.	,526(**)	,347(**)	,093(*)	-,068	-,155(**)	,365(**)	-,031	1	-,182(**)	-,240(**)	-,121(**)	-,114(*)	,607(**)	,343(**)
9.	-,159(**)	-,095(*)	-,056	,055	,158(**)	,051	-,109(*)	-,182(**)	1	,142(**)	-,019	-,084	-,024	,010
10.	-,091(*)	-,047	,106(*)	,150(**)	,098(*)	,063	-,134(**)	-,240(**)	,142(**)	1	-,081	-,012	-,128(**)	,050
11.	-,178(**)	,002	,003	,090(*)	,079	-,124(**)	-,026	-,121(**)	-,019	-,081	1	-,015	-,070	-,210(**)
12.	-,117(**)	-,129(**)	,147(**)	,207(**)	-,190(**)	-,206(**)	-,090(*)	-,114(*)	-,084	-,012	-,015	1	-,049	-,053
13.	,521(**)	,311(**)	,284(**)	,088	-,232(**)	,322(**)	-,248(**)	,607(**)	-,024	-,128(**)	-,070	-,049	1	,305(**)
14.	,241(**)	,200(**)	,056	,063	-,018	,240(**)	-,157(**)	,343(**)	,010	,050	-,210(**)	-,053	,305(**)	1

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).