Dynamics in Knowledge, ICT-use and Organizations; a Regional Perspective
(Draft)

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Abstract

Changing knowledge structures are assumed to be highly dependent on the growing use of ICT and innovations in organizations. Starting from the assumption that ICT-use, innovation and knowledge co-determine each other, the central question is after the effect of ICT-use and innovation on knowledge capital and how this differs regionally. For this purpose some assumptions are theoretically elaborated and compared with empirical findings. This includes assumed spatial patterns. We focus on small scale municipal spatial patterns of change in the Netherlands.

Firstly, we analyse theoretically the relationships between changing of ICT-use, innovations in organizations and changing knowledge capital. As far as the relationship between ICT-use and knowledge capital is concerned, 'skill biased technology changes' (SBTC) is central. In relation to organizational changes 'skill biased organizational changes' (SBOC). Although extensive research has been dedicated to SBTC and SBOC in general, the link to the regional pattern is rather small. To fill this gap, this paper analyses locational changes in ICT-using industries, in organizational innovation and their relationship with changes in regional knowledge capital.

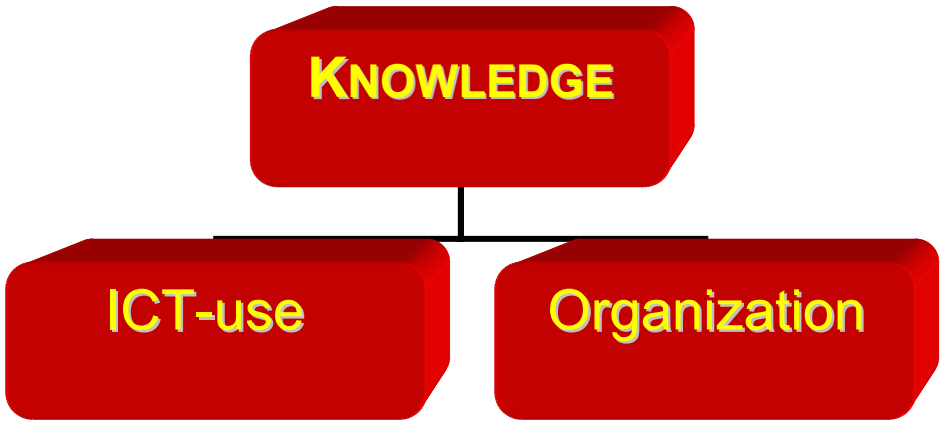
Following these sections, we discuss the measurement of changing knowledge capital, ICT-use and organizational changes and their regional pattern. The empirical section uses correlation analysis and OLS-regressions for determining the effect of ICT-use and innovation on knowledge capital and how this differs regionally. In the regional perspective various levels of urbanism are distinguished. Based on disaggregated zip-code level micro data on industrial organizations, these include the highly urbanized Randstad regions, the intermediate zone and the national periphery. The concluding section compares the theoretical assumptions with the empirical findings.

1. Knowledge, ICT-use and organizations

Changing knowledge structures are assumed to be highly dependent on the growing use of ICT and innovations in organizations. This relationship between ICT-use, organizations and knowledge is reflected in figure 1. The triad of changes in knowledge, ICT and the organization is increasingly used to explain economic performance (Van Ark, 2003). In line with this, Bartelsman and Hinloopen (2000) stated that ICT-use plays a role for economic growth, albeit not in a direct sense, but rather via 'unknown' aspects hidden in the increases of total factor productivity (TFP). These hidden factors are related to the manner ICT is implemented in organizations. Also Bresnahan *et al.* (2001) showed how effects of ICT on economic growth strongly depend on simultaneous changes in the organization and the application of human capital. If organizations only concentrate on ICT-investments, productivity effects are smaller compared to those of organizations which do not apply ICT. ICT effects on productivity can even be negative. Black and Lynch (1997) found

similar results. Also Steijn (2001) concluded that ICT does not function as an element on its own, but is embedded in the organization and in people, i.e. knowledge.

Figure 1 ICT-use, the organization and knowledge



This paper does not focus at the effects of changes in knowledge, ICT and the organization for economic performance, but has a more limited aim and focuses on the interrelationship of these three elements. More specific the paper addresses the question how organizational changes and the growing use of ICT determine changes in knowledge. Moreover we use a spatial perspective. The aim of this paper is to explain the regional changes in knowledge by changes in the use of ICT and changes in organizations. In terms of figure 1, the blocks of 'ICT-use' and 'organization' are supposed to explain the block of 'knowledge'. This leads to our first assumption:

Assumption 1:
Changes in knowledge capital are strongly related to changes in the ICT-use and organizational changes.

In order to focus our research, we take a closer look at the relationship of knowledge, ICT-use and organizational changes. In this also the regional aspect is included.

2. ICT-use, knowledge and regional development

Economic activities are increasingly related to ICT. In the Netherlands there was a huge growth of ICT-related employment from 25% in 1991 to 81% in 2002 (Van der Laan et. al, 2005). However, ICT does not function as an element on its own, but is embedded in activities of people and organizations. Therefore, ICT-use can only be properly understood if they are related to the changes in knowledge (Eliasson, 2000). Organizations use ICT for two purposes: for the substitution of other production factors and/or facilitating production processes. For the first purpose, ICT is supposed to make coordination more efficient and less costly by substituting traditional production factors, including labour and transport.

2.1 Skill biased technological change

An important question is which kind of knowledge, i.e. which educational category of workers profits more or less from ICT. This is the SBTC, the `skill biased technological change'. Theoretically four different impacts on the educational structure can be distinguished: upgrading, downgrading, dualization and selectivity (see also Steijn,

2001). The first, `upgrading' vision assumes a positive relationship between technological changes and the share of the higher educated. New technology needs more knowledge. Moreover higher education is considered as a sign of larger productivity and better trainability for the employer a more efficient investment strategy. The more so since skills are learned increasingly in professional practice. The educational level is assumed to give an indication of one's potential productive capacities and therefore functions as a selection device in recruitment. Organisations set up their educational efforts thus preferably at those employees who have received already a certain degree of education. In contrast to this `upgrading' vision is the `downgrading' perspective, which expects that new technology, like ICT, leads particularly to lower educational requirements. Especially by the application of new process technologies thinking is taken over by the computer. Only simple control and supporting activities remain. A higher level of education is thus not necessary. A third perspective concerning the impact of new technology is the `dualization'. In this vision it is expected that innovations favour both higher and lower educated, whereas the middle group with secondary education will become less necessary. Higher educated are asked more by an increase of the complexity in decision-making. Lower educated can be applied for automated simple control, supporting and service activities. The middle group loses, because the need of supervision decreases, their activities are automated and they have too little training and skills to be adequately involved in decision making in rapidly changing and complex situations. A fourth perspective is selective. Whether `upgrading', ` downgrading ' or 'dualisation' appears, depends on many, sometimes contrary, sometimes each other reinforcing processes. The impact of technological renewal differs by industry and groups. Aspects which play a role are for example whether product- or process technology is involved. Also the technological level and the organizational strategy play a role. Additionally, the phase in the life cycle of innovation can be important. At the beginning of the cycle higher educated are needed, while in due time lower educated can use the technology concerned. Finally also the spatial environment plays a role. Changes in a city like Amsterdam are different from those in Rotterdam (Steijn et al, 2000).

Under the influence of ICT there was in the Netherlands a process of upgrading (Borghans and Ter Weel, 2003). However, processes were different by educational category. By an increase of the number of computers especially the proportion of higher educated increased. On the other hand the share of the lower educated decreased. Two groups show small and no significant changes. It concerns the middle group and the unskilled. The role of ICT differs for all these groups. Whereas for the higher educated ICT has especially a facilitating role, it substitutes the lower educated. The more or less unaltered position of the middle group is supposed to be caused by two contrary processes. They profit on the one hand of the upgrading of jobs for which formerly a lower training was sufficient, but on the other hand also higher educated take over their jobs. The unaltered position of unskilled is explained because ICT does really influence their work. It concerns work, like that of cleaners, which ICT cannot replace. These empirical findings lead to second assumption:

Assumption 2:
Growth in the use of ICT leads to an upgrading of the educational structure of employment.

2.2 Regional development

If we link the change in ICT-use to regional development, it is assumed that particularly traditional means of transport or transactions are substituted by ICT. This results in a reduction of time- and distance costs. In this perspective, physical distance becomes less stringent. Production chains of organizations are reduced, either by internal and/or

external vertical integration (Amirahmadi and Wallace, 1995; Peck, 1996). ICT enables entrepreneurs to become less place bound: a liberalizing or centrifugal effect, summarized as the 'death of distance' or the 'weightless economy'. The physical distance to customers, suppliers, services and labour supply becomes less important. Economic value is transmitted across physical space at zero marginal costs (Horan *et al*, 1996). The spatial effects of ICT are assumed to be similar to those of earlier 'new' technologies like the telephone and automating machinery (Battey and Langley, 1994). Another wave of technological development, ICT, causes similar spatial effects. Industries become geographically more uniformly distributed and resulting in spatial convergence (Graham and Marvin, 2001; Kolko, 2002). If we relate this spatial theoretical line of reasoning to the second assumption, indicating an upgrading of the employment structure, this results in third assumption:

Assumption 3:
The growth in ICT-use leads to spatial convergence by which particularly non-central locations will profit and by this will show an upgrading of the educational structure of employment.

An alternative view on the possible role of lower transport costs by ICT on spatial patterns is linked to the role of scale economies. This perspective is reflected in the 'new economic geography', having its roots in the new trade theory, and which stresses that agglomeration results from demand linkages. These are created by the interaction of transport costs and costs of production, the variety of goods demanded and the substitution elasticity of labour between, often two, sectors (agriculture and manufacturing). In this, next to footloose labour, particularly scale economies internal to firms are important (Krugman, 1991, 1996; Martin and Sunley, 1996). If scale economies are strong and transportation costs low, production is located at a single location. Production costs are lower there because of positive scale economies. In turn, local demand is highest were the producers locate. Therefore, given fixed production costs and linear effects of transport costs, production concentrates at large markets. Effects will be stronger if local demand is greater and internal scale economies are larger. Spatial concentration creates an environment that stimulates further spatial concentration (Puga, 1999). This circularity continues. In formal modelling eventually the result is the concentration of production at a single location. Agglomeration also holds in related models, like those that emphasize intermediate inputs within or between firms (Venables, 1996) or demand-linked forces arising from endogenous capital building (Baldwin, 1999). Because of higher and increasing productivity, positive agglomeration effects outweigh negative effects due to, for example, congestion or high land rents.

Spatial models used in this framework predict a continuous agglomeration of economic activities. Only if transport costs are sufficiently high, producers outside the agglomeration can survive. Due to these high transportation costs they face less competition for their local demand from more scale efficient competitors of the large agglomeration. However, transport costs and markets are not given. ICT applications lower transport costs of material goods and codified information and by this have a liberating effect on the burden of transport. Given the now lower transport costs because of ICT, scale economies become most relevant. These are lowest at the location with the largest production: the agglomeration. A lowering of transport costs by ICT will induce further agglomeration. Non-urban locations are cumulative confronted with lower scale economies (Krugman, 1996). The pull of scale economies is larger than the push of transportation costs. As long as the models use two sectors of production (manufacturing and agriculture) the inevitably of non-urban decline is robust (Kilkenny, 1998). If we relate also this spatial perspective to the second assumption, indicating upgrading, this

results in a fourth assumption which does not assumes spatial convergence like the third assumption, but rather spatial divergence by which central locations will profit.

Assumption 4:
The growth in ICT-use leads to spatial divergence by which particularly central locations will profit and by this will show an upgrading of the educational structure of employment.

3. Organizational changes, knowledge and regional development

When efficiency of tasks is complemented by or even concentrated on tasks related to the support of production, the picture becomes different (see Nooteboom, 1999). In this, the role of ICT is particularly facilitating. ICT supports existing and new activities and supports non-technological innovations like new management and marketing techniques, changes of the organizational structure and aesthetic product changes.

3.1 skill biased organizational change

As with ICT, important is also here which category of workers profits particularly from organisational changes. This concerns the SBOC, the `skill biased organizational change. Organisational changes are mostly related to changing internal processes in firms and institutions such as decentralisation in decision-making, the growth of teamwork and multitasking (Caroli, 2001). With decentralisation, the decision-making is moved close to the shop floor. This would stimulate the involvement and autonomy of workers on the shop floor. It also would facilitate quality control and just-in-time production. Because of decentralization, different intervening management levels become superfluous. With teamwork Tayloristic specialisation is rejected. This makes it possible to improve the quality of production. However, more communication is necessary. With multi-tasking workers carry out several tasks and/or circulate between tasks.

By the organisational changes the contents of labour thus also changes. A shift takes place from product-oriented to process-tied labour and which goes together with a shift of branch-tied technology to generic technology. Process-tied labour is related to processes which appear in several industries. An example of this is that, by the application of ICT, trade related labour is displaced by control- and guarding activities and use of software. The larger emphasis on process-tied labour and generic technology goes together with a stronger customer - and market orientation of labour where handling of non-routine problems plays an important role. In turn, this goes along with working in teams where the own responsibility is important. The expectation is that a larger emphasis on these organisational changes, appearing frequently simultaneous, also will lead to an upgrading of the educational level. It appears however that especially for the middle group organisational changes are unfavourably (Borghans and Ter Weel, 2003). Given the effects of the organizational changes a fifth assumption is:

Assumption 5:
Organizational changes lead to an upgrading of the educational structure of employment.

As discussed, organisational changes are in the literature mostly related to changing internal processes. In or view, however, organisational changes, particularly when they are related to ICT, involve also external relations. Therefore, next to internal processes like changes in the organizational structure, management techniques or the implementation of new long-term strategies, these include the development of new products, processes and services, marketing techniques or aesthetic product changes. For

that reason, assumption 5 does in this paper apply to both internal and external oriented organizational changes.

3.2 Skill biased change = SBTC + SBOC

Before turning to the regional aspect of the role of knowledge for organizations, we can observe that it is increasingly emphasised that changes in ICT-use and organisational changes go together. Therefore it is suggested that the outcomes for the educational structure must be examined simultaneous from both an ICT and organizational perspective (Tijdens and Steijn, 2003). Changes in the one bring along added values for changes in the other. They are complementary. This applies in particular to ICT. Technological changes caused by ICT and organisational changes cluster (Hitt and Brynjolfsson, 2002). Because of this, the combined impact of changes in ICT-use and in the organisation an upgrading of the educational structure is expected. In relation to this Tijdens and Steijn (2003) indicate that the developments lead to a Matthew-effect: those who already have a good position improve it. The others their position deteriorates relatively. This leads to the sixth assumption:

Assumption 6:
Changes in ICT use and organizational changes are complementary and result equally to an upgrading of the educational structure of employment.

Although the connection between ICT and organisational changes strongly emphasized in assumption six, Borghans and Ter Weel (2003) have a contrasting view. They suggest that changes in ICT and those of the organisation fairly independently influence the educational level. In this, changes in ICT-use are most important. The impact of the SBOC is small and clearly smaller than those of the SBTC, and frequently also not significant (Borghans and Ter Weel, 2003). This view leads to an alternative to assumption six about the relationship of changes in ICT and organizational changes and their effect on the educational structure.

Assumption 7:
Changes in ICT use and organizational changes are not complementary. While the impact of ICT is important and results in upgrading, that of the organizational changes is small.

3.3 Regional developments

What about the regional aspects of the role of knowledge for organizations? It is assumed that particularly urban agglomerations with their diversified production structure, labour supply, physical and social infrastructures create externalities which foster organizational innovations (Van Oort and Atzema, 2004). Spatially then theories which relate non-technological knowledge to concentrated growth patterns become relevant (Gaspar and Glaeser, 1998). Spatial dynamics are related to processes of cumulative causation in which particularly knowledge supply and spill over plays a role. If non-technological innovations come to the fore, then above all also knowledge capital becomes important.

In relation to this, Rosenthal and Strange (2001) made – empirically – a distinction between knowledge supply and knowledge spill over effects. For the supply of knowledge, knowledge workers are important (Florida 2002; Lambooy *et al.* 2001). These are supposed to be social competent, network sensitive and aimed at cooperation. Kolko (2002) confirms this in relation to ICT: the slow regional convergence of high skill level IT using industries is due to their high skill level rather than their usage of IT as such. It is assumed that ICT reduces distance-related burdens for many resources, and therefore enterprises

concentrate on the locational preferences of the most important (and least mobile) production factor: labour (Van Oort *et al.*, 2003b). And this knowledge supply is found particular in the larger urban regions. For employers searching for rather immobile knowledge workers, a location near these workers is attractive (Horan *et al.*, 1996; White, 1999). Boarnet (1994b) earlier showed that urban employment changes are endogenous to labour market supply changes. This constitutes an important departure from past patterns of urban development in which labour supply was largely exogenous to residential location. That worker residential preferences appear to be extremely important for industrial location is also confirmed by several empirical studies (Glaeser and Kahn, 2001). For the Netherlands, using a spatial two stage least squares model with instrumental variables, Sorber (2001) as well confirms this.

An extension of the supply approach concentrates on knowledge spill over. Spatial concentration of activities increases the opportunities for interaction and knowledge diffusion. The agglomeration of labour makes workers more productive (Black and Henderson, 1999; Ciccone, 2002). Spill over minimizes the cost of obtaining knowledge. Costs of acquiring knowledge are sunk costs, and city-specific human capital can be exploited locally at virtually zero marginal costs (Simon and Nardinelli, 2002). Especially face-to-face contacts and networks are important. To reduce interaction costs, face-to-face contacts of knowledge workers take place in agglomerated (urban) environments. Knowledge workers benefit from being near other knowledge workers. Proximity to knowledge networks is of utmost importance for creating spill-over, stressing the interchange of knowledge in localized networks. Learning, an essential element of endogenous growth mechanisms, is related to these networks (Lucas, 1993; Glaeser, 1999; Beardsell and Henderson, 1999).

Empirical research on knowledge spill over reveals that the (physical) spatial reach of influence is rather small and that urban borders are only seldom crossed. Knowledge is apparently most fruitfully exchanged around the corner of the street (Jaffe *et al.*, 1993; Van Soest *et al.*, 2001; Rosenthal and Strange, 2001). Result of the strong spatial knowledge distance decay is a strong increasing return at the location where knowledge is most present, the urban agglomeration (Acs, 2002). In this, the role of ICT is not subsidiary, but forms the glue in facilitating more efficient networks (Glaeser, 1998; Gaspar and Glaeser, 1998; Duranton, 1999). More emphasis on networks, facilitated by ICT, coincides with a growing importance of knowledge workers and for knowledge networks within and between organizations (Van der Laan, 2001). The importance of knowledge for organisations and its assumed spatial pattern lead to an eight assumption:

Assumption 8:
The importance of organizational changes and the spatial bias of knowledge result in a growing spatial clustering at central locations.

In the following sections, we will discuss the empirical measurement and regional pattern of changes in knowledge capital, ICT-use and organizations. Following this, their spatial relationships are analysed. This sheds light on the eight assumptions related to the theoretical perspectives discussed so far:

- *Assumption 1:*
  Changes in knowledge capital are strongly related to changes in the ICT-use and organizational changes.
- *Assumption 2:*
  Growth in the use of ICT leads to an upgrading of the educational structure of employment.

- *Assumption 3:*
  The growth in ICT-use leads to spatial convergence by which particularly non-central locations will profit and by this will show an upgrading of the educational structure of employment.
- *Assumption 4:*
  The growth in ICT-use leads to spatial divergence by which particularly central locations will profit and by this will show an upgrading of the educational structure of employment.
- *Assumption 5:*
  Organizational changes lead to an upgrading of the educational structure of employment.
- *Assumption 6:*
  Changes in ICT use and organizational changes are complementary and result equally to an upgrading of the educational structure of employment.
- *Assumption 7:*
  Changes in ICT use and organizational changes are not complementary. While the impact of ICT is important and results in upgrading, that of the organizational changes is small.
- *Assumption 8:*
  The importance of organizational changes and the spatial bias of knowledge result in a growing spatial clustering at central locations.

4. Knowledge capital

In this section we first focus at one of the blocks of the triad of figure 1: knowledge. In this paper knowledge is related to the classical approach of human capital. More knowledge means stronger competitiveness and higher economic growth. Particular the attainment of high educational levels is seen as an investment for generating economic capital. In this paper we use the educational level as an indicator of knowledge capital. The OECD (2001) and Glaeser & Saiz (2003) showed the strong regional relationship between a high educational level and economic growth.

We measure the educational level of the regional employment. Three educational levels are distinguished. The lower educated category includes workers with primary education, lower general and professional secondary education. The middle category includes intermediate professional education, senior general secondary education and pre-university education. The higher educated include workers with higher professional education and scientific education. For each category changes in their share of the employed labour force were calculated. Moreover, the average educational level was determined for each 2-digit economic sector as the weighted average of the shares of the categories, ranging from 1 for the lower educated and 3 for the higher educated. For the regional educational level, the average level was calculated by a summation of the weighted sectoral educational levels in that region.

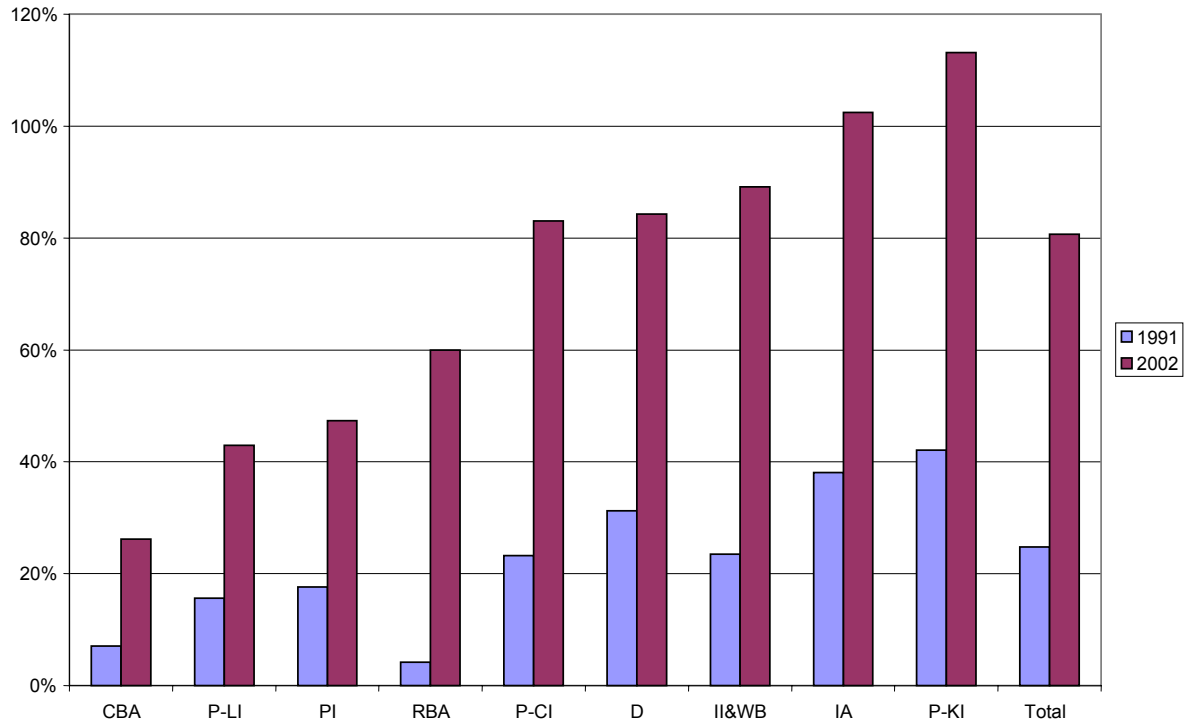
Data on the changing educational level for each municipality between the year 1997 and 2002 were derived by linking the Labour Force Survey (see CBS, 1997) with the sector oriented National Labour Information System (LISA, 1997). The latter focuses at the location of work and is disaggregated at a regional 4-digit zip code level.

In 2002 about a quarter of total employment consisted of higher educated workers. Particularly the Western part of the country, including the larger cities in the Randstad, has high educational levels. Notwithstanding this bias towards the West, also some intermediate and peripheral regions have a high average. This is caused mainly by the presence of universities, higher vocational training and research institutes.

5. ICT-use

ICT-use builds the second block of the triad of figure 1. What is the intensity of ICT-use? Several methods are available to measure ICT-use, depending particularly on the distinction between an organizational or user perspective and/or direct versus indirect measuring (Van der Laan, 2005). However, so far, these methods do not permit a detailed regional analysis. Therefore we introduce an alternative in which employment is related to the use of information and communication technology, the ICT-index (Van der Laan *et al.* 2001). The ICT-index reflects the – potential - degree of participation of workers and organizations in the information economy. The index is constructed in three steps. The first step determines the absolute number of computer screens for 55 two-digit economic sectors (CBS, 1997). Each computer screen is related to a stand-alone or paired pc or a computer terminal. Secondly, a sectoral ICT-index was constructed by dividing the number of computer screens in a 2-digit sector with the number of employees in that sector. This reflects the relative intensity by which employees (potentially) work with ICT. A value of 1 indicates that each worker in a sector disposes of a computer screen.

Figure 2 Share of ICT-related employment by economic sector and total in the Netherlands (%; 1991; 2002)



CBA	- Consumer based activities	D	- Distribution, incl. telecommunication
P-LI	- Production - labour intensive	II & WB	- Information infrastructure: institutions; education; welfare
PI	- Physical infrastructure	IA	- Information activities
RBA	- Resource based activities	P-KI	- Production - knowledge intensive
P-CI	- Production - capital intensive	Total	- Total employment

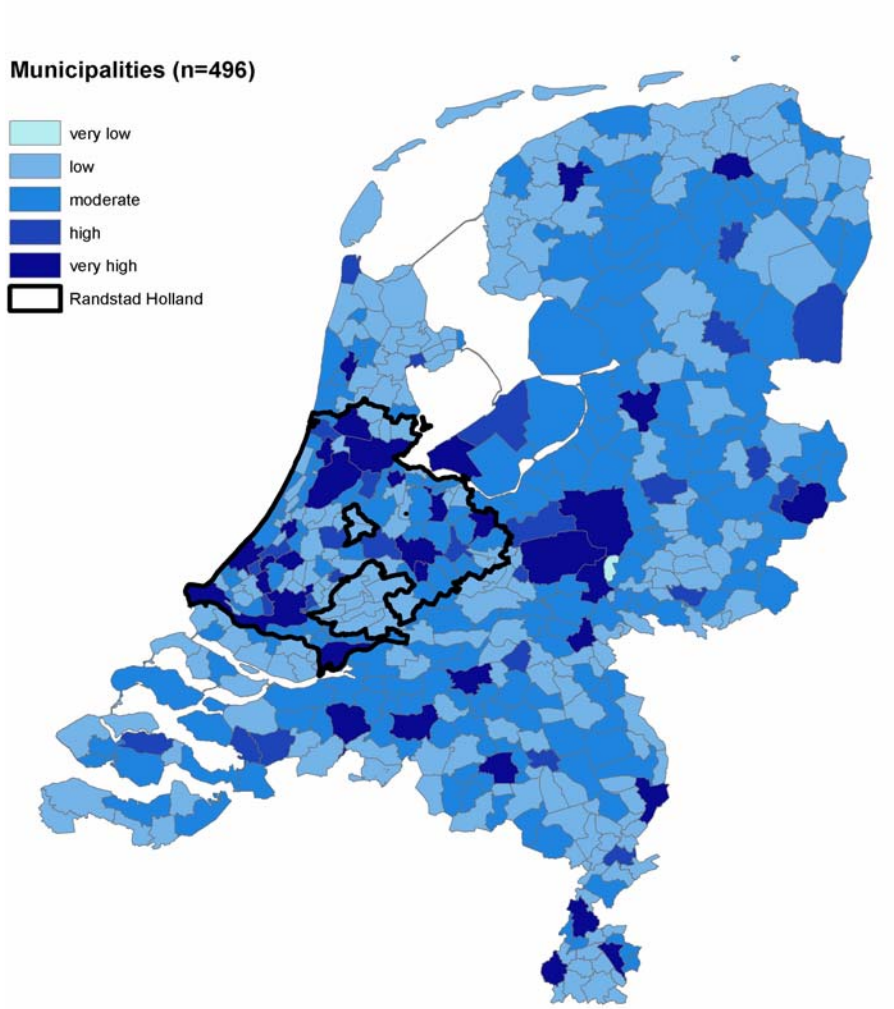
Source: Van der Laan, et al (2005)

The index is not limited. Values above 1 are possible and indeed exist. In a third step the ICT-index is regionalized by linking the sectoral ICT-index to the sectoral composition of

the employment in each region. This implies that spatial variations in ICT-use are determined by the industrial structure. This regionalizing method is necessary, because true regional figures of ICT-use regrettably do not exist (compare Sohn *et al.*, 2002). The ICT-index does not grasp the full extent of ICT use in organizations. Unknown is the intensity by which personal computers are actually used and for what purposes. Also unknown is what other kinds of skills are combined with this use. These are clearly different for clerical workers; call centres employees or university professors. Notwithstanding this, the ICT-index gives an indication of the intensity by which workers - in a region - potentially can use ICT for their internal and external relations. We analyse the index for the period 1991-2002.

Figure 2 shows the ICT-intensity by sector in 1991 and 2002. For the purpose of clearness, the original 55 two-digit figures have been aggregated to 9 main industrial sectors. For the Netherlands as a whole, in 1991 25% of the employment was related to ICT. In 2002 this increased to 81%. Sectoral differences clearly exist. While the 'consumer based activities' have a low level in 2002 of 26%, particular the 'knowledge intensive production' has, with 113%, a very high level. The latter figure, above 100%, means that on average each worker in that industry could use more than one computer screen.

Figure 3 Regional structure of ICT-related employment in the Netherlands (deviation from the average in z-values; 2002)



Differences in the sectoral ICT-intensity lead to a specific regional pattern. Using the original 55 two-digit sectoral data, figure 3 shows the regional of pattern of ICT-related

employment in 2002. Although the Dutch Randstad and cities with high levels can easily be traced, the spatial pattern is rather dispersed. High or low values can be found in each part of the country. So, there are no definite spatial patterns such as a North-South decline or a core-periphery.

6. Organizations and innovations

The last block of the triad of figure 1 is that of the organization. Changes of organizations are reflected in technological and non-technological innovations. These can be measured in various ways. A common distinction is between an input and an output orientation. In this paper we focus on output indicators and distinguish between technological and non-technological innovations. Data on innovations were based on Raspe, et al (2004)[1]. Originally these data are based on the European 'Community Innovation Survey' (CIS-3). For this paper each municipality was classified by z-scores indicating the share of employees in technological and non-technological innovative companies of the total employment during the period 1998-2000. Five classes were distinguished ranging from very low (z-score < -0.85) to very high (z-score > 0.85).

Technological innovations are defined as new products, processes and services using new technologies or as new adaptations of older technologies. Organizations use ICT for technological innovations which result in higher efficiency. By substituting traditional production processes, technological innovations lead to new production processes or new products and services. Next to manufacturing, also innovations in the service industry are included. Technological innovation is seen here from the perspective of the organization. While innovations may have been adopted elsewhere, they still are new for the organization concerned. Areas with high levels of technological innovativeness are in the Western and middle parts of the country. For the rest of the country, hotspots of innovation are rather dispersed.

Non-technological innovations are innovations based on the implementation of new long-term strategies, management and marketing techniques, changes of the organizational structure and aesthetic product changes. Also non-technological innovations are seen here from the perspective of the organization. And also, next to manufacturing, also non-technological innovations in the service industry are included. Although definitely local differences are present, the general pattern is quite similar than those of the technological innovations. High levels in the Western and middle parts of the country. And again, in the rest of the country, hotspots of non-technological innovations are dispersed.

Although theoretically a distinction is often made between technological and non-technological innovations, it shows that both types of innovations show to a large degree a similar regional pattern (Raspe, et al; 2004). Regions with a high level of technological innovation, particularly in the western, middle and eastern parts of the country, also have high levels of non-technological innovations.

7. Knowledge, ICT-use and organizational changes

We have now reached the stage where empirically changes in regional knowledge capital are explained by changes in the use of ICT and organizational changes. In this discussion we focus at the eight assumptions which were elaborated in the first three

[1] Due to restrictions on the use of the original innovation data, new innovation indicators had to be constructed. These were distracted from the figures 14 and 15 in Raspe et al (2004). Each of the 496 municipalities was classified in one of the five categories ranging from very low, low, moderate, high to very high.

sections. First we discuss the national pattern. Following this examine the regional dimension.

7.1 the national pattern

The first assumption relates change in knowledge to changes in ICT-use and organizations:

Assumption 1:
Changes in knowledge capital are strongly related to changes in the ICT-use and organizational changes.

Table 1 shows the spatial correlation of the variables concerning the changing average and changing shares of three categories of education, ICT-use and innovation. Generally, the relationships are not very strong. Quite often, particularly for those with a secondary education, and the lower educated as far as innovations are concerned, they are even not significant. These weak relationships imply that the first assumption, stressing *strong* relationships has to be rejected.

Table 1: Correlation of changing ICT-use, innovations and education in 496 municipalities (Pearson correlations)

Variable	Average	High	Middle	Low
ICT-use	.32**	.39**	.01	-.28**
Technological Innovation	-.03	-.12**	.09	-.07
Non-technological Innovation	-.05	-.11*	.03	-.01

* = significant at the 0.05 level; ** = significant at the 0.01level

Notwithstanding this, for some categories, an increase in ICT-use is relevant. Besides for the average educational level, a growth in the use of ICT is rather strong for the higher educated. The latter, although less strong, also applies to technological changes. Particularly for the use of ICT, there are positive and significant relationships. The relationship between changing ICT-use and the lower educated is also significant but negative. There is no relationship between a growing use of ICT and the category with a secondary education. In total these developments point tentatively at an upgrading of the employment structure. In relation to this, we bring back assumption 2 in memory.

Assumption 2:
Growth in the use of ICT leads to an upgrading of the educational structure of employment.

In order to analyse this assumption systematically and control for the possible influence of other variables, we use at this stage ordinary OLS-regression[2]. Because we want to relate the different aspects of changing organizations and ICT-use to regional changes in knowledge, it is necessary to control for the close relationships of the explanatory variables. By this we avoid problems like multicollinearity in using regression. Table 2 shows low correlations between ICT-use and both types of innovations. A very high correlation exits though between both types of innovations (0.70). Although we could use factor analysis for solving this problem, the small number of variables involved and their

[2] At a later stage we will use methods including indicators of spatial autocorrelation (Van Oort, 2002)

high correlation, made us choose for selecting one of these two variables involved: technological innovations.

Table 2: Correlation of change in ICT-use, technological and non-technological innovations (Pearson 2 tailed; N=496)

Variables	ICT-use	TI
Technological innovation (TI)	-.14**	1
Non-technological innovation (NTI)	-.05	0.70**

* = significant at the 0.05 level; ** = significant at the 0.01 level

Table 3 shows the results of the regression for the total of the 496 municipalities. Similar to the result of the correlation analysis (table 1), the table indicates the rather low explanatory power of the models. The highest level of explanation is produced by the model for changes in the share of the higher educated, but still the R2 is only 0.15. Notwithstanding this, the table shows that ICT is positively and significant related to the change of the average educational level and to change of the share of the higher educated. Change in ICT-use is negatively related to lower educated and not significant to middle category. The resulting total effect of ICT-use on the educational structure is upgrading. This implies that assumption two is confirmed.

Table 3: Regression of changing ICT-use and technological innovation on the changing average educational level and the changing shares of three educational categories (standardized coefficient (β); t-statistics in parentheses; N=496)

	Average	High	Middle	Low
ICT-use	**.33 (7.60)**	**.38 (9.14)**	.02 (0.49)	**-.30 (-6.84)**
Technological Innovation	.02 (0.42)	-.07 (-1.61)	.09 (1.95)	**-.11 (-2.43)**
Adj. R2	*.10*	*.15*	*.00*	*.09*

This result is similar to the findings of Borghans and Ter Weel (2003) who stated that by an increase of ICT-use especially the share of higher educated increased while that of the lower educated decreased. They also established that the middle group with a secondary education showed no significant changes. Also this is similar to our findings.

Before turning to the regional aspects, we focus with the help of table 3 on the assumptions 5, 6, and 7, which also include organizational aspects:

- *Assumption 5:*
  Organizational changes lead to an upgrading of the educational structure of employment.
- *Assumption 6:*
  Changes in ICT use and organizational changes are complementary and result equally to an upgrading of the educational structure of employment.
- *Assumption 7:*
  Changes in ICT use and organizational changes are not complementary. While the impact of ICT is important and results in upgrading, that of the organizational changes is small.

Table 3 shows that technological innovation is, except for the lower educated, not relevant for changes in the educational structure. Given the high correlation of technological tot non-technological changes, this applies also to this latter group of innovations. The significant relationship for the lower educated is negative. By this observation, assumption 5 has to be rejected. There is no upgrading of the educational level. Also the hypothesis that organisational changes are especially unfavourable for the middle group is not confirmed.

If we look at the two contrasting assumptions 6 and 7 which deal with whether there is complementarity between ICT-use and organizational changes, table 3 indicates that assumption 6 is rejected. The assumption that changes in ICT and in organisations are complementary, like Tijdens and Steijn (2003) and Hitt and Brynjolfsson (2002) suggest does not hold in our case. However, assumption 7 is partly confirmed. Changes in ICT and in organisations appear to be rather independent. In this, changes in ICT-use are clearly most important. Similar to the findings of Borghans and Ter Weel (2003), the impact of organizational changes is indeed mostly not significant.

7.2 the regional pattern

After having examined the general relations at the national level, this section discusses the regional dimension. At first we focus at the role of ICT for spatial con- or divergence. For this, the two contrasting assumptions 3 and 4 are relevant.

- *Assumption 3:*
  The growth in ICT-use leads to spatial convergence by which particularly non-central locations will profit and by this will show an upgrading of the educational structure of employment.
- *Assumption 4:*
  The growth in ICT-use leads to spatial divergence by which particularly central locations will profit and by this will show an upgrading of the educational structure of employment.

In order to reject or confirm these assumptions, 12 regression models were considered. This resulted in table 4. If we focus at first at the assumptions 3 and 4, all regions reflect the national pattern of upgrading as far as *ICT-use* is concerned (assumption 2). ICT is, on the one hand, positively related to the change of the average educational level and to change of the share of the higher educated and, on the other hand, negatively related to the share of the lower educated. Also here the relationship is not significant for the middle category. Crucial for the assumptions 3 and 4 is also whether the upgrading effect of ICT-use has a central or non-central bias. If the values of the effects of changing ICT-use of the higher and low educated are compared (the middle group shows no significant relationships), then it appears that the positive effect is similarly large for the higher educated in the Randstad as in the periphery (0.49). For the low educated the negative effect is, with -0.44 larger, in the periphery than in the Randstad (-0.31). The intermediate zone shows much smaller figures. This finding points at a somewhat stronger process of upgrading in the periphery and by this at a preference for confirming the non-central focused assumption 3 and rejecting the centrally focused assumption 4. This would confirm the 'weightless economy' resulting in spatial convergence (Graham and Marvin, 2001; Kolko, 2002). However, given the small differences in upgrading, the rejection of assumption 4 is not a strong case. Does this means that both central and non-central focused processes work simultaneously?

Table 4: **Regression of changing ICT-use and technological innovation on changing average educational level and the changing shares of three educational categories in three parts of the country (standardized coefficient (β); t-statistics in parentheses)**

	Average	High	Middle	Low
Randstad (n=90)				
ICT-use	**.39 (4.08)**	**.49 (5.45)**	-.02 (-.14)	**-.31 (-3.04)**
Technological Innovation	**-.20 (-2.05)**	**-.23 (-2.57)**	.03 (.28)	.11 (1.04)
Adj. R2	*.18*	*.29*	*-.02*	*.09*
Intermediate zone (n=175)				
ICT-use	**.16 (2.13)**	**.19 (2.60)**	-.03 (-.45)	**-.17 (-2.24)**
Technological Innovation	-.03 (-.42)	-.12 (-1.64)	.12 (1.56)	-.07 (-.92)
Adj. R2	*.02*	*.05*	*.01*	*.02*
Periphery (n=231)				
ICT-use	**.47 (7.81)**	**.49 (8.23)**	.12 (1.78)	**-.44 (-7.26)**
Technological Innovation	.12 (1.98)	.02 (.27)	**.24 (3.61)**	**-.20 (-3.30)**
Adj. R2	*.21*	*.23*	*.05*	*.19*
Average adj. R2	*.13*	*.18*	*.01*	*.10*

Next to the effect of ICT, also organisational changes and its spatial bias are assumed to be important for the changing regional pattern of the knowledge economy. As discussed in section 3.2. Spatial dynamics are related to cumulative causation at urban locations in which particularly knowledge supply and spill over play a role. If non-technological innovations come to the fore, then above all also knowledge capital becomes important. And this capital is assumed to be particularly present in central locations. This was reflected in assumption 8.

- *Assumption 8:*
  The importance of organizational changes and the spatial bias of knowledge result in a growing spatial clustering at central locations.

Although the theory makes a rather strong distinction between technological and non-technological innovations, Table 2 showed a very high spatial correlation between both types of innovations. This resulted in selecting, in section 7.1, technological innovation as the indicator for both types of innovations. From table 4 it appears that innovations are mostly not related to education. Exceptions are in the Randstad for the average (-) and higher educated (-) and in the periphery for the middle group (+) and the lower educated (-). If there is a significant relationship, it is mostly negative. This latter finding clearly contradicts assumption 8 which supposed a central bias of the effect of innovations on upgrading. This assumption therefore could not be confirmed.

Conclusions

On basis of the paper and particular guided by eight assumptions related to theoretical perspectives (see p. 7), three conclusions concerning the - regional - relationship between changes in knowledge, ICT-use and innovation can be drawn.

ICT-use
The changing use of ICT is not strongly related to changes in the knowledge structure. The spatial correlation of the changing average and changing shares of three categories of education and changing ICT-use are weak and quite often, particularly for those with a secondary education, not significant. This contradicts our first assumption. However, there is a positive relationship between the changing use of ICT and the higher educated and a negative one for the lower educated. These developments point at an upgrading of the employment structure. The latter confirms assumption 2.

Concerning the regional aspects of the effect of ICT-use, it is crucial whether the upgrading effect of ICT-use has a central or non-central bias. Although differences are not large there is a somewhat stronger process of upgrading in the periphery. This confirms the non-central focused assumption 3 and rejects the centrally focused assumption 4. This also confirms stronger ideas about 'weightless economy' resulting in spatial convergence. However, given the small differences, this confirmation is not a strong case. It can be hypothesized that both central and non-central focused processes work simultaneously.

Organizational changes
As with ICT, and even less, are organizational changes are not strongly related to changes in the knowledge structure. Spatial correlations are small but significant only for the higher educated. Also this contradicts the first assumption. Controlling for the use of ICT, innovation is, except for the lower educated, not relevant for changes in the educational structure. All in all there is no upgrading of the educational level due to organizational changes as assumption 5 assumed.

If we look with the help of assumption 8 at the regional aspects on the educational structure of organizational changes, it was assumed that spatial dynamics are strongly related to cumulative causation at urban locations in which knowledge supply and spill over play a role. This particularly appears at central locations. However, innovations are spatially mostly not related to education and if there is a relationship, it is mostly negative. This contradicts assumption 8 which supposed a central bias of the effect of innovations on upgrading.

ICT-use and organizational changes
We discussed also the debate whether there is complementarity between ICT-use and organizational changes. The two contrasting assumptions 6 and 7 were related to this. The assumption 6 that changes in ICT and in organisations are complementary does not hold in our case. Assumption 7 is partly confirmed. Changes in ICT and in organisations appear to be rather independent. Changes in ICT-use are most important. The impact of organizational changes is mostly not significant.

In summary most of the assumptions stated had to be rejected. The first of this was that changes in knowledge capital are strongly related to changes in the ICT-use and organizational changes. The growth in ICT-use also did not lead to spatial divergence by which particularly central locations will profit. However, this is not established very clear. Moreover organizational changes do not lead to an upgrading. Also the assumption that changes in ICT use and organizational changes are complementary could not be

confirmed. Also the assumption about the importance of organizational changes which results in a growing spatial clustering at central locations could not be confirmed

Assumptions which were confirmed were that a growth in the use of ICT leads to an upgrading of the educational structure of employment and that this goes along with spatial convergence by which particularly non-central locations profit and will show an upgrading of the educational structure of employment. The latter is, however, not strongly demonstrated. It also appeared that changes in ICT use and organizational changes are not complementary. While the impact of ICT is important that of organizational changes is small.

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Addition and selection needed

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