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The German ICT industry

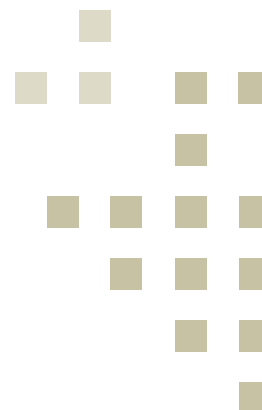
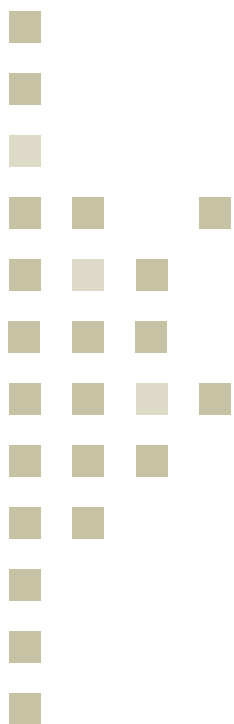
Spatial employment and innovation patterns

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Spatial employment and innovation patterns

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JEL Classification Numbers: L63, L86, L96, O30, O40, R11, R12

Keywords: ICT, clusters, innovation, regional developments, spatial growth.

The German ICT industry: Spatial employment and innovation patterns.

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Abstract

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1. Introduction

It is well known that economic activity tends to cluster geographically. This applies to total production and to production per capita.¹ Similarly, several industries are known to cluster in space. From discussions on new technology, the ICT cluster in Silicon Valley, California, is a popular example. In Krugman (1991) several examples of such clusters are discussed. These are not only high-tech clusters. Also productions of goods as different as cars, carpets, jewellery and shoes are geographically clustered. Research has identified several mechanisms through which clusters occur as well as forces that counteract clustering. A short summary of this literature is given in the next section. Our focus however, is the spatial patterns of production, employment and growth in the German ICT industry. From the public debate there seems to be much optimism about ICT and its potential growth stimulating effects for the rest of the economy. On the European scene, the recent very high growth rates in ICT industries in Ireland, Finland and Sweden have gained much attention. These growth centres in the European ICT industries support the idea that these industries grow in clusters. In Fagerberg et al. (1999) Europe's lagging productivity growth, high unemployment and

¹ See e.g. Maurseth (2003)

increasing inequality are mainly explained by lacking investments in new technologies. Is a strategy that stimulates geographic clustered growth of ICT more conducive for economic growth than a policy that is neutral with respect to industries or regions? Or, will an economy's growth be more stimulated by introduction of ICT on a grand scale across regions and industries? We have no ambition of answering these questions here, but we document the extent to which the German ICT industries grow in spatial clusters.

Germany is not an ICT leader. As compared to other countries, be they OECD countries or EU countries, production and use of ICT in Germany rank low. It is of interest whether the regional developments in Germany promise some emerging ICT clusters or whether German developments will result in a scattered landscape of use and production of ICT. In the next section, we discuss the relations between ICT, productivity and economic growth. In section 3 comparisons of ICT use and production in Germany and other OCED countries are given. The spatial patterns of ICT in Germany are discussed in sections 4, 5, 6 and 7. Section 8 concludes.

2. ICT and economic growth

Growth theory has increasingly become theories of technological change. While previous growth theories focused on growth in physical factors of production and treated technological change as a 'residual' it is now developments in the 'residual' that is the topic of research. Some important demarcations in growth theory may be illustrated by simple economic modelling. Using a Cobb-Douglas production function, total income in an economy may be written as:

$$1) \quad Y = AK^\alpha L^{1-\alpha}$$

K indicates capital, L labour and A total factor productivity. Under perfect competition α equals capital's share of production and $1-\alpha$ labour's share. Now assume a constant savings rate, s , so that growth in capital is sY . Differentiate the above equation with respect to time and solve for growth in production per worker to obtain:

$$2) \quad \frac{\dot{Y}}{Y} - \frac{\dot{L}}{L} = \frac{\dot{A}}{A} + \alpha \left[s \left(\frac{K}{L} \right)^{\alpha-1} - \frac{\dot{L}}{L} \right]$$

It is seen from this equation that the growth rate in production per worker is a function of growth in total factor productivity and growth in the capital intensity and in the labour force. Traditional growth analyses showed that growth in total factor productivity constituted the major share of total growth across countries and over time.² This is in line with theory since the implied production function has decreasing returns to capital. This is demonstrated by the square brackets, which is a decreasing function of the capital stock. When the economy grows more and more capital intensive, growth effects from capital accumulation decreases. Therefore, increasing capital intensity cannot be a source of long run growth without growth in total factor productivity.

In recent theories of economic growth focus has been on explanations on how growth in productivity come about. In the endogenous growth literature there are two major traditions.

² A classical article on empirical estimations of total factor productivity is Solow (1957). A modern treatment is given by Jorgensen (2002). An overview is given in Griliches (1996).

These are R&D models of economic growth and models based on externalities. In both traditions diffusion of knowledge is important. From the externalities based theories an illustrating example is the so-called AK-tradition. This may be illustrated by the following set of equations:

$$3) \quad Y_i = AK_i^\alpha L_i^{1-\alpha}$$

Eq. 3 is the same production function as above, but we now assume that it applies to individual firms only. We now endogenize total factor productivity as a function of the capital intensity in the economy in total:

$$4) \quad A = \bar{A} \left(\frac{\sum K_i}{\sum L_i} \right)^\beta = \bar{A} K^\beta L^{-\beta}$$

In eq. 4 \bar{A} is an exogenous element in total factor productivity while its total also depends on the economy wide capital intensity. In this case total production will be given by eq. 5 below. This equation is also a Cobb-Douglas production, but one in which the capital coefficient is larger than in eq. 1.

$$5) \quad Y = \sum Y_i = \bar{A} K^{\alpha+\beta} L^{1-\alpha-\beta}$$

In this case growth in production per worker will equal:

$$6) \quad \frac{\dot{Y}}{Y} - \frac{\dot{L}}{L} = \frac{\dot{\bar{A}}}{\bar{A}} + (\alpha + \beta) \left[s \bar{A} \left(\frac{K}{L} \right)^{\alpha+\beta-1} - \frac{\dot{L}}{L} \right]$$

It is seen from eq. 6 that savings' contribution to growth will not decrease as fast as in eq. 2. In fact, if $\alpha+\beta=1$, there will not be decreasing returns to capital at all. In this case it is seen from eq. 5 that total production will equal $\bar{A}K$ (which is why these models are called AK-models). Savings may in these models explain long term growth completely. The reason is that as an economy grows more capital intensive, total factor productivity of individual firms increase as well.³

The very stylistic model above illustrates how economists became very optimistic about ICT technologies. In eqs. 1 through 6 K may indicate both physical and human capital. Technology spillovers may be more relevant in production of human capital than for physical capital. A shift in the sector composition in an economy from industries with limited amount of spillovers to industries in which spillovers are more important for economic growth might stimulate sustainable growth in the long term. If $\alpha+\beta=1$ there will be sustainable growth. Even if $\alpha+\beta<1$ increased amounts of spillovers may stimulate growth for a period and result in higher levels of production per worker. A pronounced subscriber to this view is Danny Quah (2002). Quah argues that knowledge production is especially characterised by externalities. He argues that the ICT industries are knowledge intensive in the sense that both inputs and production is knowledge. Therefore, technology spillovers may be more important in knowledge intensive economies.

³ This should not however, be interpreted as if spillovers are good for the economy. Spillovers are external effects and result in market failures. When spillovers are present decentralised market economies will tend to save and invest less than what is optimal because agents do not take into account these effects.

R&D based models of growth give rise to similar conclusions on sustainable growth. In these models however, productivity growth is modelled as results of deliberate investments in R&D to invent new products or production processes.⁴

The above considerations are relevant for understanding regional growth. In eq. 6 growth is dependent on spillovers from capital accumulation whose size is determined by $\alpha+\beta$. There is now increasing empirical evidence that the scope of such spillovers decrease by geographical distance, political and linguistic borders and sector differences.⁵ If this is the case, growth effects of an industry may be limited to a smaller area only. Therefore, there will be a case for agglomeration in which the presence of one industry in one region might spur further growth in this region and in neighbour regions, but not in distant regions.

Also within static models of economic geography many theories attempt to explain how concentration of industries occurs. Here focus is on the relationships between increasing returns at the firm level, transportation costs and market size. When there are increasing returns firms concentrate their production in few production sites to reap the benefits of increasing returns. When there are transportation costs it will increase profits if these production sites are located in the largest markets. If workers move with firms, markets will be large where firms tend to locate. This could explain cumulative causation in regional economics and why some regions grow and others stagnate.

In Krugman (1991) it is explained how labour market pooling might stimulate geographical clustering of an industry. Large regional labour markets may work as insurance for individual firms in cases when firm face uncorrelated demand shocks. In that case, firms that suffer from negative demand shocks set free workers than can be used by those firms that experience positive demand shocks.

Growth need not be geographically contagious. Gunnar Myrdal (1957) discussed so-called backwash effects. This implies that growth in one region is harmful for growth in neighbour regions. If one industry is located in one region and grows fast this may attract resources and skilled labour from neighbour regions. Therefore, growth in one region may reduce the growth potential for neighbour regions. In recent literature on ICT and regional economics, Myrdal's backwash effect has received little attention. This is remarkable since many parts of the ICT sector depends on specialised labour. Therefore it is not obvious, at least not in the short run, that ICT is really an industry that grow in clusters rather than scattered. In this paper we intend to explore the spatial patterns of location and growth in the German ICT industry.

Productivity growth from ICT might be assumed to be of three different types (and combinations of these). First, there may be high growth within ICT industries. This may both be because of pure spillovers as described in eqs. 1 through 6 above or due to R&D investments or, simply, exogenous productivity growth. It may also be due to learning effects and increasing returns to scale in this sector. Second, ICT may stimulate growth in other industries that use ICT in their production processes. This may be due to limited market power in ICT industries so that parts of growth in these industries spill over through the input-output structure of the economy. Zvi Griliches (1979) denoted this type of spillovers 'rent spillovers'. In theories of catching up with technological leaders, use of technology developed

⁴ For an overview of this literature, see Aghion and Howitt (1998).

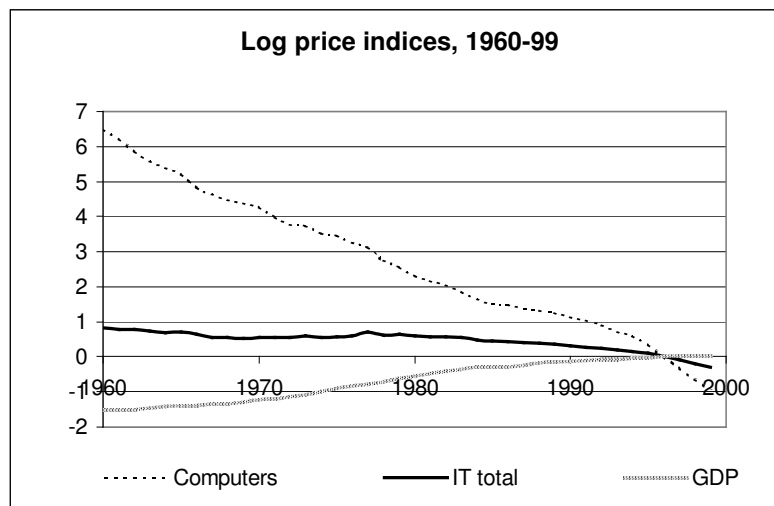
⁵ A survey is provided by Gong and Keller (2003). See also Jaffe et al. (1993) or Maurseth and Verspagen (2002).

by others is an important ingredient for understanding of how countries may grow from low levels to higher levels (see e.g. Coe and Helpman, 1995).

Third, ICT may be a revolutionising industry that improves economic institutions and changes the way in which economic activities are carried out. In Helpman (1998) such *general purpose technologies* are analysed by several authors. Throughout history several shifts in technological paradigms have been identified. This type of technologies are characterised by widespread use, strong externalities and complementarities and fast growth. Some authors (Helpman and Trajtenberg, 1998 and David, 1990) have demonstrated that in initial phases of introduction of new general purpose technologies growth effects may be negative before positive growth effects set in.

ICT industries have indeed experienced high productivity growth during the last decades. This is illustrated in figure 1 that graphs price developments (in logs) for computers, the ICT industry in total and for GDP (in the United States) in the period from 1960 to 1999. The price indices are so-called hedonic price indices so that they are adjusted for quality improvements in products. The price lines therefore indicate the nominal cost of buying a good at the same quality throughout the period. The graph demonstrates that ICT has indeed become cheaper over time and therefore more accessible for producers and consumers. While the price index for GDP is steadily rising, the price indices in ICT decline rapidly, in particular for computers. Note that the price decline does not seem to decrease over time. Rather, in the 1990s the price decline gained speed.

Figure 1.



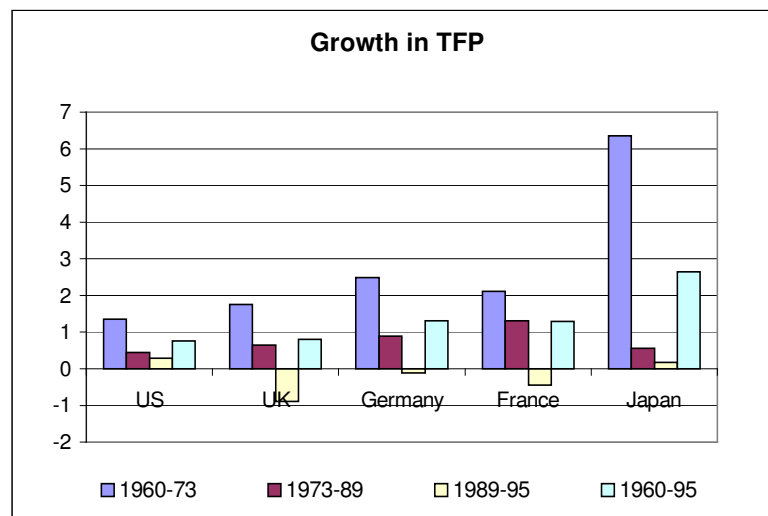
Source: Jorgensen (2002)

At least partly as a consequence of the developments illustrated in figure 1, investments in ICT have increased dramatically in most countries. In the United States ICT doubled its share of total investments from 15 per cent in 1980 to more than 30 per cent in 2000. Similar, but less pronounced developments are witnessed in most OECD countries (see below).

Still, growth in total factor productivity does not reflect the dramatic price decline in computers and ICT. Graph 2 illustrates that growth in total factor productivity has indeed declined over the last decades, and growth in productivity has been particularly low during the computer age. This applies to all the five countries reported here. During the first period described in the figure (1960-73) growth was lowest in the U.S. and highest in Germany and Japan. This was probably due to catch up effects after World War 2. In the subsequent periods, growth has stagnated in all the five countries, but most so in Europe.

Generally therefore, growth rates in total factor productivity have been on decline. This has happened at the same time as computers have been introduced at an increasing scale in the five national economies reported in figure 2 (see below). This has been regarded as paradoxical. The paradox is not decreasing productivity (which can be explained by theory) but the fact that productivity grows slowly at the same time as massive investments are being made in a new technology. If this new technology is not more productive than old technology, why invest in it? Robert Solow (1987) expressed this paradox with the phrase: ‘You can see the computers everywhere but in the productivity statistics’.

Figure 2. Growth in TFP.



Source: Jorgensen (2002)

The productivity paradox has stimulated a complete little research tradition. Triplett (1999) summarises this literature. One hypothesis is that the productivity paradox has disappeared. The U.S. economy experienced high growth during the 1990s and many interpreted this as a ‘new economy’ feature characterised by prolonged growth without inflation. Still it is too early to evaluate this hypothesis, in particular because growth in the U.S. economy stagnated from 2001 onwards. However, Europe and Japan did not experience anything like a boom in

the 1990s so at least for these countries the paradox remains. Among the other explanations Triplett discusses, two are of particular interest here:

First, Triplett proposes that productivity growth may not be observed simply because computers (still) constitute a too small share of the total economy to be visible in aggregate productivity statistics. This hypothesis is in accordance with the developments in the U.S. economy and the difference in growth patterns across European countries. In the United States the ICT industry is large and high growth here gives rise to macroeconomic effects. In some European countries, but not all the picture is similar. In other European countries, the ICT industries still constitute a too small part of the economy for its fluctuations to be reflected in macroeconomic data. This explanation implies that growth is higher in countries and regions that are particularly specialised in ICT. We explore this hypothesis at German regional data in Section 7.

Second, Triplett proposes that productivity growth is yet to be observed because we are in a period in which the seeds are sown, and not yet the period in which the fruits are harvested. This is in line with recent theories on macroeconomic effects of introduction of general purpose technologies. Such technologies are characterised by complementarities, in such a way that different types of technologies when used simultaneously increase each others productivity. Also ICT may be characterised by network externalities so that the marginal productivity or utility from using these technologies are larger when there are many users. If such effects are present there might be 'threshold effects' in ICT which do not allow productivity growth from this industry before it has reached a significant size. In section 7 we investigate whether growth in regions and in ICT sectors are higher when these regions are specialised in different types of ICT.

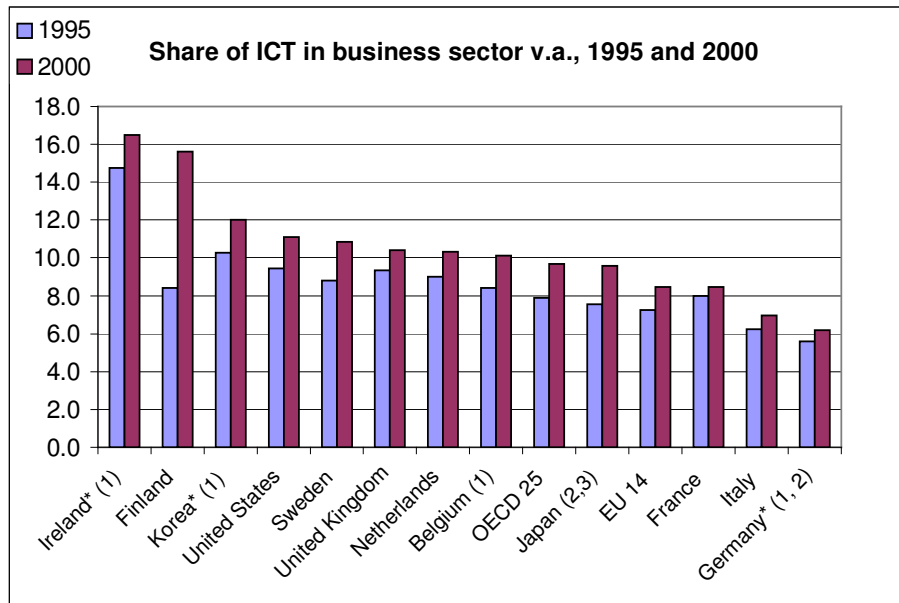
The main interest in this paper is growth effects of ICT in Germany. There are important differences across countries in use and production of ICT. Therefore the next section is devoted to a comparison of ICT performance between OECD countries.

3. ICT in Germany and other countries

Germany is an ICT laggard as compared to other countries. Neither in terms of production, use, investments nor trade does Germany perform on line with those countries that are in the front. This is evident from figures 3 through 7. These are rudimentary evidence only, but the figures give the impression that Germany and the other large continental European countries lag behind in production and use of ICT.

Figure 3 shows shares of ICT in business sector value added for some countries in 1995 and in 2000. Generally, the figure demonstrates that ICT is indeed an important and growing industry. While there are international differences, the share of ICT in business value added is larger than five per cent in all countries. The average share of this sector in business value added for OECD approached ten per cent in 2000. With shares of business value added ranging between five and 20 per cent, the explanation of the Solow paradox that the small size of the ICT industry makes growth effects from it invisible will have different relevance in different countries. In Ireland and Germany the average growth rates for ICT were about similar, but in Ireland this growth constituted 2 percentage points of total valued added, while in Germany it was less than 0.6.

Figure 3. ICT shares in value added, 1995 and 2000



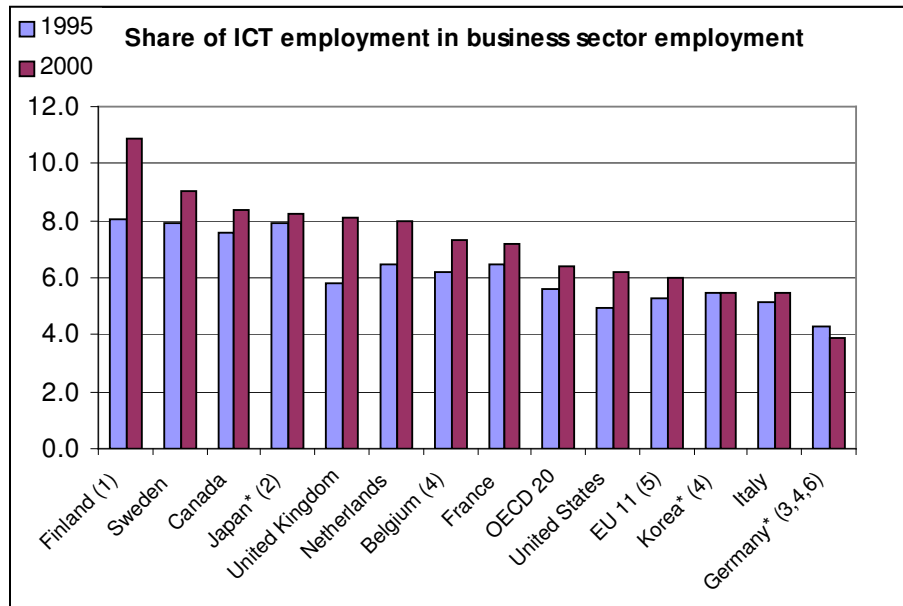
Note: * 1999, 1 rental of ICT goods not available., 2 ICT wholesale not available, 3 includes only parts of computer related activities

Source: OECD (2002)

Second, the figure confirms the success stories of Ireland and Finland. Also Korea, the United States and Sweden rank high in the figure.

Third, Germany ranks lowest of all the countries in the figure and well below the EU and the OECD average. Also Italy and France show poor performances. In fact, the importance of ICT in the German economy (measured as share of value added) is about half of that in the United States and Korea and one third of that in Finland and Ireland.

In figure 4 we present the share of ICT in employment. This figure gives an even stronger impression on how ICT differs between countries. Finland and Sweden rank high in the figure, while Germany ranks low, with *decreasing* ICT employment shares.

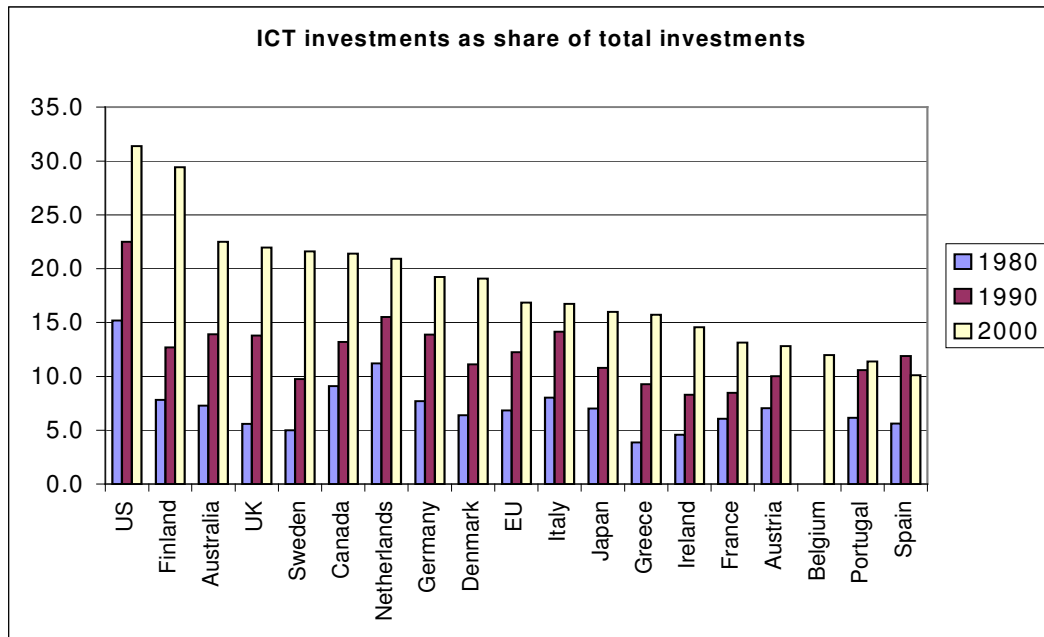
Figure 4.

1 Based on employee figures, 2 includes market research and polling, 3, ICT wholesale not available, 4 rental of ICT not available, 5 Greece, Luxembourg and Ireland missing, 6, 2000-01.

Source: OECD (2002)

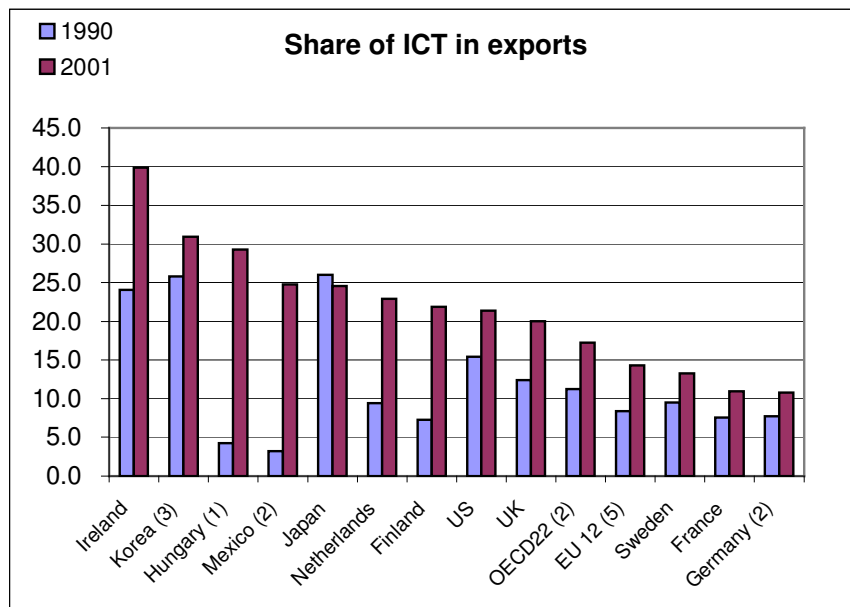
As underlined above, the potential productivity effects of ICT lie not only in production within ICT industries, but also in use of ICT in other industries. Network externalities and complementarities may raise the productivity of ICT as a function of cumulative use and production of such goods. Figure 5 shows the shares of ICT in total investments. These data include investments in the ICT industry but also ICT investments in other industries. They therefore give an impression of the importance of ICT in investments in general rather than the size of the ICT industry. All countries except from Spain have increasing ICT shares in investments. Apart from this, the figure gives a somewhat different impression as compared to figures 3 and 4 above. In terms of investments, the United States ranks highest and investments shares have increased from 15 per cent to 32. In the United States therefore, the capital stock is becoming increasingly ICT intensive. Finland and Ireland now rank differently, with Finland having high investments shares in ICT and Ireland low. In terms of investments, Germany ranks intermediate. This may indicate a modest catching up in terms of ICT intensity.

Figure 5.



Source: OECD (2002)

Figure 6.



1 1992, 2 1993, 3, 1994, 5 2001.

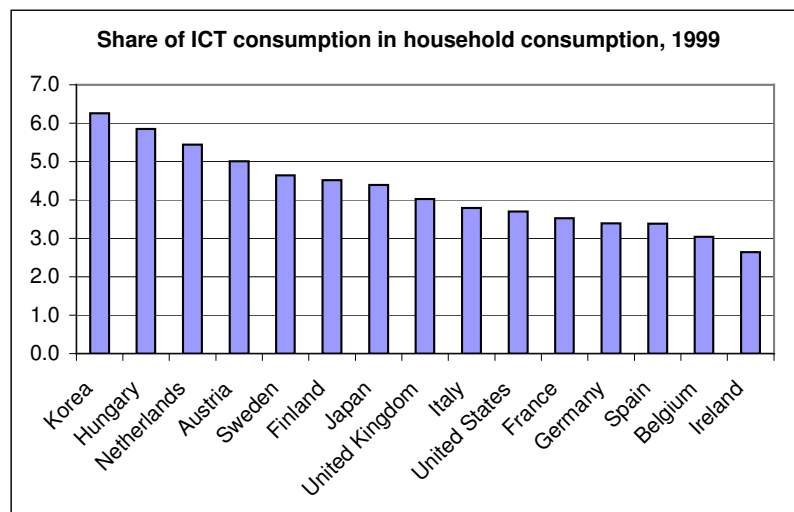
Source: OECD (2002)

Figure 6 contrasts the impression given in figure 5. Figure 6 shows export shares of ICT. That figure shows that Ireland, Korea, Hungary and Mexico rank high while Finland and the United States rank intermediate. Also in terms of export specialisation, Germany ranks low and lower than the average of both the EU and OECD.

Figure 7 present ICT shares in household consumption. This figure demonstrates that there is far less variation in consumption than there is in production, employment or investments. Also the ranking of countries is different in terms of consumption than for the other variables. This needs not surprise. Consumption of ICT reflects national preferences, market structures and welfare. Therefore, consumption of ICT may well be high even if production is low.

In the figure, Korea, Hungary and the Netherlands rank high. Finland, the United States and Germany rank intermediate while Ireland ranks lowest. Figure 7 therefore does not lend support to the idea that widespread consumption of ICT stimulates growth. Finland, the United States and Ireland were the three OECD countries with highest growth rates through the latest half of the 1990s but they do not rank at the top in terms of consumption of ICT.

Figure 7



Source: OECD.

In this section we have presented international evidence on production, employment, investments, trade and consumption of ICT. The general conclusions are that ICT is growing in importance and that there are large differences in specialisation in ICT across countries. In most countries ICT investments grow much more than ICT production. This indicates introduction of ICT in other industries. There are less differences between countries in consumption than in production of ICT.

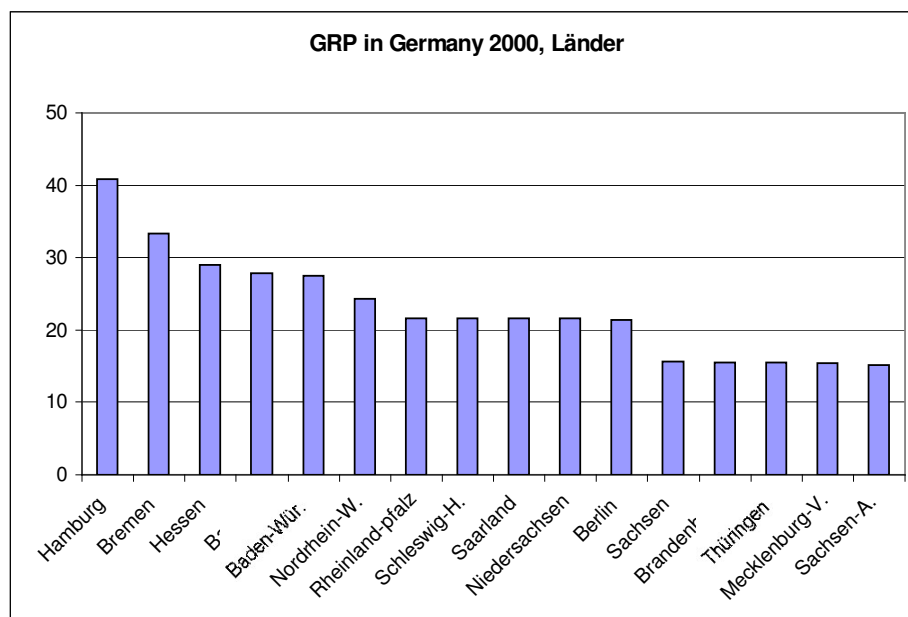
Generally Germany is a laggard in ICT. Germany lags behind the other OECD countries in terms of production, employment and exports in ICT. In terms of household consumption and investments however, Germany ranks intermediate.

4. ICT and regional developments in Germany

In section 5, 6 and 7 of this paper we will make use of a disaggregated set of the 97 German planning regions (Raumordnungsregionen). In order to set ideas and perspective to the forthcoming analyses, in this section we present some data for the more well-known German Länder.

Regional developments in Germany are characterised by the East-West divide. Through the German unification in 1990 a world leading country in terms of income per capita, industrial production and institutional sophistication effectively affiliated a crisis-ridden middle-income country. In 1990 productivity in East Germany was estimated to less than one third of that in the richer Western Germany (Akerlof et al., 1991).⁶ The East-West divide is still distinct. Chart 8 shows this in terms of gross regional products (GRP) in the German Länder. The six East-German regions rank lowest with the capital Berlin as their richest companion.

Figure 8



Source: Eurostat (2002)

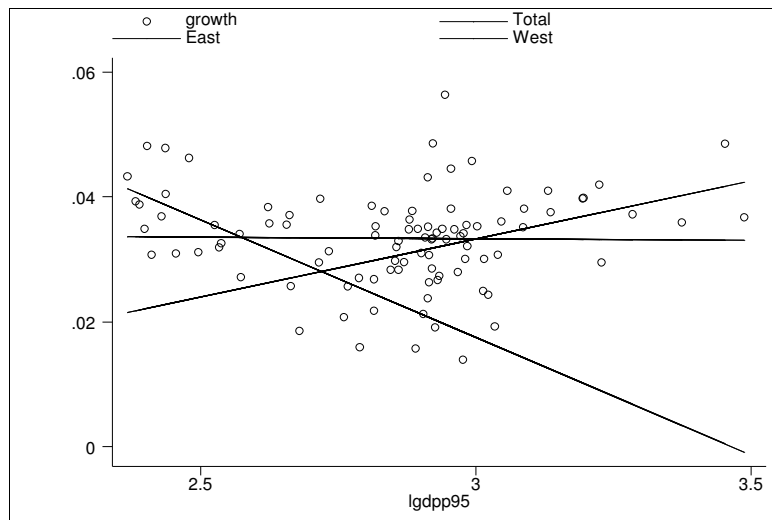
Also for other variables, the East-West divide in Germany is important. While the national unemployment rate is about ten per cent, in Eastern Germany it is about 18 per cent. Migration from the eastern parts of the country is high. Industrial production, productivity and

⁶ The exact size of productivity and national income in GDR (and the other formerly centrally planned economies) is subject to controversy. Official figures indicated gross product per capita in Eastern Germany being about two thirds of the West German levels. Data from CIA indicated a national income level in GDR of about one half of the OECD level.

real wages are lower than in the western parts of the country, more than a decade after unification.

Figure 9 below graphs growth rates in GRP in the period from 1995 to 2000 for the 97 German planning regions against the (log of) GRP in 1995. The figure is interesting in (at least) three senses. First, there is an overall lack of convergence in Germany. The (almost) horizontal regression line is for the full sample of regions. A converging development would have been characterised by a downward sloping regression line indicating that poor regions would have had higher growth rates than richer regions.⁷ The horizontal line indicates a complete lack of convergence. Second, there is divergence among the West-German regions. This is demonstrated by the (not significant) positive sloping regression line resulting from regressing growth rates against (log of) initial income for the West German regions only. Third, the East-German regions display convergence. The negative (and significant) regression line indicates that growth is higher for poor East German regions than for the rich ones. This line is the result of a separate regression for these regions only.

Figure 9. Income and growth in Germany



Source: Eurostat (2002)

In general therefore, regional developments in Germany seem to be characterised by what Danny Quah (1996) has denoted *twin peaks*: In West Germany some regions are forging ahead and forming a rich elite while the East German regions seem to converge into a ‘club’ of poor regions.

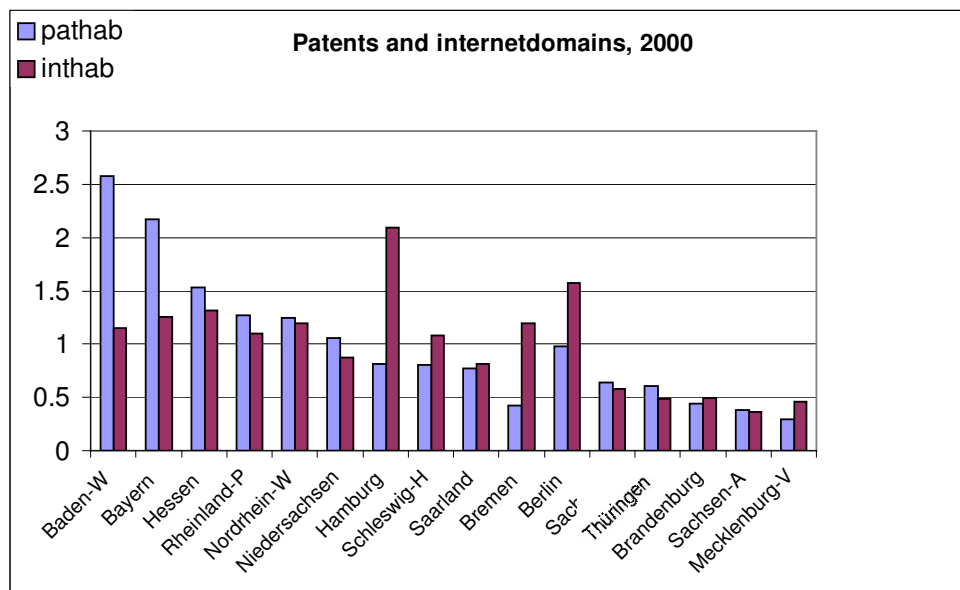
For technological developments, the picture is more or less similar. Figure 10 graphs the number of patent applications per habitants (normalised by the average across regions) and the number of internet domains registered in each Länder per habitant (normalised to the average across regions) in 2000. The internet domains are “dot.de” domains, not “dot.com” domains. We interpret this variable as measuring production of internet services for

⁷ This conclusion is valid only when absence of a negative and significant coefficient occurs together with constant or increased standard deviation in income per capita (see e.g. Quah, 1992). For the German planning regions, standard deviation of (log of) gross regional product increased for the western regions and for the country in total and decreased for the eastern regions in the period described in figure 9.

consumption rather than for business (as a “dot.com” variable would have suggested). We believe however, that these two measures would overlap to a significant degree. These data are taken from Krymalowski (2000). The patent data are from Greif and Schmiedl (2002). Länder are assigned patents according to the address of the inventors rather than the companies they (often) work for. The patent data therefore measure technological competencies represented by the residential population in the regions.

The figure adds to the above impression that East Germany is lagging behind West Germany. It is interesting to note that the rankings of the German Länder in terms of these technology related variables differ from the rankings in terms of income. In terms of patents per habitant (the light grey bars) Baden-Württemberg and Bavaria now rank highest and Hamburg and Bremen rank low. Amongst the East-German Länder, Berlin ranks highest with the industrialised Saxony and Thuringia thereafter. In terms of internet domains per habitant (dark grey bars), Hamburg and Berlin rank highest with Bremen third. This is important in at least two respects: First, registered internet domains are most frequent in the large cities. Second, there does not seem to be any significant correlation between patents per habitant and registered internet domains. Therefore, the spatial pattern of ICT services (as measured by internet domains) seem to have other determinants than the spatial pattern of other technology-producing activities. We will return to this point in section 5 where more detailed data on patenting in different fields will be used.

Figure 10



In most of this paper we make use of employment data for industries and occupations in the German planning regions. These data are from DIW (2003) and Bundesanstalt für Arbeit (2002).⁸ We have the following reason for using both: Industrial employment (defined by the NACE classification system) indicates the (employment) localisation of German industries. As such they are indicative for where production in different industries occur. For the ICT sectors these numbers reveal specialisation patterns among regions and the relative strengths

⁸ Data obtained directly from Institut für Arbeitsmarkt- und Berufsforschung (1995-2001), Bundesanstalt für Arbeit.

and weaknesses among the German regions in different industries. The occupational employment data, on the other hand, reveal technological competencies among employees. If not a direct measure, they are probably more revealing about use of different competences in the economy than employment data for the different industries are. We do not have occupational data at industry level which could have served better to indicate regional use of competencies. The data at hand however, reveal interesting patterns.

We should underline at this stage that employment data, at industry or occupational levels, are not performance data. Production and employment are positively related given constant and similar productivity across units, but in the time series dimension correlations are probably weak. For the cross section dimension used in this paper, these considerations are not likely to influence the results very much. We use employment data together with innovation data (patents). There is a large literature on the relationships between employment and innovation. At the firm level, there is no clear relationship. At the regional cross sectional level we use here, we expect there to be a positive relationship. A recent survey study on innovation and employment is provided by Evangelista and Savona (2003).

For the industry data we identified the following industries as ICT-industries or ICT related (their NACE numbers are reported in parentheses): Publishing (2050), office machinery (2120), electrical components (2130), electrical products (2140), ICT services (4000) and R&D (4700). Here we report the regional specialisation in employment in hardware production (inclusive and exclusive of electronics) and in ICT services (i.e. employment in these industries as shares of total employment). Results are graphed in figures 11, 12 and 13. Also in these figures the eastern regions are located to the right.

For production of hardware, the overall picture is one of significant geographical clustering. Baden-Württemberg, Bavaria and (to a lesser extent) Rhineland-Palatinate are relatively heavily specialised in hardware production. This is in line with the findings in Hoski et al. 2002.

The general picture is also one of industrial decline. Most regions were less specialised in this kind of production in 2002 than in 1998. This is in line with the weak performance in German electronics industries as compared to other countries as described in section 3. The decline is evident both for direct ICT hardware production (figure 11, NACE number 2120) and even more significant for electronics in general (figure 12, NACE numbers 2120, 2130 and 2140). It is also evident that this decline is more pronounced in the western regions. In e.g. East-German Thuringia there is growth in employment in production of office machinery.

Figure 11

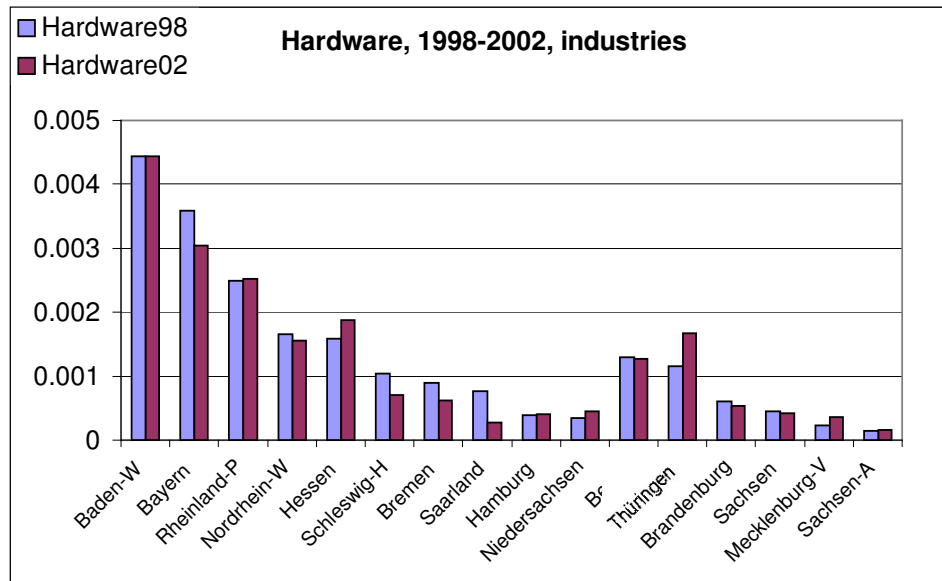
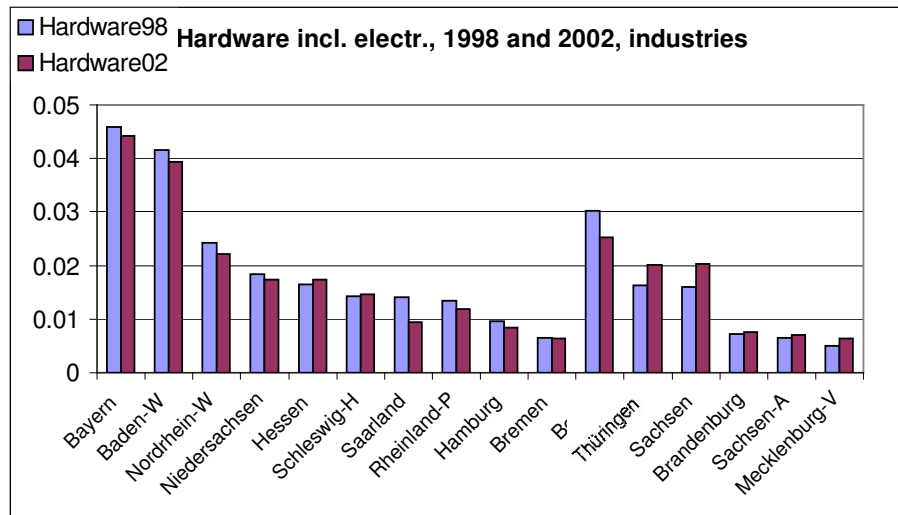


Figure 12 shows the similar graphs for electronics in general. The graph shows that the two regions most specialised in the narrower hardware-industry (Barden-Württemberg and Bavaria) are also the two most specialised in electronics. This pattern is in line with a “Silicon-Valley” effect in these industries: New firms or production of new products in this industry might have been attracted to regions being specialised in similar industries. The reasons might be technology spillovers, pooled labour markets or backward and forward linkages. The reasons might also be simpler, i.e. that firms that produced electronics shift to production of office machines but remain localised in the same regions.

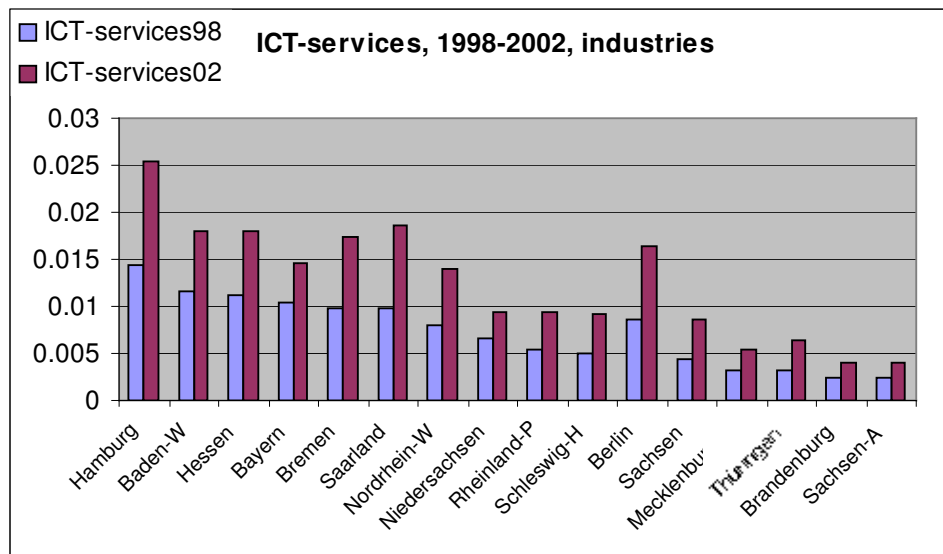
Figure 12 strengthens the overall picture that electronics is an industry on decline in Germany. For regions in which production of hardware were relatively important, the decline is significant (Bavaria, Baden-Württemberg and Berlin). Only three regions experienced growth in these sectors in the period covered here. These were the West-German region Hesse and the East-German regions Saxony and Thuringia. For Saxony and Thuringia the growth is significant.

For Germany in general therefore, we get the impression that there is a south-west cluster of hardware-producers. Also in Berlin and to a limited extent South-East (in which growth rates seem to be high) there is a high preponderance of hardware related employment. This is in line with the findings of others (see e.g. Hoski et al., 2002).

Figure 12

For ICT service industries (NACE number 4000) the development is different. All regions experienced growth in these industries' employment. The growth rates over the short time span reported here are well over 50 per cent for some regions. The three city states (Hamburg, Bremen and Berlin) perform well in this industry while Baden-Württemberg, Hesse and Saarland are also relatively specialised in ICT services. The East-West divide is also visible for employment shares in ICT services, with the five East-German regions ranking lowest. Note that the two regions with the highest employment shares in ICT manufacturing are not the same regions with the highest employment in services. This is interesting in so far as an optimistic "Silicon Valley" scenario would predict positive spillover effects between production of ICT services and ICT manufactures.

Together the three figures (11, 12 and 13) give an impression of both spatial clustering (in the north-west, south-west and in Berlin), relative decline in hardware production and increase in production of ICT services. The figures also indicate that there are reasons to discriminate between ICT services and ICT hardware in analyses of the ICT industries. The German case, based on the simple statistics reported here, indicates different dynamics and spatial patterns in the two.

Figure 13

While industrial employment data indicates the location of (employment in) industrial production, they do not reveal patterns of competence among employees. To give an expression of these characteristics of the German ICT industries we make use of regional employment data for occupations. We use a similar classification for occupations as we did for industries. The first classification are people working with construction and reparations of ICT devices (denoted hardware here). The second ICT sector is for data-consultancy. For industries the new NACE classification, which contains ICT specifically, was available only from 1998 onwards. For occupations we use data stretching back to 1995. The German unification in 1990 makes it sensible to use data from the mid-1990s onward only. The dynamics are reported in figures 14 and 15 below for hardware and ICT-services respectively.

In general the occupational employment data show less regional variation than the industrial employment data do. We interpret this as indicative that ICT competencies are also used in other industries than those producing ICT (be they hardware or ICT-service producers).

For employment in 'hardware' occupations figure 14 gives the same overall impression as figures 12 and 13 above. Baden-Württemberg and Bavaria are relatively specialised in employment in these occupations. So are the large cities, Bremen and Hamburg in the West and Berlin in the East. Generally, the picture is also one of relative decline, as it was for hardware producing industry employment. Only Bavaria and Saxony report growth in employment in these occupations.

Figure 14

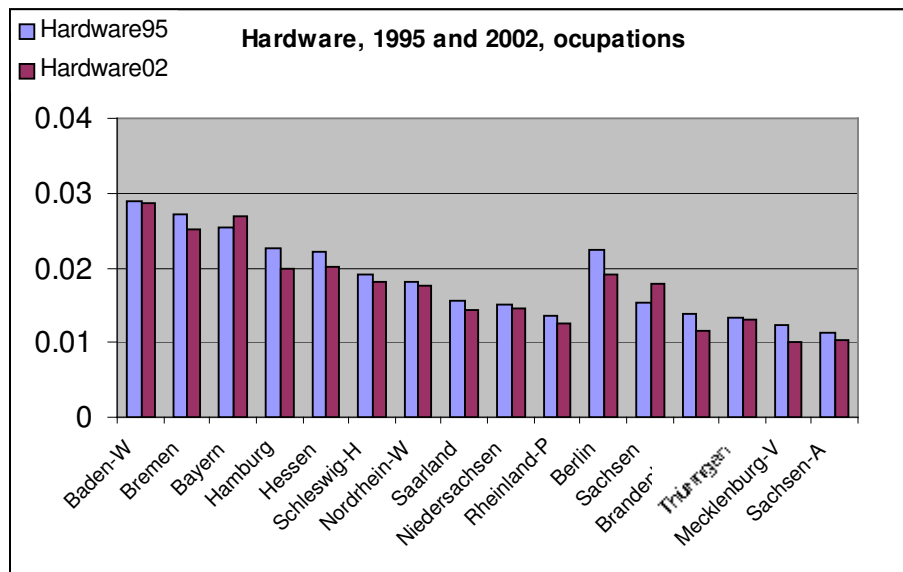
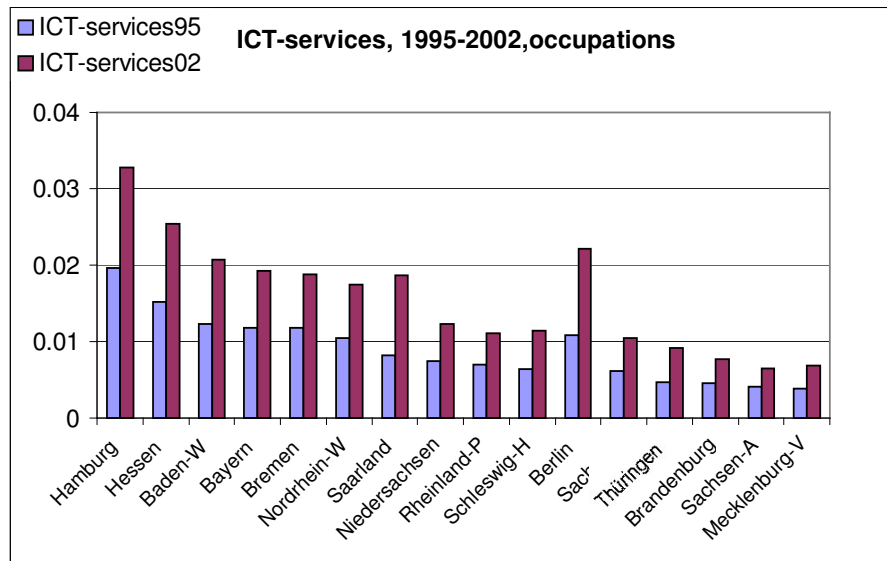


Figure 15 shows employment of occupations in ICT service occupations. As for ICT-service industries there is fast growth in all regions. In Berlin the share of employees in these occupations doubled in the period from 1995 to 2002. Also in Hamburg, Hesse and Saarland growth rates are very high. Again the occupational data show less variation than the industry employment data do. The data support the idea that the cities are doing well in terms of ICT services, with Hamburg, Bremen and Berlin ranking high. Also for employment in ICT service occupations the East German regions (except from Berlin) perform worse than the rest of the country.

Figure 15

We have hypothesised that occupational employment data better indicate employees' competencies than does industrial employment. We expect there to be correlations between ICT-related employment in industries and occupations, however. Correlations for growth in specialisation are shown in figures 16 and 17 below for hardware and ICT-services, respectively. There is a neat correlation between growth in employment of people in datawork occupations and in ICT-service producing industries. For employment in ICT hardware producing industries and in hardware related occupations correlation is present, but much weaker. From the two figures the positive growth rates in ICT services and the negative growth rates in hardware production are also evident.

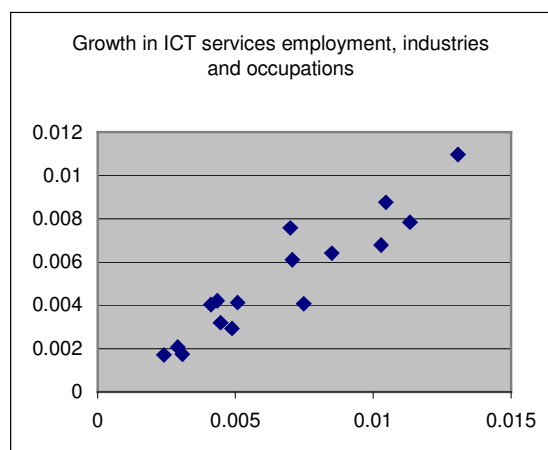
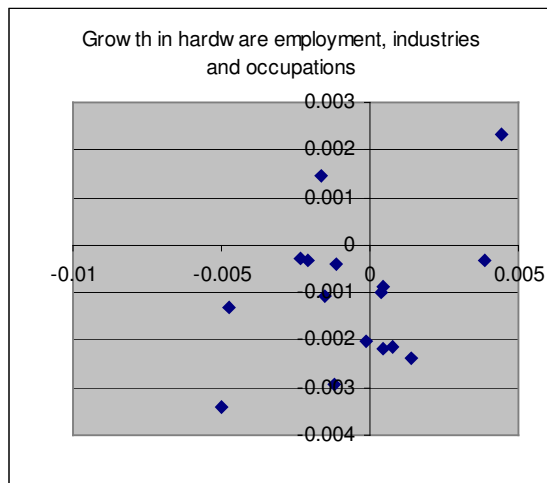
Figure 16

Figure 17

In summary, the descriptive statistics reported above suggest the following conclusions on ICT-employment in Germany: First, ICT employment in hardware and in software, in industries and in occupations, seems to obey geographical clustering. Some regions are more specialised in these types of employment than others. In particular it seems that the southern part of Germany (Bavaria and Baden-Württemberg) are the most prominent ICT clusters in Germany in addition to the cities Hamburg, Bremen and Berlin. ICT service production does not seem to be attracted to regions that show general technological strengths, measured by e.g. patents. Rather ICT services seem to be attracted to urban regions. A possible exception from this pattern is the south-east regions, Thuringia and Saxony. This section has also indicated that, at least for the German case, location of ICT services and production of ICT devices, do not seem to have similar determinants. While ICT hardware production is more dominant in the south-west cluster, ICT services seem to be more attracted to urban centres.

5. The spatial patterns of ICT production and employment

5.1 Spatial patterns

The descriptive statistics reported above indicated that the German Länder differ significantly in their performance in ICT. In this section we aim at giving an analysis of location of employment in German ICT. Uneven specialisation in industries as we reported above is one common measure in regional economics. A related and stronger type is when specialisation patterns are contagious across regions. This would result in an economic landscape in which neighbour regions tend to be similar to each other. In order to test for this we make use of a distance weights matrix of the following type:

$$W_{ij} = \frac{1/w_{ij}}{\sum_j 1/w_{ij}}$$

Above w_{ij} is a measure of the distance between region i and region j . The variable W_{ij} is therefore a function of the inverse of the distance between region i and j . This inverse distance measure is normalised with the sum of all such distances between region i and the other regions. This 'row-standardisation' makes it possible to construct weighted averages. In spatial econometrics analyses, the hypothesis is very often that a variable in one region will influence on a variable in another region as a negative function of the distance between the two regions. This is what the variable W_{ij} expresses. The distance variable, w_{ij} , can be constructed in different ways. Often geographical distance is used. Here we use contiguity between regions. That is, spatial spillovers are measured on the basis of neighbourhood between regions. Consider region j 's employment specialisation in a sector k , s_{jk} (normalised as deviations from the mean). For region i the variable

$$\bar{s}_{ik} = \sum_j W_{ij} s_{jk}$$

denotes the weighted average of that region's neighbours' employment in sector k . In figures 18 -23 we graph this variable for (log of) gross regional product, (log of) patents per habitant, and employment shares in ICT against each regions' performance in the same variables. These plots are so-called Moran scatter plots.

Figure 18. Moran scatter plot of income per habitant

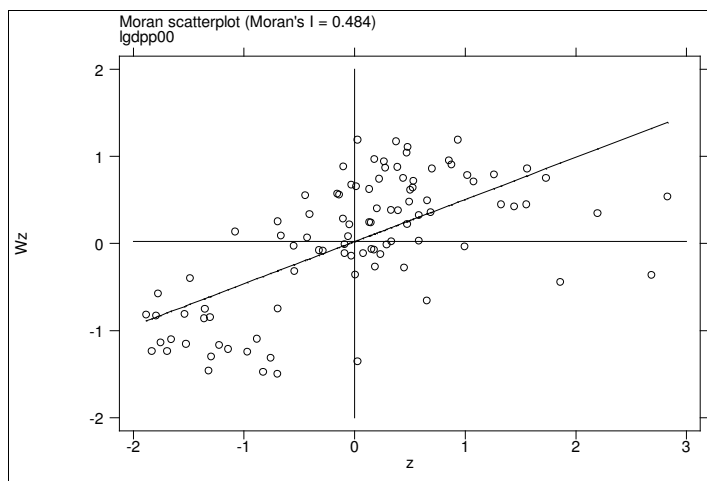
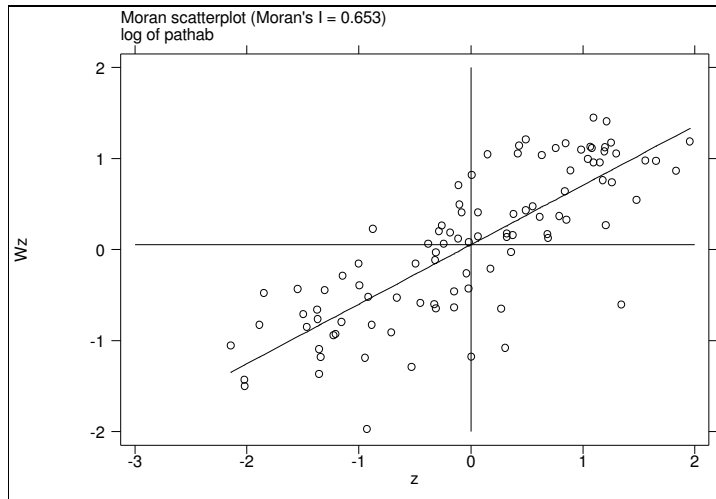


Figure 18 shows that income per habitant is indeed spatially clustered. Most regions are located in the north east quadrant (rich regions with rich neighbours) or in the south west quadrant (poor regions with poor neighbours). This is partly due to the fact that the East German regions are poorer than the West German ones. The positive relationship is present and significant also when normalising for means of income per capita in East and West, however.

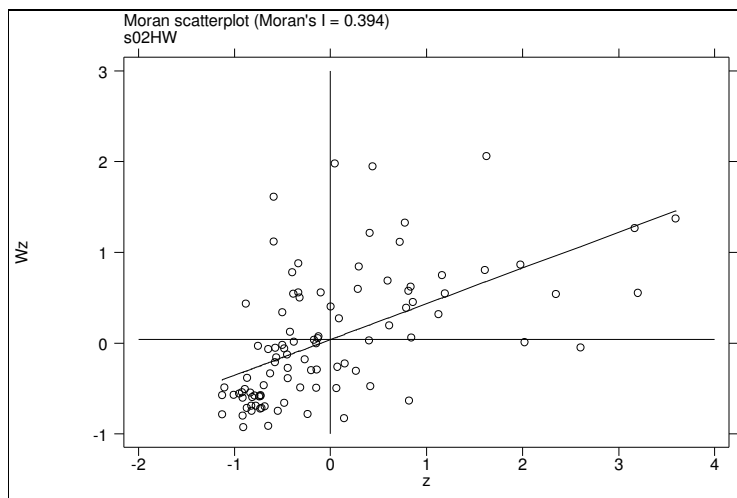
In figure 19 we show the similar relationship for patents per habitant. The figure shows that spatial clustering is present also for patents. The spatial relationship for this variable is not as sensitive for the east-west divide as that for income per habitant.

Figure 19 Moran scatter plot of patents per habitant



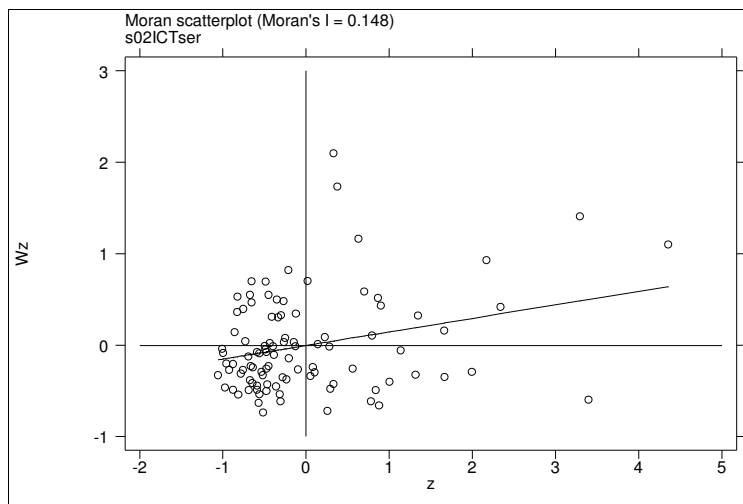
For the ICT related variables we find less spatial correlation. Figures 20 to 23 show Moran scatter plots for employment in hardware (including electronics) and ICT service *industries* and for hardware (including electronics) and ICT service *occupations*. For hardware industries (figure 20) there is positive spatial correlation, in particular for the regions with less than average employment shares (there are more observations in the south west quadrant than in the north west quadrant). For the well performing regions the degree of spatial clustering is limited. This result does not suggest positive spillovers between regions in this industry. In that case there would have been more observations in the north west part of the figure. For employment in office machines only (not reported) the parallel figure shows negative spatial correlation.

Figure 20 Moran scatter plot of employment shares in hardware industries (incl.electronics)



Employment shares in ICT services also display positive spatial correlation. This relationship is weakly significant, however. The figure reveals that most regions are located in the south west quadrant, i.e. regions with low employment shares surrounded by neighbours with low employment shares too. This finding indicates that Germany does not have clusters of ICT service producing regions located nearby each other.

Figure 21 Moran scatterplots of employment shares in ICT service industries



Spatial clustering in industrial employment is reflected in occupational employment (figures 22 and 23). Both for hardware (figure 22) and (less significant) for ICT services (figure 23), occupational employment does display spatial clustering.

Figure 22 Moran scatterplots of employment shares in hardware occupations

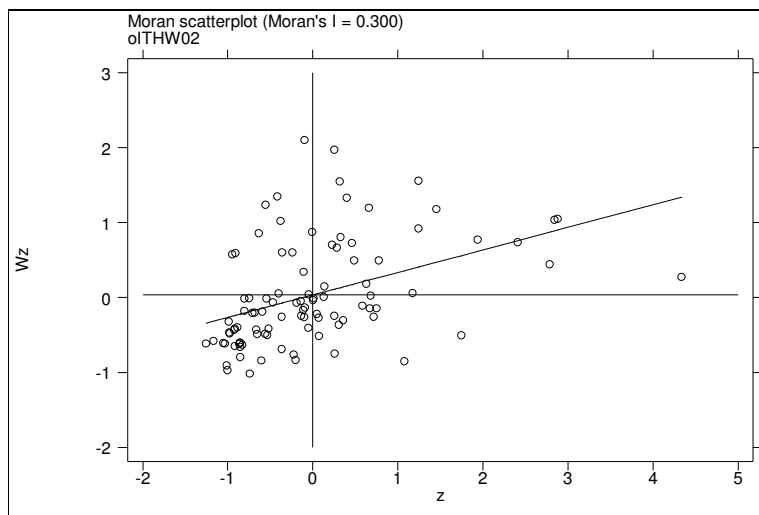
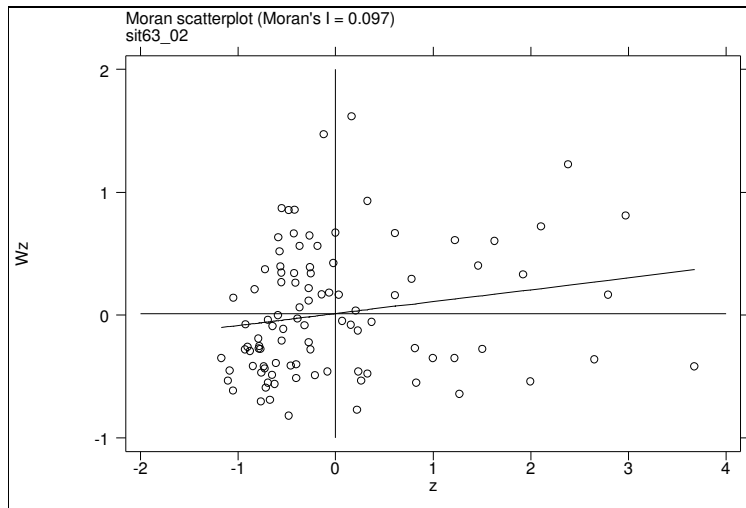


Figure 23 Moran scatterplots of employment shares in ICT service occupations



Figures 18 through 23 showed the correlations between levels of the different variables against their spatially lagged values. The global Moran's I is a summary statistics for spatial correlations. Define the spatially weighted average of a variable S for region i as $w_{ij}(S_j - S)$ in which S denotes the average of the S_j . For each region this is the so-called local Moran's I. The global Moran's I is defined as

$$I = \left(\frac{N}{R} \right) \left\{ \frac{S'WS}{S'S} \right\}$$

Here S is the vector of the variable S, N is the number of observations, R is the sum of all spatial weights and W is the distance weight matrix. The transformation $z = \{I - E(I)\} / \{V(I)^{1/2}\}$, in which $E(I)$ is the mean and $V(I)$ is the variance of I, gives a normally distributed variable when the variable in question is itself normally distributed. Therefore the degree of spatial spillovers might also be tested statistically. In table 1 we report the global Moran's I and its significance for the employment shares used here (2002), for patents per habitant in total and in different ICT related technology fields and for population and gross regional product per capita.

It is evident from table 1 that employment shares in ICT related activities are generally spatially correlated. There is positive and significant spatial autocorrelation in employment shares in the electronics industries, but not in the case for computers (office machines). For occupations, there is positive spatial autocorrelation for all occupations reported here, except for advertisement and natural scientists. For employment in ICT services, there seem to be positive spatial correlation, in particular for industries and occupations directly related to the ICT sectors (ICT-services and ICT data work). This does not imply however, that these clusters of ICT sectors (in hardware and service employment) are located in the same locations.

For patenting spatial clustering is pronounced, both in magnitude and in significance. However, patenting in ICT-related technological areas is not more clustered than patenting in total.

Regional product per habitant does show spatial autocorrelation (c.f. figure 19) as does population size (to a lesser extent).

Table 1. Moran's I for variables used in analysis.

	Moran's I
<u>Industry employment shares (2002)</u>	
<i>Devices</i>	
Office machines	-0.008
Electr. comp	0.270***
Electronics	0.313***
<i>Services</i>	
ICT-services	0.148***
Publishing	0.239***
R&D	0.010
<u>Occupational employment shares (2002)</u>	
<i>Devices</i>	
Telecom.	0.262***
Electronics	0.147***
Elec. engineer	0.169***
Techn.electr.	0.297***
<i>Services</i>	
Datawork	0.097***
Publishing	0.405**
Other engineers	0.355***
Nat. scientists	-0.125**
Advertisement	-0.028
<u>Patents per habitant (1995-2000)</u>	
Total	0.677***
Electronics	0.190***
Electrotechnique	0.519***
Computer	0.235***
Accounting	0.321***
Optics	0.446***
Printing	0.088**
<u>Log of GRP per habitant (2000)</u>	
	0.484***
<u>Population (1999)</u>	
	0.105**

5.2 What factors explain the spatial distribution of ICT employment?

The correlations showed in figures 19 through 23 are *gross correlations* in the sense that we did not take into account how localisation of industries are influenced by other variables. The spatial weight matrix W_{ij} can also be used in regression-based explorations. There are two basic approaches on how to integrate spatial correlation into regression techniques. The first is to assume spatial lags in the dependent variable in question. Such an approach assumes that in addition to ordinary explanatory variables, also the magnitude of the dependent variable in other regions influence on the dependent variable for each region. For e.g. some models of economic growth, a deduction is that regions (or countries) may benefit from growth in their neighbour regions. Formally, this assumption may be written as

$$7) \quad g = \alpha + \rho Wg + \mathbf{X}\gamma + u$$

$$8) \quad |\mathbf{I} - \rho W|g = \alpha + \mathbf{X}\gamma + u$$

In eq. 7. the dependent variable g in one region is assumed to depend on the vector of explanatory variables \mathbf{X} (where γ is the vector of coefficients), the constant term α , the error term u and a weighted average of g in the other regions. The weights are the same as W_{ij} above. Therefore, it is assumed that g in one region influences its neighbours with weights depending on contiguity. ρ is the spatial autocorrelation coefficient to be estimated. Models of the type described by eq. 7 are spatial lag models. A reformulation of eq. 7 in matrix notation is eq. 8. Eq. 8 can not be estimated by ordinary least squares regression techniques, but has to be estimated by means of a maximum likelihood procedure (see Anselin, 1992 and 1988).

The other approach is to assume that spatial autocorrelation enters the error term in the regression equation:

$$9) \quad g = \alpha + \mathbf{X}\gamma + u$$

$$u = \lambda W u + e$$

While eqs. 7 and 8 expresses that g in one region influences systematically g among its neighbour regions, eq. 9 expresses that ‘errors’ in g is influenced by parallel ‘errors’ in g in other regions. The magnitude of such errors is given by the parameter λ to be estimated. This is an indication that there are local clusters for which the dependent variable are either high or low, but that this is not a general feature. In this case, the explanatory variables may be correctly specified, but errors from the predicted g will transfer to neighbours. Linear squares estimation of 9 will result in unbiased coefficients, but inference about them will be wrong. Also in this case correct inferences depend on a maximum likelihood estimation procedure.

We are interested in the determinants of regional specialisation in ICT. In table 2 below, we report regression results of specialisations in these industries and occupations for 2002. We regress specialisation on (log of) GRP per habitant, (log of) population, the total number of patents per habitant and patents per habitant in ICT related technological fields. We expect these variables to be able to reveal whether ICT employment are attracted to urban areas,

regions with technological sophistication or by innovations in the specific technological areas for which we have employment data for. We also include a dummy variable for whether the region belongs to the Eastern German Länder and for each Länder that includes more than one region. All regression results reported in table 2 are the results of either spatial lagged models or spatial error models. The choices between these models were based on diagnostic tests performed after OLS regressions. In some cases the spatial effects were not significant.

In the table results for employment in industries are presented in the first bloc of rows and results for employment in occupations in the second. The first subgroups in each of these two main groups are for employment related to hardware, the second subgroups for employment related to ICT services.

There are two striking main results in the table. First, locations of employment in industries and (to a smaller extent) occupations that are related to hardware production neither seem to be influenced by income per habitant ($L(\text{grph})$) nor population ($L(\text{pop})$). This is remarkable since these sectors are probably characterised by increasing returns to scale. As mentioned in section 2, theories in economic geography predict that such industries might be attracted to regions with large market sizes. Rather, this type of employment is located where regions are strong in innovation in the particular field (note the significant effects of field specific patenting). Regions that have many patents in for instance accounting machines are also the regions specialised in production of hardware in terms of employment. For employment in ICT services, the situation is different. Regions specialised in these types of employment (be it in industries or in occupations) are generally richer and more populous. An exception to this pattern is employment in the occupational sector *datawork*. For this sector patenting in several fields significantly influence on employment in addition to market size (measured by income per habitant and population).

Note also that patenting per habitant (*Pat.*) in general does not significantly influences on location of ICT employment (except for patents in printing devices). This underlines the indication above that the German ICT industry is not located in areas that are characterised by general technological strengths.

Our findings support the view that “ICT” covers a broad range of activities. It is important that in the German case, there does not seem to be common variables that explain all types of ICT locations. Rather, the ICT sector in Germany seem to be of a differentiated nature, in which location patterns in production of hardware are different from those in production of ICT services.

Second, there is only limited evidence of spatial spillovers. ρ indicates the magnitude of spatial autocorrelation while λ indicates the magnitude of spatially lagged error terms. It is apparent in the table that in several cases these coefficients are not significant. When they are significant they are often negative. Negative and significant spillovers indicate a situation in which high specialisation in one industry in one region is harmful for specialisation in the same industry in neighbour regions. This might reflect the backwash effect described by Myrdal (1957). This interpretation would imply that regions that are specialised in a certain industry attract labour and other factors of production in this industry from its neighbour regions and therefore has harmful effects for employment in the same industries in these regions.

Positive and significant spillovers in the sense of positive and significant spatial autocorrelation are only present for employment in the electronics industries, for ICT services (in industries) and for natural scientists.

In the regressions reported in table 2 dummy variables for each Länder and for East Germany were included. Therefore, the tests for spatial dependency are very strict in the sense that all characteristics of regional specialisation which are typical for a federal region vanishes from the regression result.

Table 2. Spatial regression results on industry and occupational employment shares, 2002.

	L(grph)	L(pop)	Pat.	P.elect.	P.elect1	P.ICT	P.account	P.optics	P.print	Rho/lambda	R ²
<u>Industries</u>											
<u>Devices</u>											
Office machines	-.06**	-.01	.01	-.18***	-.19***	-.16	.88***	-.03	.09*	$\lambda=.34$	.62
Electr. comp	-.03	-.01	-.04*	-.11	.75***	-.10	-.07	.09	-.04	$\rho=-.12$	.51
Electronics	.00	.00	-.02*	-.11	.35***	.06	-.09	-.13	.08	$\rho=.37***$	.53
<u>Services</u>											
ICT-services	.16***	.03**	-.02*	.18**	-.03	-.13	.13	.15*	.42***	$\rho=.29***$	.70
Publishing	.09**	.02*	-.02**	.04	-.10*	.13	.16	.07	.22***	$\lambda=-.49**$	.58
R&D	.02	.02**	-.02**	.08	.02	-.01	-.12	.27**	.21***	$\lambda=-.46**$	.49
<u>Occupations</u>											
<u>Devices</u>											
Telecom.	.02	-.00	-.00**	-.04	.13***	.21***	-.05	-.03	-.03	$\lambda=-.55***$	.65
Electronics	-.00	-.00	-.00**	.02***	.00	-.03**	.01	.01	.01	$\lambda=-.70***$	.35
Elec. engineer	.04***	.01*	-.00	.07***	.09***	-.44***	.31***	.02	.02	$\rho=-.26***$	.87
Techn.electr.	.04***	.01***	-.00	-.01	.03*	-.01	.06*	.03	.04*	$\rho=-.06$	.77
<u>Services</u>											
Datawork	.21***	.03***	-.00	.13***	-.05	-.29	.30***	.09	.28***	$\rho=.11$	.86
Publishing ⁺	-.00	.01	-.00	-.00	-.00	.03	.00	.03	.04	$\rho=-.06$	.56
Other engineers	.04***	.01**	.01***	.00	-.03	-.01	-.01	.03	.04	$\lambda=-.43**$	.80
Nat. scientists	.00	.00	-.01***	.02	.01	.04	-.04	.09***	.07***	$\lambda=.67***$	.38
Advertisement	.05***	.01***	-.00	.00	-.02*	.00	.01	.00	-.01	$\lambda=-.33$	.78

Note: All coefficients are multiplied by 10. ρ indicates spatial lags while λ indicates spatial errors. R² indicates squared correlation between predicted values and observed values. Dummy-variables for each German Länder and for East Germany were included in regression but are not reported. L(grph) =log of gross regional product per habitant. L(pop) =log of population. Pat.= patents per habitant. P.electr =patents per habitant in electronics, P.electr1 =patents per habitant in electrical devices, P.ICT. = patents per habitant in information technology, P. account=patents per habitant in accounting machines, P.optics=patents per habitant in optical instruments, P.print=patents per habitant in printing technology. ⁺ Dummy for Schleswig-Holstein significant at 1%. Regression without Länder dummies gave negative and significant coefficient for East (1 %) and positive and significant coefficient for patents in publishing.

5.3 The Herfindahl index and Moran's I

In regional economics a common measure for regional concentration of an industry is the Herfindahl-index. This index measures the concentration of an industry across regions. Let S_{ij} denote employment in industry j in region i and let S_j denote total employment in industry j . The Herfindahl index for industry j is defined by:

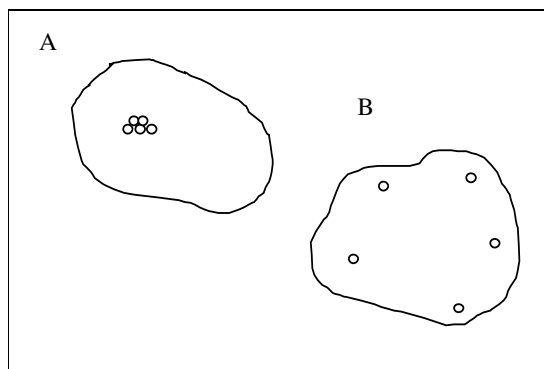
$$H_j = \sum_i \left(\frac{S_{ij}}{S_j} \right)^2$$

The Herfindahl index varies between 1 (complete concentration) and the inverse of the number of regions in question (equal distribution of industries across regions). Since regions differ in size, the lower limit to H_j will normally be higher. A generalised Herfindahl index that takes regions' size into account is the following:

$$HH_j = \sum_i \left(\frac{S_{ij}}{S_j} - \frac{S_i}{S} \right)^2$$

It is important that the Herfindahl index and Moran's I are two different measures of regional concentration. Moran's I measures the degree to which regions located in the neighbourhood of each other are similar with respect to specialisation in an industry. The Herfindahl index measures the extent to which an industry is located in few or many regions. In principle, the relationship between the two measures can be both positive and negative. The figure below shows why this may be the case.

Figure 23



The figure illustrates two landscapes, A and B. It is assumed that these landscapes consist of contiguous regions where most regions have no employment in an industry (not marked in the figure) while five regions (the ones marked as circles) have equal shares (of 20 percent) of employment in the industry in question. In this case the Herfindahl index is 0.2. In case A the

regions specialised in the industry are contiguous. In case B they are located away from each other. In the first case, Moran's I will be positive, in the second case it will be negative.⁹

The two cases illustrates two different types of agglomeration. In the first case (A) agglomeration effects, through e.g. technology spillovers, pooled labour markets or forward and backward linkages result in one cluster of regions specialised in this industry. In the second case (B) there are five smaller clusters of independent regions being located away from each other (and which may be serving the local markets around). In case B there is centrifugal forces working to spread the industrial cores in addition to the forces making regions becoming specialised in this industry.

For employment in German industries the relationships between the generalised Herfindahl index and Moran's I (for employment shares) are as illustrated in figure 24.

Figure 24

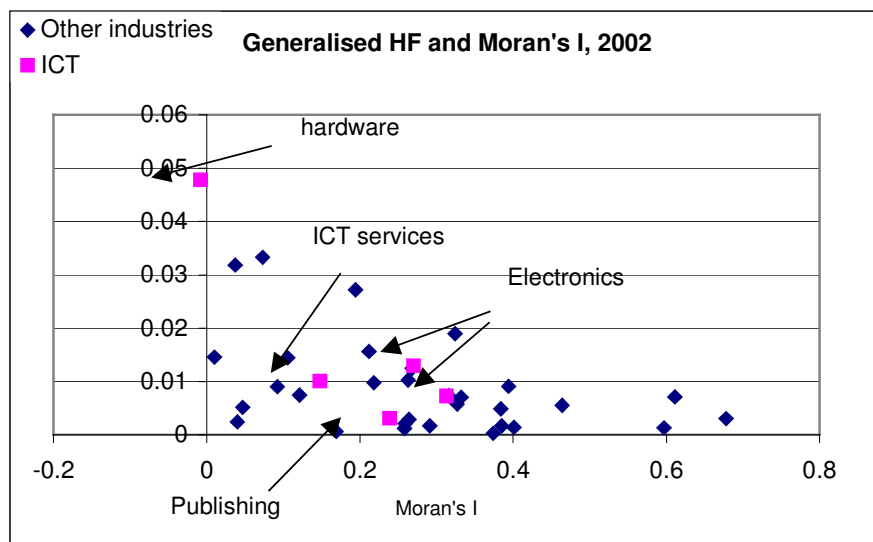


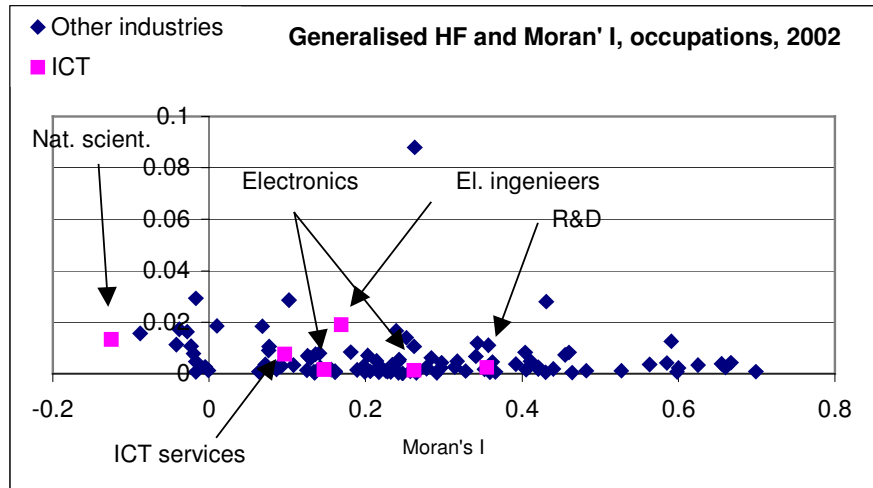
Figure 24 indicates that in general there is a negative relationship between the Herfindahl index and Moran's I. Generally therefore, industries that are located in few regions only do not tend to be part of interregional clusters. From figure 24 it is evident that this is the case for (employment in) the German hardware industry. In fact, Moran's I is negative for this industry. The German electronics industry is of the opposite nature: There are more regions being specialised in these industries and these regions are located together. ICT services and publishing are intermediate cases with higher Herfindahl indexes and lower Moran's I. ICT seems to fit well into the general negative relationship between the Herfindahl index and Moran's I.

For occupations there is also a (less significant) negative relationship between the Herfindahl index and Moran's I. This is illustrated in figure 25. As for industries, there seems to be a negative overall relationship into which ICT seems to fit nicely. For occupations however, only natural scientists are displaying negative Moran's I. The other occupations have positive Moran's I. This also applies to occupations that naturally belong to the hardware industry, like

⁹ This will definitely be the case when the distance weight is based on contiguity, but this result might vary with use of other distance matrixes and the size and definition of regions. For a discussion of the size of regions and spatial econometrics, see Amrhein (1995).

occupations within electronics and electric engineers. It is notable that R&D have high and positive Moran's I while natural scientists do not. The figure gives a visible expression that Herfindahl indexes are low for occupations. This is due to the outlying occupational group (miners). Apart from this occupational group, the negative relationship between the Herfindahl index and Moran's I remain. And, apart from natural scientists, ICT related occupations seem to have relatively low Moran's I and intermediate Herfindahl indexes.

Figure 25

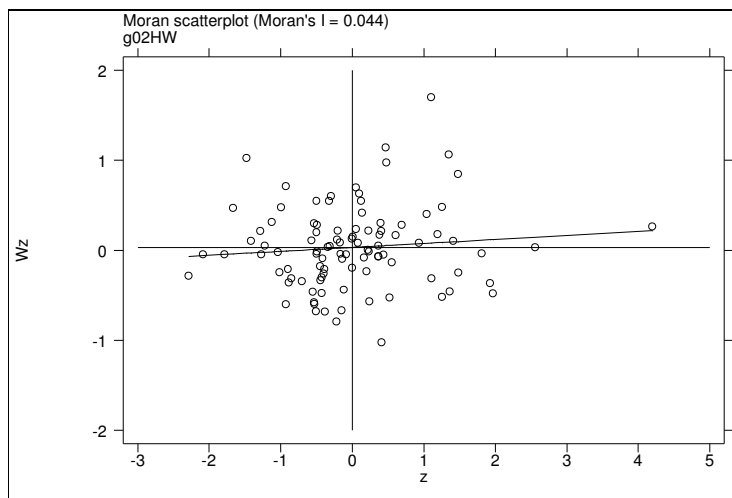


6. Industry dynamics

Above we noted the different performance in hardware-related employment and employment in ICT-related services. Generally, employment in the former is on decrease while it is increasing in the latter. In this section we take a closer look on the dynamics of the German ICT industry. We use growth in employment shares for the disaggregated sets of industrial and occupational employment. For the first the time series run from 1998 to 2002, for the second it runs from 1995 to 2002. We present evidence on the spatial patterns of growth before we present regression results. In the same vein as we did for the levels of employment shares, we present results for growth in aggregated hardware related industries and occupations and for industry and occupation employment in ICT services.

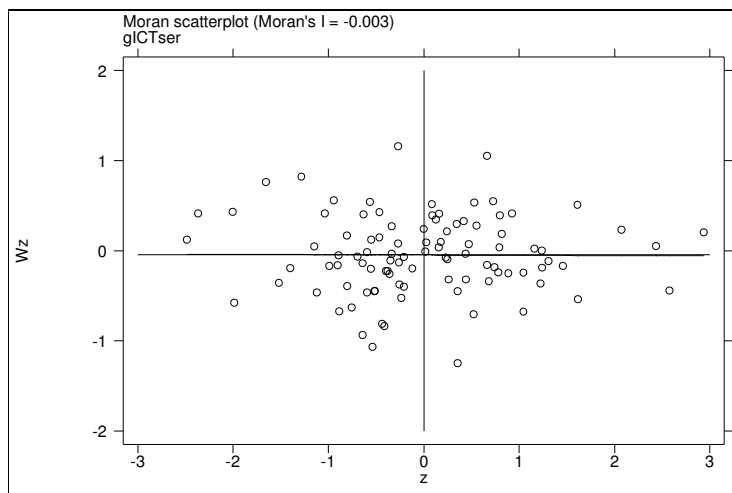
For hardware industries, figure 26 indicates the spatial pattern of growth rates (from 1998 to 2002). By comparing figure 20 and figure 26 it is seen that growth rates are less spatially correlated than its level counterparts. Generally therefore, there does not seem to be an emerging cluster of this industry in Germany. If that was the case, clusters with specialisation in these industries would have had high growth rates, resulting in a clustered landscape also for growth rates.

Figure 26. Moran scatter plot of growth rates for employment in hardware industries (incl. electronics)



For ICT service industries spatial correlation in growth rates is virtually absent. This is similar to their level counter parts (figure 21). This is shown in figure 27. While there were some signs of positive spatial correlations for the ICT industries in terms of levels for the regions with low employment shares, this is not the case for growth rates. The figure gives no indication of spatially correlated growth rates whatsoever, neither for regions for high growth rates nor for regions with low growth rates.

Figure 27. Moran scatter plot of growth rates for employment in ICT service industries.



As underlined above, employment is not a performance indicator. However, ICT services is an industry experiencing high growth and it is to be expected that growth rates in employment will be highest where profit opportunities are highest. As such, figure 27 indicates an extreme lack of spatial correlation. Below we explore the determinants for growth in ICT employment in more detail.

For occupational employment the results are somewhat different. Figure 28 show the spatial patterns of growth rates in hardware-related occupations and figure 29 the similar figure for ICT service related occupations.

Figure 28. Moran scatter plot of growth rates in hardware-related occupations

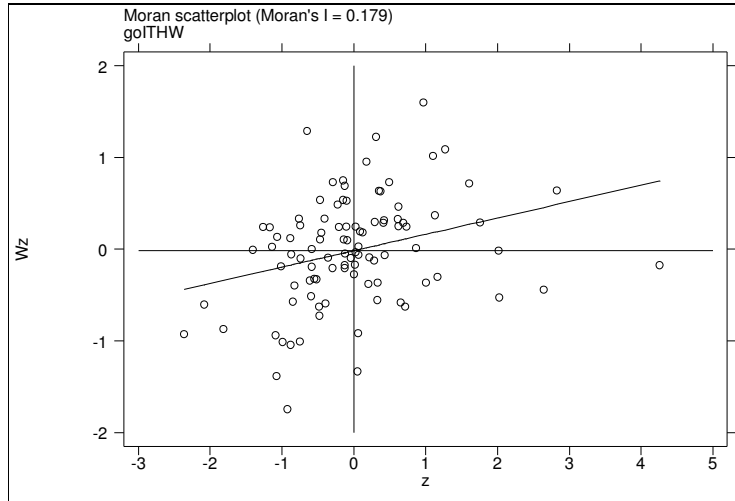
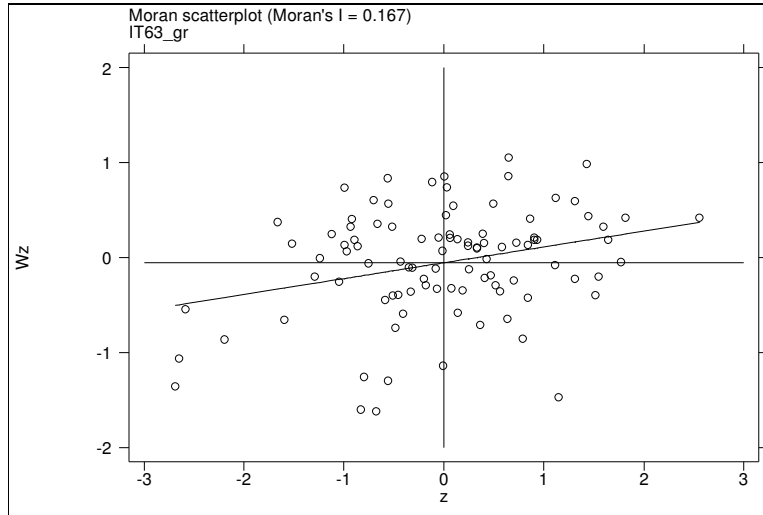


Figure 29. Moran scatter plot of growth rates in ICT service-related occupations

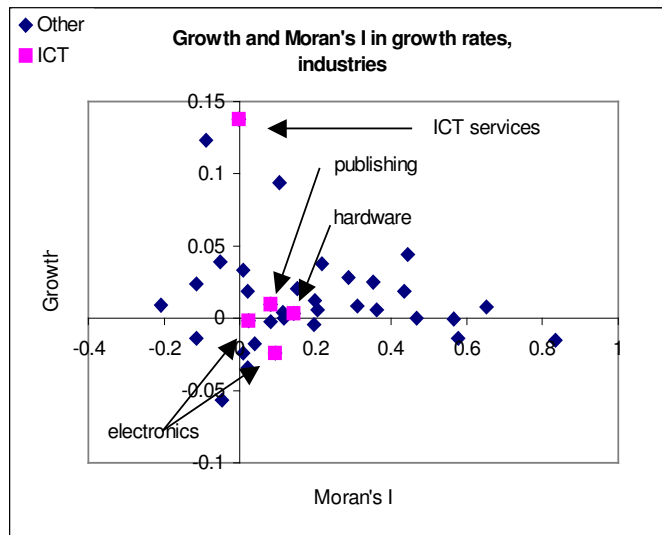


Generally, spatial correlations are higher for occupational employment than for industrial employment. We interpret this as an indication that competencies in these industries are spatially clustered but that this does not result in spatially clustered growth rates in the related industries. This could indicate that some regions are taking ICT into use without necessarily being specialised in ICT-related industries.

Figure 30 and 31 compare the spatial nature of employment growth in ICT with other industries. Those figures show growth rates and Moran's I in growth rates. These figures therefore serve to characterise industries and occupational groups. Some industries have high

growth rates and high Moran's I in growth rates, some have high Moran's I and low growth or low Moran's I and high growth rates while some have low growth rates and low Moran's I. There is no evidence of any systematic relationship, but that would not have been expected. The figures are meant to characterise employment groups, not to illustrate general growth mechanisms. As such the figure is revealing: ICT do not represent industries that grow in clusters. For ICT services, clustering is absent while Moran's I are positive for hardware industries, but growth rates are low. This finding contrasts the Silicon Valley vision of ICT.

Figure 30



The figures illustrate the importance of our discrimination between ICT services and hardware/electronics. ICT service industries have high growth rates but this growth does not occur in geographical clusters. Hardware industries have low growth rates in employment, but positive Moran's I. For these industries there are clusters (of low growth) to a limited degree. For electronics growth rates are negative and Moran's I are positive. Neither hardware nor electronics have very high Moran's I in growth rates compared to other sectors, however.

The same conclusions apply for employment in occupations. For occupations however, growth rates in ICT services display spatial clustering to a limited degree. Also for occupations, ICT-related employment does not have high Moran's I as compared to other industries.

Figure 31

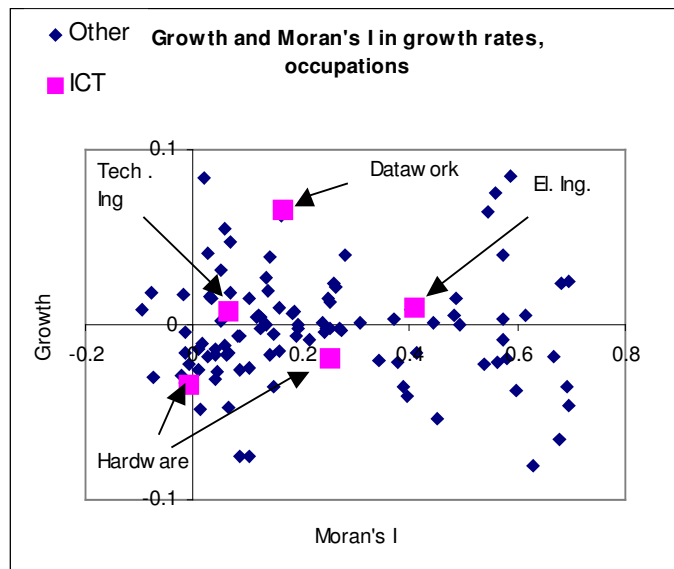


Table 3 reports regression results for growth rates in ICT related employment. Growth rates in industries and occupations are regressed on the initial specialisation in that employment sector, on gross regional product per habitant, population, the total number of patents per habitant and the number of patents per habitant in ICT related technological fields. In addition we included dummy variables for regions belonging to East Germany and for each individual German Länder (which contained more than one region).

A striking result in table 3 is the fact that no industries or occupational groups have positive and significant coefficients for the initial share of the employment sector in question. For most sectors, the coefficients are negative and significant. This implies that there is not clustering in the German ICT industry in the sense that high specialisation stimulates further employment growth. Generally the results indicate the opposite: Regions with high employment shares in a sector (in industry or occupations) have lower growth rates than other industries. This is so for employment in office machines, electronics and for employment of engineers. For ICT services however, the coefficients for initial shares are generally insignificant. This indicates that employment in ICT services grow independently of initial specialisation.

For employment growth in hardware industries or occupations, patenting in specific technology fields is important for some sectors, but not for all. For services, patenting does not seem to be of importance (except for patenting in optics).

The results do not give support for spatial clustering. Positive and significant spatial effects (be they spatially lagged effects or spatially error terms) are absent, while several sectors have negative and significant effects. This gives further support for the back-wash effect in ICT which we discussed in relation to regressions for levels. Negative spatial effects are particularly evident for ICT service industries. For ICT service occupations, there seems to be

a general lack of spatial effects, except for advertisement for which there are significant negative spatial error effects.

Note that neither income levels nor population size seem to influence on growth in ICT related employment.

The growth regressions have both lower explanatory power and less spatial correlation than the level regressions. These regressions do not support any hypothesis about emerging ICT clusters in the German economy. Employment in hardware and electronics are generally on decline while employment in ICT services has experienced high growth rates. The high growth rates in ICT service employment are not located in clusters. Rather this type of employment seems to be on the increase either in isolated regions (for industries) or across regions for the whole country (in the case of occupations). An important question which will be analysed in the next section is the extent to which growth in ICT employment has positive effects for regional economic growth in general.

Table 3. Regression results on growth in ICT related employments

	In. share	L(grph)	L(pop)	Pat.	P.elect.	P.elect1	P.info.	P.account	P.optics	P.print	Rho /lambda	R ²
<u>Industries</u>												
<u>Devices</u>												
Office machines	-14.52**	-.22	-.06	.04	-.50	-.59*	-.73	2.07**	-.18	.23	$\rho=-.15$	.28
Electr. comp	-.51	-.01	-.01	.00	-.10	-.02	-.11	.32	-.07	.05	$\rho=-.10$	.26
Electronics	-3.03*	.11	-.02	-.03**	.23*	.29***	-.21	-.25	.02	-.07	$\lambda=-.38^*$	.25
<u>Services</u>												
ICT-services	1.60	.06	-.02**	-.00	-.00	-.00	-.13	-.23**	.12*	-.03	$\lambda=-.65***$	.22
Publishing	-.32	.00	-.00	-.01***	-.03	-.05**	.06	.08	.11***	-.03	$\rho=-.28^*$	.44
R&D	-4.78	-.07	.04*	-.01	.08	-.09	.02	-.05	.13	.14	$\rho=-.36**$	.19
<u>Occupations</u>												
<u>Devices</u>												
Telecom.	-.15	.01	-.01**	.00	-.03	.04*	-.04	.06	-.06**	-.03	$\lambda=-1.16***$	.54
Electronics	-11.00	.02	-.00	-.00	.07	.01	-.22**	-.03	-.02	.06	$\lambda=-0.39^*$	.15
Elec. engineer	-2.42**	-.01	-.01*	.00	.04	.08***	-.34***	.14**	-.02	.03	$\lambda=-.45**$	.65
Techn.electr.	-4.70***	-.00	.00	.00	-.02	.01	-.05	.09	.02	.06	$\rho=-.27^*$	.45
<u>Services</u>												
Datawork	-1.72	.00	.00	-.01	.01	-.02	.03	.05	.04	.05	$\rho=-.07$	.36
Publishing	.08	-.02	-.00	-.00	-.02	.00	-.04	.05	-.01	.00	$\rho=-.46***$	.54
Other engineers	-4.32***	.02*	-.01*	.01**	.04*	-.02	.01	-.00	-.01	.02	$\lambda=-.70$	.87
Nat. scientists	-6.60	.01	.00	-.01	-.03	.12**	.03	-.20	.18**	.07	$\rho=-.62$	.41
Advertisement	-12.09*	.08**	.02**	-.01	-.01	.01	.02	-.04	.02	-.02	$\rho=-.71***$	.26

Note: ρ indicates spatial lags while λ indicates spatial errors. R^2 indicates squared correlation between predicted values and observed values. Dummy-variables for each German Länder and for East Germany were included in regression but are not reported. In. share=initial share of employment group in beginning of period. L(grph) =log of gross regional product per habitant. L(pop) =log of population. Pat.=patents per habitant. P.electr =patents per habitant in electronics, P.electr1 =patents per habitant in electrical devices, P.info. = patents per habitant in information technology, P. account=patents per habitant in accounting machines, P.optics=patents per habitant in optical instruments, P.print=patents per habitants in printing technology.

7. ICT and regional growth

The analyses in the above sections have indicated that growth and specialisation in ICT in Germany have different determinants. For specialisation in ICT hardware, innovation seems to be important. Regions with a high number of patents in ICT related technology fields have high employment shares. For ICT service specialisation, market size seems to be more important, while innovation is of less significance. For growth rates, innovation seems to be more important both for hardware employment and for employment in ICT services. Neither for specialisation patterns nor for growth rates did we find clear spatial effects. For some subgroups of employment there was positive spatial correlation and for some there was negative spatial correlations. In several cases spatial effects were not significant.

While Germany is performing badly in terms of hardware related employment, ICT services are growing fast with respect to employment. In general therefore, ICT is growing in importance in German employment.

In section 2 we discussed ICT in economic development. There has been great optimism on the possible growth stimulating effects of production and diffusion of new technologies. As underlined there, ICT may stimulate growth both because ICT becomes an important industry or because it stimulates growth in other industries or both. In order to investigate this, in this subsection we investigate growth patterns in the 97 German planning regions. We make use of data on growth in gross regional product in the period from 1995 to 2000. This is the most recent period we have data for. This period is before the fall in stock market prices in 2001 which was significant in Germany and which reduced optimism on ICT for a period.

Optimism on ICT and growth has not been accompanied with empirical observations. As reviewed in section 2, in the 1990s there was stagnating overall productivity growth in many OECD countries at the same time as ICT was increasing in importance both in production and in use. This ‘paradox’ is still under debate, but it seems from recent literature that growth stimulating effects of ICT are characterised by lags and threshold effects. Growth effects from ICT may first become visible after a time lag and first when the ICT industries have reached a certain magnitude.

In the analyses below we regress growth rates in gross regional product in the period from 1995 to 2000 across German regions on a set of explanatory variables. The ICT-related variables we use are:

Employment shares in ICT in industries and occupations. These are the same data we made use of above. In the same way as above we discriminate between specialisation in hardware related employment and ICT service related employment. We expect that hardware related employment to a larger extent will reflect growth stimulating effects from ICT production while ICT service related employment will reflect growth effects of use of ICT.

ICT-related patenting per habitant together with data on total patenting per habitant. These are also the same data as used above. We expect that patent data reflect innovation in ICT to a better extent than employment shares do.

The number of internet domains per habitant. These data are expected to reflect business and consumer use of internet. As such they might be an indicator of regional differences in

terms of use of new technology. These data are from 2000. This is a deficiency in growth regressions because right hand variables are assumed to be exogenous. We do not expect this to matter very much for our cross section sample.

We also included (log of) initial GRP and a dummy variable for East Germany in the regressions.¹⁰ We ran the regressions both with and without Länder dummy variables. As for the other regression results, the choice between spatial lag models and spatial error models were based on diagnostic tests performed after OLS regressions.

First, note that growth rates in Germany are spatially correlated. Figure 32 and 33 show Moran scatter plots of growth rates and growth rates normalised for the average in East and West respectively. These graphs show that growth in German regions are spatially clustered and that such clustering is independent of the East-West divide of the country.

Figure 32. Moran scatter plot of growth rates

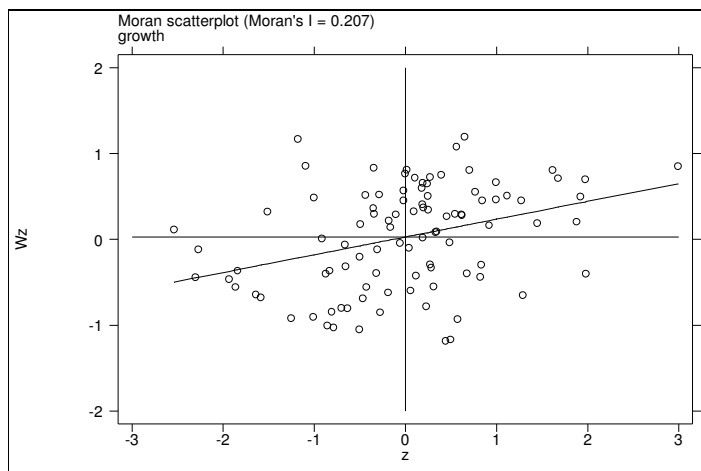
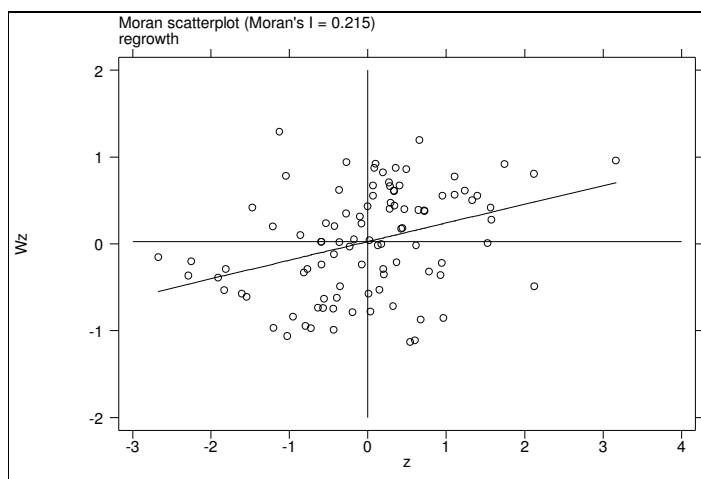


Figure 33. Moran scatter plot of grow rates normalised to average in East and West



¹⁰ We experimented we inclusion of population and unemployment rates as well, but these variables were not significant and did not influence significantly on the magnitude or the significance of the other variables. We also experimented with using averages of ICT-related variables in neighbour regions, but this neither resulted in significant results nor did it influence on the coefficients of the other variables.

The fact that growth is spatially correlated, however, does not mean that growth in one region necessarily influences positively on its neighbour regions. It might instead be that determinants of growth are spatially correlated, either as a result of agglomeration forces like those described in Section 2 or for other reasons.

In table 4 and 5 we report results from ten regressions. Table 4 reports OLS results for five regressions. Here growth was regressed on ICT employment shares in industries and occupations with and without dummy variables for Länder. The last column reported in table 4 is for OLS regression of growth on employment shares in both industries and occupations. Due to limited degrees of freedom we do not report results for inclusion of dummy-variables for this regression. Table 5 reports similar results from spatial regressions.

Table 4. Regression results on growth in regions.

Variable	Without dummies	With dummies	Without dummies	With dummies	Without dummies
Ln(grph95)	.010	.005	.000	-.001	-.001
East	.005*	-.019**	.000	-.019**	-.001
Ln(int.hab)	-.013***	-.005	-.012***	-.006	-.013***
Ln(pat.hab)	.006***	.006***	.006***	.006***	.006***
Ln(IT.pat.hab)	.003*	.002	.003*	.002	.004*
Industries					
Office machines	.012	.050			-.055
El. Comp.	.003	.019			-.030
Electronics	.027	.088			-.017
ICT-services	.262	.156			-.132
Occupations					
Telecom.			.621*	.711*	.655
Electronics			-1.496	.385	-1.686
Elec. engineer			-.266	-.280	-.165
Nat. scientists			-.146	-.054	-.098
Techn.electr.			.484	.037	.453
Datawork			.499	.516	.606
Adj. R ²	.29	.40	.31	.41	.28

Note: Ln(grph95) denotes log of initial GDP. Ln(int.hab) denotes log of internet domains per habitant. Ln(pat.hab) denotes log of patents in total per habitant. Ln(IT.pat.hab) denotes log of ICT related patenting (in computing and accounting).

There are no sign of (conditional) convergence among the German regions. The coefficients for log of initial gross regional product is not significant in any regressions and its sign shifts from positive to negative depending on which variables are included. Also the sign of the dummy variable for East Germany shifts, but the coefficients are (most often) significant. When regressions are run without dummy variables, it is positive. This indicates higher growth in the eastern regions. The sign shifts when dummies are included because we have no dummy variable for Berlin (which consists of one region).

Innovation measured by patenting per habitant is positive and highly significant. This confirms the finding from many studies that innovation is indeed important for economic growth, also at disaggregated regional cross-sectional data sets.

The ICT related variables included give rise to the following conclusions: First, the number of internet domains per habitant is negatively related to economic growth. This is a robust finding in the sense that it keeps its sign (though not significance) when regional dummy

variables are included. Most theories and some empirical evidence have indicated positive growth effects of use of ICT. To the extent that internet domains reflect use of ICT, this finding is a puzzle. Clearly this finding requires further work. Here we would like to propose the following hypotheses as potential explanations:

- The threshold effect for when ICT gives growth effects are present in Germany in the sense that in the period covered here, the extent of ICT was too small for stimulating growth. Not until use of ICT has become more widespread in the economy will regions specialised in use of ICT in service production experience growth. This explanation cannot however, explain the robust significant negative coefficients.
- The data covers “dot.de” internet domains, not “dot.com” domains. A priori we would expect two such data sets to correlate highly, but we do not know whether “dot.de” addresses reflect use of ICT which is not productive while “dot.com” would have reflected more productive use of ICT.
- The data are for internet domains in 2000 while our growth regressions cover the period from 1995 to 2000. These data need therefore not be exogenous, but might instead reflect that regions with low growth had many internet domains at the end of the period. Low growth might, for instance, stimulate registering new internet domains in order to stimulate growth.
- It might be that the estimated coefficients do not reflect the impact of new technology, but instead catching up. We have included initial gross regional product in the regressions (and we experimented with non-linear versions of it). However, gross regional product might be badly measured. There is a neat correlation between income per habitant and internet domains per habitant (the coefficient of correlation is .88). It might be that internet domains better reflect a high economic and technological level (to which regions may catch up) than does gross regional product. However, the negative and significant coefficient does not depend on inclusion of income per habitant.

ICT related patents seem to be positively related to growth. The variable included is for such patents as share of total patents. The estimated coefficients indicate extra effects of such patenting in addition to overall patenting. In the regressions reported here we only included patents that were directly related to ICT (computers and accounting) and not electronics, optics nor publishing (which were not significant). This finding indicates that innovation in new technologies are important for economic growth. The significant effect is sensitive to inclusion of dummy variables, however.

Employment shares in ICT do not seem to influence very much on growth. Regions with high employment shares either in ICT related industries or in ICT related occupations do not have significantly higher growth than other regions. For occupations, it seems that employment in telecommunication occupations might have growth stimulating effects. Other technical occupations, like engineering or work with electronics, are not stimulating growth. Their coefficients are most often negative. Datawork on the other hand, which may reflect ICT services, have positive, though not significant effects.

Table 5 rejects cluster effects in the German economy, in the sense that growth in one region stimulates growth in neighbour regions. For regressions without dummy-variables, the sign of the spatial effects are positive, but they are not significant. When dummy-variables were included, the effects are negative and more significant (and on one occasion at ten per cent level). Therefore, even if growth in Germany is spatially correlated this seems to be because

determinants of growth are spatially correlated rather than because of local contagion of growth itself.

Table 5 Spatial regression results on growth

Variable	Without dummies	With dummies	Without dummies	With dummies	Without dummies
Ln(grph95)	.010	.005	-.000	.000	-.001
East	.005*	-.019***	-.000	-.017***	-.002
Ln(int.hab)	-.013***	-.005	-.012***	-.006*	-.012***
Ln(pat.hab)	.006***	.006***	.005***	.006***	.005***
Ln(IT.pat.hab)	.033*	.002	.003*	.002*	.004*
Industries					
Office machines	.012	.066			-.060
El. Comp.	.003	.034			-.036
Electronics	.028	.091			-.020
ICT-services	.264	.141			-.139
Occupations					
Telecom.			.628*	.697**	.670*
Electronics			-1.478	.812	-1.679
Elec. engineer			-.277	-.225	-.161
Nat. scientists			-.165	.154	-.123
Techn.electr.			.472	-.041	.437
Datawork			.535	.460	.647
Rho/lambda	$\lambda=.01$	$\lambda=-.37^*$	$\rho=.08$	$\rho=-.26$	$\rho=.09$
R ²	.35	.54	.40	.58	.40

Note: ρ indicates spatial lags while λ indicates spatial errors. Ln(grph95) denotes log of initial GDP. Ln(int.hab) denotes log of internet domains per habitant. Ln(pat.hab) denotes log of patents in total per habitant. Ln(IT.pat.hab) denotes log of ICT related patenting (in computing and accounting).

The explanatory powers in the regressions are limited. For the regressions without dummy-variables, R² is lower than 40 per cent. This indicates that our focus on ICT in this paper has not revealed the main determinants of growth in the German economy.

9. Summary and conclusion

ICT has attracted much attention for its potential growth stimulating effects. The Silicon Valley example and in recent years, very high growth in countries such as Ireland, Finland and the U.S. have been explained by special characteristics of ICT. According to one view, ICT represents a genuinely new technology which may transform economic life. Its knowledge intensive character, networks externalities, technological complementarities and its widespread use, make ICT a general purpose technology. The geographical distribution of ICT has been analysed in theoretical and empirical research. This interest has partly been inspired by observations of emerging ICT clusters. In this paper, we have examined the geographical distribution of ICT employment and its growth in the German economy. The findings do lend support to a view that ICT in the German economy is more clustered than other sectors. Rather it seems that ICT employment is attracted to innovating regions (hardware related employment) and to large markets (for ICT services).

We did not succeed in establishing ICT a growth engine for the German economy. Regions specialised in ICT do not experience higher growth than do other regions. Innovation however, does stimulate growth and regions with many patents in ICT-related technologies grow faster than other regions.

Despite these findings we hesitate in concluding that ICT does not live up to its growth promises. In the United States there is now (2005) high growth rates and this may be due to 'new economy' mechanisms. Many have argued that this is consistent with a 'sow and harvest' hypothesis implying that ICT stimulates growth after long time lags. If this is correct, the weak European performance in growth may reflect a temporary recession before growth effects of new technologies set in.

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