Evolution of the geographical concentration pattern of the Danish IT sector

Østergaard, Christian Richter; Dalum, Bent

Publication date:
2011

Document Version
Early version, also known as pre-print

Evolution of the geographical concentration pattern of the Danish IT sector

Christian R. Østergaard

Department of Business Studies, Aalborg University, Fibigerstraede 4, 9220 Aalborg Oe,

Denmark, Tel.: +45 9940 8266, Fax: +45 9815 6013, cro@business.aau.dk

Bent Dalum

Department of Business Studies, Aalborg University, Fibigerstraede 4, 9220 Aalborg Oe,

Denmark, Tel.: +45 9940 8222, Fax: +45 9815 6013, bd@business.aau.dk

WORKING PAPER: A revised version is published as Østergaard, Christian Richter & Dalum, Bent (2011), 'Evolution of the geographical concentration pattern of the Danish IT sector'. i H Bathelt, MP Feldman & DF Kogler (eds), Beyond Territory: Dynamic Geographies of Knowledge Creation, Diffusion, and Innovation. Routledge. Regions and Cities Series, Ch. 5, p.82-104

Abstract:

This paper analyzes the employment growth and spatial evolution of the Danish IT sector during the upswing in the 1990s. The employment and the number of IT firms have more than doubled during this decade, but the spatial evolution indicates a 'non random' concentration of the sector around the larger urban areas. The paper analyses, which factors shaped the growth and spatial evolution of the sector and analyzes how and why it agglomerated in the urban areas.

Keywords: Information Technology; Industry Evolution; Specialization; Diversity; Universities

JEL - codes. R11, L86, O18

1 Introduction

The rapid growth and increasing economic importance of the information technology (IT) sector during the 1990s has made it an often-studied subject in various fields of economics and economic geography. IT is often argued to reduce the importance of geographical distance, since people are able to communicate and coordinate over vast distances. Likewise the IT sector is well-known for outsourcing and long distance collaboration, e.g. engineers working in the growing Indian IT sector are developing software in close cooperation with their US based customers. However, studies of the IT sector also reveal that it tends to agglomerate and locate close to large cities, such as Silicon Valley near San Francisco and Route 128 near Boston (Saxenian, 1994). This urban tendency is also seen in small countries, such as the Netherlands (van Oort and Atzema, 2004), Ireland (Crone, 2004) and Sweden (Eriksson, 2006). A similar pattern is found in Denmark where most of the IT sector employment is located in the largest urban regions.

The IT sector is not a new industry in itself, but holds some of the features of a new industry, such as uncertainties, lack of standards and dominant design[1]. The technological change is very fast and the products and services today did not exist a decade ago. The entry barriers appear to be low. The physical capital requirement for a new IT firm is low and the general skills needed in software programming are not hard to obtain. However, the IT sector is also labour intensive and skill biased. The share of master degrees in the Danish IT sector employment is three times as high as the average for total Danish employment. Furthermore, the IT sector has a high share of employees with master degrees in engineering or computer science.

The IT employment and the number of IT firms more than doubled during the 1990s. Despite the rapid growth 90 per cent of the IT sector employment was located in the four largest urban regions in 2002. An apparent explanation for this pattern is the supply of skilled labour, since these regions have a high share of highly educated people and are also home of the four largest Danish universities. It appears not to be a sufficient condition to have a university. Odense, the third largest region and home of University of Southern Denmark, experienced the lowest growth of the four regions. However, the university did not offer a master degree in engineering or computer science in the 1990s. Therefore, factors such as the location and specialization of universities and the skill composition of the regional labour force are likely to play an important role in the spatial evolution of the IT sector.

The location of particular industrial activities and their spatial evolution are often explained by the presence of location-specific externalities. Some industries benefit mostly from externalities related to specialization, while others grow faster in regions characterised by diversity or urbanization. The purpose of this paper is to analyse which types of location-specific externalities that appear to have shaped the growth and spatial evolution of the Danish IT sector during the upswing in the 1990s. However, since the IT sector employment has more than doubled in this period, all Danish regions have experienced employment growth. Especially, a few regions that start at a very low level experience high growth. Like Alice and the Red Queen the regions with a high level of IT employment and specialization have to keep running to keep their position during the decade of rapid growth. '"Well, in our country," said Alice, still panting a little, "you'd generally get to somewhere else – if you ran very fast for a long time, as we've been doing." "A slow sort of country!" said the Queen. Now, here you see, it takes all the running you can do, to keep in the same place. If you want to get somewhere else, you must run at least twice as fast as that!' (Carroll et al., 2003, p. 175).

Therefore, the more specific purpose of this paper is to analyze why some regions are able to stay ahead and why others fall behind. Thus, to maintain a relative high share of IT employment during the period is seen as a success. Furthermore, the paper analyzes why and how the IT sector is concentrated in the largest urban regions and investigates the effect of the local universities and regional labour force.

The analysis reveals that the spatial pattern of Danish IT employment is fairly stable during the high growth period. Specialization externalities appear to be important since the two most specialized regions in 1992 remained in the lead during the period, while the regions with a low location quotient stay behind. The IT sector employment is concentrated in the large cities, which indicates the existence of urban externalities. However, urban size or initial specialization is not a guarantee for success if the region is lacking the supply of highly skilled technical employees. The Vejle region was initially specialized, but falls behind since it does not have a university and it is not able to attract the high skilled labour. Odense is the third largest city in Denmark, but was not initially specialized and remained at a low level, mainly because the university in Odense did not educate masters in engineering or computer science. Aalborg, the fourth largest city, was not initially specialized, but became so during the period, partly because the local university provides masters in engineering and computer science. Thus, the skill composition of the labour force and the profile of the universities appear to have influenced the spatial evolution of Danish IT sector and

helped the Aalborg region overcome the initial lack of specialization externalities in the growth race of the IT sector.

The paper is structured as follows: The next section presents theories of spatial evolution of industries. The empirical analysis is presented in Section 3. The results and implications are discussed in Section 4. Finally, the conclusion is presented in Section 5.

2 Theories of geographical evolution of industries

Studies of the spatial evolution of industries show that some regions provide better generic local conditions and stimulating environments for new industries (Porter, 1998; Boschma and Knaap, 1999; Brenner, 2004). However, the effect of local conditions depends on the novelty and discontinuous nature of the new industries. If these are competence destroying, the existing regional industrial structure and knowledge base are less important, while competence enhancing new industries benefit from specific existing knowledge bases (Tushman and Anderson, 1986; Storper and Walker, 1989; Boschma and Knaap, 1999). Firms in competence enhancing new industries are more likely to start up in regions with a related and supportive industry structure and, thereby, incrementally change the regional knowledge base. Firms in competence destroying industries can emerge everywhere, but they may be more likely to emerge in regions that provide better generic conditions.

The interaction between firms and the region is important for development of industries in a region. Maskell et al. (1998) argues that the industry structure, knowledge and skills, natural resources and institutions constitute a region's capabilities. These have been developed through historical interactive processes. The formation of new firms is affected by the regional structure and capabilities and often builds on existing specialized skills and knowledge. The new firms will also shape the future evolution of the regional capabilities, since they reproduce existing knowledge and create new knowledge and skills (Storper, 1997; Maskell et al., 1998). Therefore, the evolution of a new industry will be influenced by the firms' ability to create the specialized labour and knowledge and the responsiveness of the regional capabilities to provide factors that support the growth of the new industry. This evolutionary process creates the possibility for location-specific externalities coming from inter-industry and intra-industry interactions and interactions with local conditions, in particular public knowledge organizations.

2.1 Location-specific externalities

Location-specific externalities can be related to existence of other firms within the industry in the region i.e. intra-industry externalities or existence of firms in other industries i.e. inter-industry externalities. Available empirical studies on the effect of location-specific externalities on the spatial evolution of industries have mainly analyzed manufacturing, while the knowledge intensive service sector has not been analyzed sufficiently. Furthermore, these studies indicate that multiple types of externalities are important and sometimes co-exist. Henderson et al. (1995) finds evidence of specialization externalities for the mature capital goods industries, while high-tech manufacturing industries exhibit specialization and diversity externalities. Feldman and Audretsch (1999) finds that diversity enhanced growth in employment and innovation, while Beardsell and Henderson (1999) argues that the evolution of the computer industry in the USA is strongly supported by specialization externalities. Henderson et al. (1995) argues that new industries prosper in large, diverse metropolitan areas, but move to specialized regions when they mature. In addition, recent empirical research indicates that the location-specific externalities varies over time (Neffke, 2008).

The empirical results suggest that location-specific externalities exist and influence spatial distribution of economic activity, where particular economic activities tend to agglomerate (Henderson et al., 1995; Audretsch and Feldman, 1996). However, as noted by Hanson (2000), finding evidence of agglomeration economies is not the same as identifying their sources. Brenner (2004) argues that sources of location-specific externalities arise from three types of local interactions: Within the firm population, with another firm population in the region and with local conditions, such as human capital, local education system, public research, local capital market, culture and historical specificities, local attitudes, and local policy. These interactions are bounded in space, and only firms with specific relationships, such as common technology base and buyer-supplier relations, may interact in this process.

2.2 Intra-industry externalities

Intra-industry externalities make location of a firm in a region more likely once there are other firms in the same industry located in the region. These are often named Marshall-Arrow-Romer (MAR) externalities (see e.g. Henderson et al., 1995). The MAR externalities can take various forms. Marshall (1920) observed that firms within the same industry often continue to co-locate in particular localities based on three kinds of externalities: (i) economies of specialization caused by a

concentration of firms being able to attract and support specialized suppliers thereby achieving economies of scale like large companies, (ii) economies of labour pooling, where the existence of a pool of labour with particular knowledge and skills attracts firms, which in turn attract and create more specialized labour, and (iii) technological externalities, where knowledge, ideas and information flow easily between co-located actors than over long distances.

The intra-industry externalities can emerge also from increasing returns to scale by specialization at firm or regional level. An early regional industrial specialization would then be enhanced by factors that support particular technological trajectories, such as bounded rationality, switching costs, path dependency and learning by doing that accumulates specific knowledge (Arrow, 1962). Thus, regions would specialize in particular industries and have a tendency to remain specialized, since their competitiveness is based on the evolution of dynamic economies of scale, such as skills and competencies. Brenner (2004) has used an evolutionary approach to analyze the existence, emergence, and evolution of local industrial clusters in Germany. He argues that in some regions the positive feedback mechanisms and level of particular industrial activity (firms and/or employment) are sufficiently high to start a self-augmenting process that induces further growth in that particular industry, while other regions suffer from a low level of industrial activity or from insufficient positive feedback mechanisms.

The foundation of the first firm brings variety to the existing innovation system. Brenner (2004) argues that additional firms enter depending on the attractiveness of the region. These firms provide the ground for further growth in the region, but also cause congestion effects. These dynamics result in a steady state of the activity level in the industry. However, self-augmenting processes may lead to further growth and create an agglomeration. When the industry in the region reaches this level of activity, it is less likely to decline because the self-augmenting processes are sustaining the cluster through entry of new firms. The existence of two steady states indicates a fairly persistent geographical specialization pattern after the transition period of the industry life cycle with a few regions possessing a cluster, while most would remain non-concentrated. The exception is a region that manages to increase the number of firms and employees above the critical level and initiate sufficiently strong self-augmenting processes to go the high level steady state. This approach indicates a fairly stable pattern of specialization, where the specialized regions will have the highest growth and remain in the front.

- Hypothesis 1: Regions with high employment specialization will benefit from intra-industry externalities and remain specialized, while regions with low specialization will stay at a low level unless specific circumstances might cause a significant change.

The labour market is a key factor for knowledge diffusion and the main transmission mechanism for intra- and inter-industry externalities (Boschma et al., 2008). For specialization externalities it is the creation and pooling of specialized labour; for urban externalities it is the size of the labour market. For diversity externalities it is the pool of various types of labour. In their study of agglomeration economies in the Dutch ICT sector van Oort and Atzema (2004) argues that: 'Thus, wage rates within a sector would be uniform and there is little need to control for labour force characteristics such as level of education, proportion of workers with particular skills…' (p.268). However, the distribution of skills is not equal in space. Therefore differences in skills between regions might be a powerful part of the explanation of differences in the regional industry structure within the IT sector.

The rapid employment growth of the IT sector has created a demand for qualified labour. Demand is skill biased, which favours regions with a large labour force with particular skills and knowledge. However, high demand also put requirements on growth of the supply of this labour and not only the stock. Skilled labour could come from other firms in the region, be attracted from other regions or created within the region. The Marshallian economics of labour pooling indicates that firms would be attracted to the region by the labour force and more importantly, the IT firms in the region would create a further supply through training and on-the-job learning. Growth in supply of skilled labour can, however, also come from a local university. Thus regions with many large firms and supply of newly educated skilled labour would have an advantage, while regions without these will have problems attracting IT employees. Furthermore, the IT sector has a high demand for technical (especially electrical engineering) or computer science skills, which would favour regions with universities offering these degrees.

- Hypothesis 2: A university providing tertiary education in engineering or computer sciences has a positive effect on IT employment specialization in the region.

2.3 Inter-industry externalities

Other parts of the literature focus on three types of inter-industry externalities: Urbanisation, diversity and related variety. Urbanisation externalities relate to urban size and density, where firms

benefit from being located in metropolitan regions that provide good infrastructure, a large local market and availability of customers, suppliers, labour and public knowledge organizations. The debate on urban areas as a source of knowledge spillovers is closely related to the discussion of the rise of the creative class and the growth potential of metropolitan areas in knowledge intensive sectors. Florida (2002) argues that large cities attract creative talented people because these prefer places that are diverse, tolerant and open towards new ideas. Creative talented people combined with a large pool of highly educated labour, often is found in cities, support growth of new creative industries. Large cities also host large universities that offer multiple teaching programmes and create a supply of highly educated people that often prefer to live in the city, where they were educated. Large urban regions are characterised by many industrial activities, many private research laboratories and public knowledge organisations and a large diverse labour market. IT companies can thus benefit from the general trend towards outsourcing of internal IT activities and become specialized suppliers. The large and diverse labour market creates a pool of IT employees in IT as well as non-IT companies.

- Hypothesis 3: Urban size will have a positive effect on the relative size of IT employment

Urbanisation externalities are closely related to diversity externalities that are caused by the degree of diversity in the workforce and industry. Jacobs (1969) describes how cities are a source of economic development. Not only because of larger size, but because of larger diversity of activities, that creates cross-industry knowledge spillovers and opportunities for emergence of new activities. Diversity externalities also have a static element. Marshall (1920) argues that the agglomeration of firms in a single industry can cause problems with too high demand for similar resources. These disadvantages can be avoided through the co-location of several distinct industries, since they mitigate the negative effects of other industries and provide a variety of employment opportunities. Regional knowledge spillovers based on accumulated knowledge associated with diversity are often named Jacobs' externalities and are frequently measured by regional industrial diversity (Henderson et al., 1995). A string of recent literature has suggested that variety in the regional industry structure can be divided into unrelated variety (between sectors) and related variety (within sectors) (Frenken et al., 2005; Boschma et al., 2008; Boschma and Iammarino, 2008). Frenken et al. (2005) argues that Jacobs' externalities are coming from related variety and that these support employment growth, while unrelated variety dampens unemployment growth. However, for the IT sector it is not entirely clear, which sectors are related and it is pointless to apply the standard method of measurement[2]. Diverse regions are characterised by large numbers of diverse related industrial

activities and often many knowledge intensive services and diverse labour markets. As a result there are many possibilities for spillovers and diffusion of ideas between industries. Firms located in a diverse industrial region learn quickly about new ideas and innovations from other sectors that they might be able to apply. Thus, new industries are likely to grow in regions with Jacobs' externalities.

- Hypothesis 4: Regions with diverse industry structures will benefit from Jacobs' externalities and experience positive effects on the relative size of the regional IT employment.

3 The Danish IT sector

From 1992 to 2002 the Danish IT sector experienced a very high growth in employment of 130 per cent from 18,100 to 41,700 employees[3]. The period has been very turbulent, consisting of a long high-growth period from 1993 to 2001, followed by a decline in 2002. The growth period has been supported by the relative fast economic growth in Denmark in the 1990s, where the aggregate unemployment level has decreased from 12 per cent in 1992-3 to 5-6 per cent in 2002. IT employment peaked at 44,200 employees in 2001. The number of IT firms increased 140 per cent from 2,800 in 1992 to 6,800 in 2001, while the total number of Danish firms decreased 5 per cent.

3.1 The IT sector and data sources

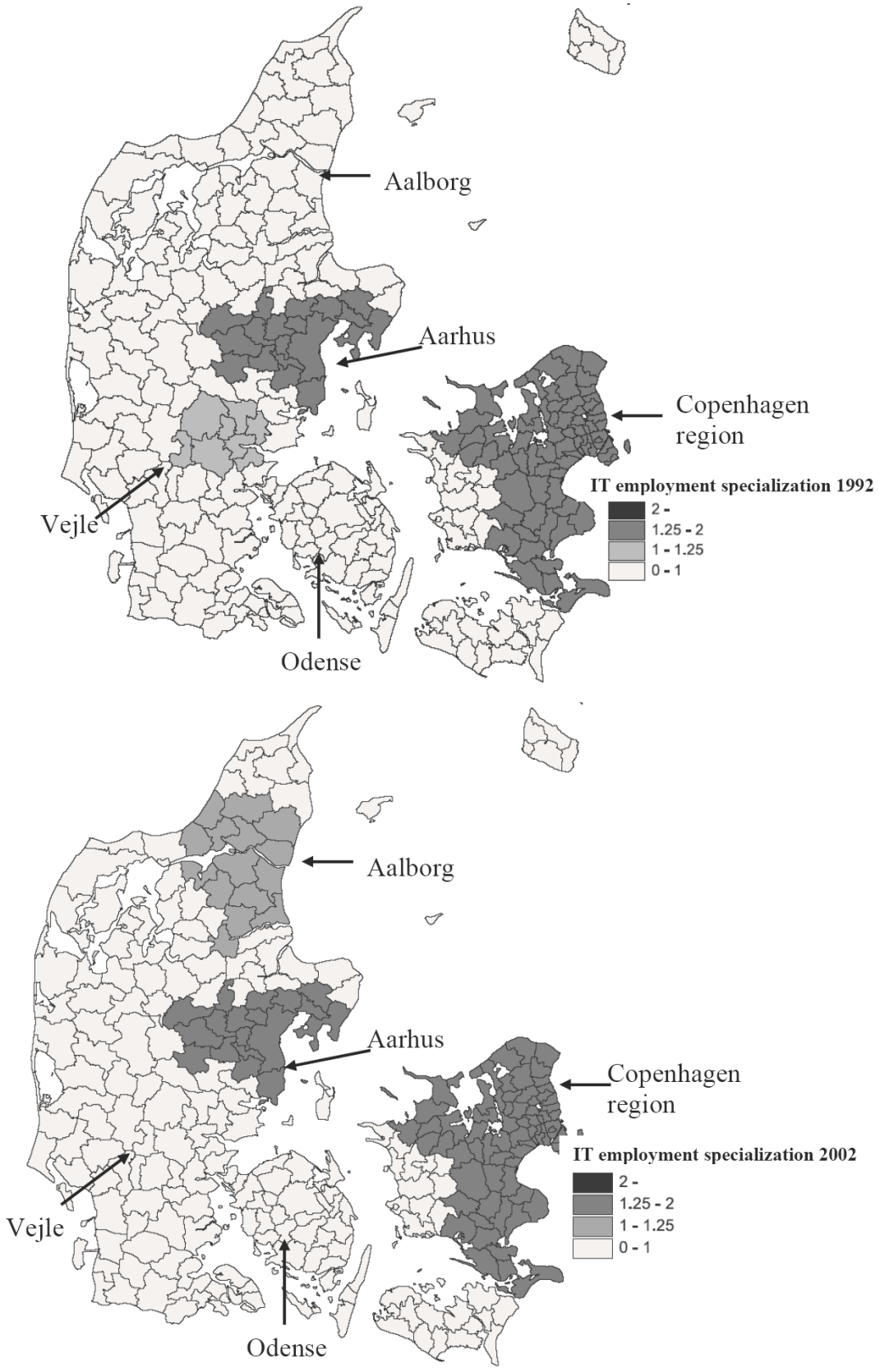
The IT sector mainly consists of two segments: Consultancy and software. These are intermingled, but still distinct since software sold as a product and easily reproducible is different from software delivered as a service (Steinmueller, 1996). The distinction between consultancy and software firms is blurred, because the borders are fluent. Consultancy firms are customising and implementing standard software, and that segment is labour intensive and requires a lot of programming, while software firms develop and supply a software package, although they also provide a wide range of services in combination with standard software. Customisation of standard software is quite important for the Danish IT sector. Large multinational firms dominate the market for standard packages, but the customisation and implementation have to be done by firms located within the country. This has allowed the existence of a large segment of IT consultancy firms. It should be noted that the largest of these are divisions of multinational firms, but the customisation and implementation of the software require physical presence.

The paper draws on employment and firm data from Statistics Denmark. The IT service sector is defined as NACE 72 'computer service and related activities'. Data on 277 municipalities are grouped into 35 functional urban regions defined by commuting patterns (Andersen, 2000). This level of aggregation is likely to provide more precise evidence on the role of geography than many of the previous studies using fairly aggregated and institutionally defined regions.

3.2 Evolution of the geographical concentration pattern and location of universities

Employment and the number of workplaces in the IT sector have more than doubled during the 1990s, but the geographical concentration pattern remained stable apparently unaffected by the rapid growth. Figure 1 shows the IT employment specialization (i.e. an above average share of employment) in 1992 and 2002. It indicates a relative concentration in the cities of Copenhagen, Aarhus and Aalborg in 2002, while Vejle (ninth largest) initially was specialized, but fell behind. Odense, the third largest was not specialized in this period. Aalborg was not specialized in 1992, but became so during the 1990s.

Figure 1 IT employment specializations in functional urban regions in 1992 and 2002



Source: Based on data from Statistics Denmark

Table 1 shows that the two largest regions Copenhagen and Aarhus accounted for 78 per cent of the total private employment in the IT sector, but only 49 per cent of total private employment. The third and fourth largest regions, Odense and Aalborg, were not specialized, but ranked respectively as four and three in terms of total IT employment in 1992.

Table 1 Top 10 total employment regions 1992

Region	IT employment 1992 (persons)	Share of IT employment (%)	IT Rank	Total employment 1992 (persons)	Share of total employment (%)	IT specialization location quotient
COPENHAGEN REGION	11,891	65.8	1	1,034,038	39.8	1.65
AARHUS	2,279	12.6	2	247,668	9.5	1.32
ODENSE	798	4.4	4	185,022	7.1	0.62
AALBORG	964	5.3	3	143,447	5.5	0.97
ESBJERG-RIBE	95	0.5	11	98,581	3.8	0.14
FREDERICIA-KOLDING	435	2.4	6	72,382	2.8	0.86
HERNING-IKAST	235	1.3	7	68,972	2.7	0.49
VEJLE	569	3.1	5	68,470	2.6	1.19
KALUNDBORG	42	0.2	16	67,931	2.6	0.09
KRONJYLLAND	102	0.6	8	62,165	2.4	0.24
Total Denmark	18,075	100	-	2,598,374	100	1

Source: Based on data from Statistics Denmark

In 2002, the Top 5 regions in terms of IT employment remained the same although employment had grown 130 per cent. Copenhagen and Aarhus increased their share of total IT employment to 79.5 per cent. Aarhus added 1.6 percentage points to its share of IT employment, while Aalborg added 1.2 percentage points and became specialized with a 14 per cent higher IT employment share than the national average. These three regions accounted for 56 per cent of the total employment, but 86 per cent of the IT employment. The followers Odense, Vejle and Fredericia-Kolding have all experienced a below average growth and the IT specialization location quotients declined.

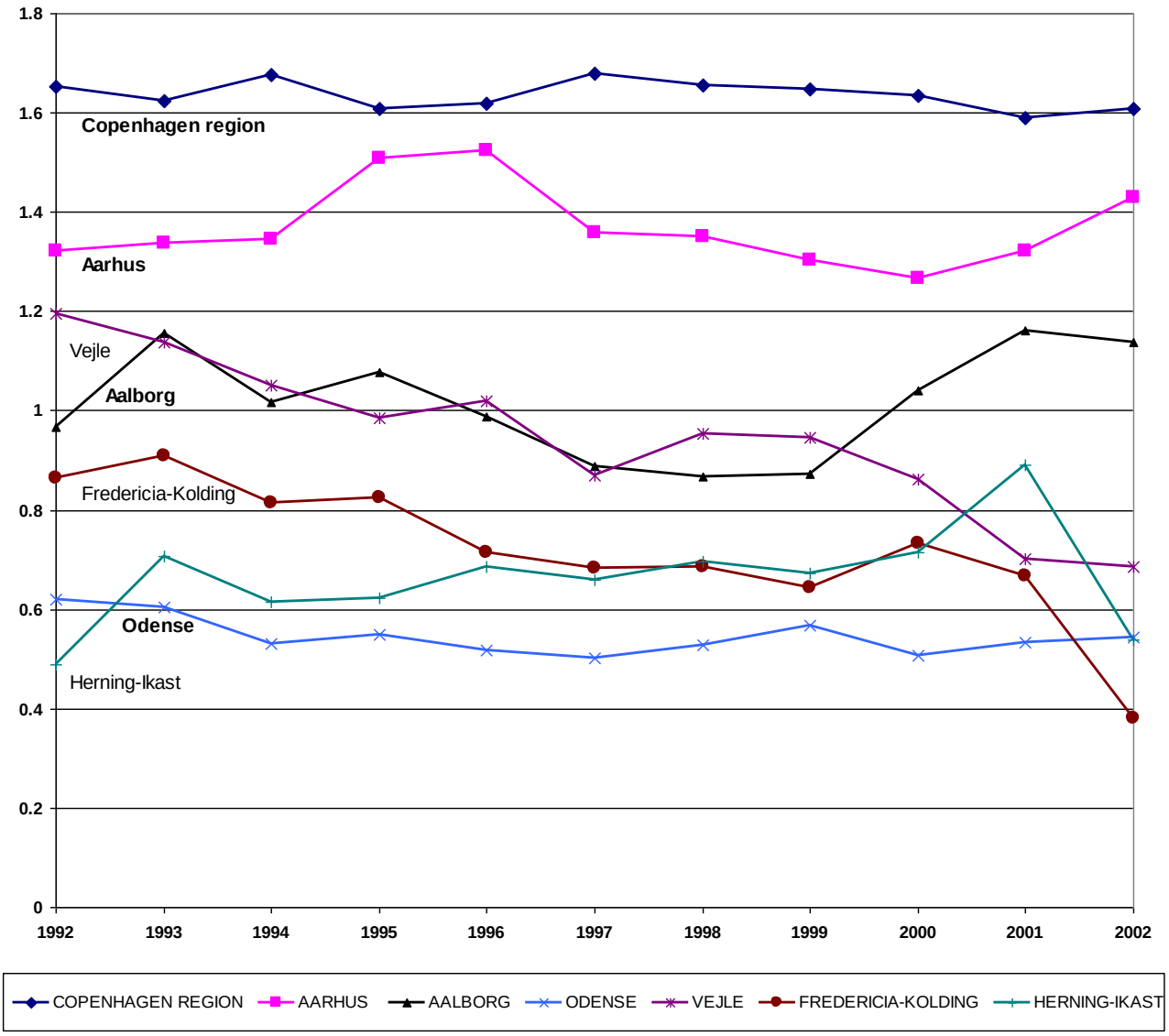
Table 2 Top 10 total employment regions 2002

Region	IT employment (persons)	Share of IT employment (%)	IT Rank	Total employment (persons)	Share of total employment (%)	IT specialization location quotient
COPENHAGEN REGION	27,254	65.3	1	1,114,160	40.6	1.61
AARHUS	5,924	14.2	2	272,121	9.9	1.43
ODENSE	1,559	3.7	4	188,631	6.9	0.54
AALBORG	2,712	6.5	3	156,512	5.7	1.14
ESBJERG-RIBE	273	0.7	11	99,546	3.6	0.18
FREDERICIA-KOLDING	464	1.1	7	80,031	2.9	0.38
VEJLE	791	1.9	5	75,695	2.8	0.69
HERNING-IKAST	572	1.4	6	69,780	2.5	0.54
KALUNDBORG	177	0.4	12	66,296	2.4	0.18
KRONJYLLAND	289	0.7	9	63,192	2.3	0.30
Total Denmark	41,729	100	-	2,741,386	100	1

Source: Based on data from Statistics Denmark

Table 1 and Table 2 indicate a fairly stable ranking in the period. A closer look at the changes 1992-2002 for all functional urban regions reveals three distinct groups. The upper group consists of Copenhagen and Aarhus both specialized in IT employment during the entire period. The middle group is Vejle, Aalborg, and Fredericia-Kolding, of which Vejle was specialized 1992-6 and Aalborg from 1993-5 and 2000-2. The remaining 29 regions all showed a below average share of IT employment and constitute the lower group. Figure 2 shows the evolution of IT specialization in the seven most specialized functional urban regions 1992-2002. They showed the highest specialization in 1992 and constituted the upper and middle groups during the period. The remaining 28 regions had a fairly stable evolution and remained at a low level of specialization (0.4). Only four of these regions grew above the 0.4 level during the period, but they stayed below a location quotient of 0.6.

Figure 2 IT sector specialization in functional urban regions in Denmark from 1992 to 2002



Source: Based on data from Statistics Denmark.

Figure 2 indicates three levels of specialization. The upper level above 1.2-3 in which the regions remain specialized despite rapid employment growth. The middle level is between 1.2 and 0.8. This area is unstable and the regions either increase their specialization or decline. Aalborg fluctuates around being specialized or not during the period, but has been specialized from 2000. The other two regions, Vejle and Fredericia-Kolding have declined and end below the 0.8 mark. The lower level, below 0.8, is characterised by stability. These regions remain un-specialized and have only a small chance of getting above the 0.8 limit that may induce further growth. Only one region, Herning-Ikast, moved from the lower to the middle level in 2001, but declined again in 2002.

However, none of the regions in the unstable middle area did grow above the upper level border of 1.2. The existence of two steady areas and an unstable middle area can also be found in Brenner (2004). His main argument is that when an industry in a region grows beyond a threshold, self-augmenting processes outweigh the congestion effects and the industry enters a new growth path. Then the industry can enter a high level steady state supported by the self-augmenting processes.

The specialization pattern in terms of IT firms was also fairly stable. Analysis of the Top 10 number of IT firms in 1992 reveals that Copenhagen and Aarhus were the only specialized regions. They had 77 per cent of the total number of Danish IT firms compared to 44 per cent of the entire private sector. Thus, the IT sector was heavily concentrated in the two largest urban regions. These regions have been specialized during the entire period and the other regions remained at a low level.

Copenhagen and Aarhus are the largest and second largest urban centres in Denmark and both have universities and a large labour market. Therefore, they are more likely to benefit from urban externalities. Furthermore, the IT companies have benefited from local outsourcing of IT functions from large companies and being specialized suppliers to these. Copenhagen is by far the largest functional urban region in Denmark with 1,467,000 inhabitants in the age of 15 to 69, followed by Aarhus with 354,000; then Odense with 276,000 and Aalborg with 217,000 inhabitants. The fifth largest is Esbjerg-Ribe with half the size of Aalborg. Only the two largest seem to benefit from urban externalities. Odense has experienced a 95 per cent growth in IT employment, but decreasing specialization (0.54 in 2002). Aalborg has experienced a 181 per cent growth in IT employment and the number of IT firms increased from 107 in 1992 to 292 in 2001. It seems that Copenhagen and Aarhus are the only two sufficiently large cities in Denmark. This confirms Hypothesis 3 that urban size will have a positive effect on the relative size of IT employment, but the effect is highest for the largest cities. However, the four largest functional urban regions are also home to universities. Therefore young people move to these regions to get an education and the labour force in these regions have a larger share of highly educated people than other regions. Thus the location of universities has an impact on the educational structure of the regional labour force. The rapid expansion of the IT sector has created a high demand for these skills which have favoured regions with universities.

3.3 The impact of the location of Danish Universities on the local labour market and qualifications of the IT employment

The education level in the IT sector is higher than the private sector average. In 1992, the share of employees with a master degree was 4.2 per cent for the total private sector, while it was 11.7 per cent in the IT sector. In 2002, the difference was more outspoken. The share of employees with master degrees in the total private sector had grown to 5.9 per cent, while the share in the IT sector had grown to 18.2 per cent. This skill biased growth points towards an increasing importance of either a local supply of highly educated people from local universities or the ability to attract talent educated elsewhere.

The cities of Copenhagen, Aarhus, Odense and Aalborg are hosting different kinds of universities. In Copenhagen there is a broad portfolio consisting of Copenhagen University with a natural science faculty, computer science included, as well as faculties for the social sciences and humanities and a medical faculty. Copenhagen also hosts Copenhagen Business School, The Technical University of Denmark and a fairly new IT University. The entire field of higher education and research is covered in the capital. Aarhus University has basically the same breath in terms of a multi faculty university, including a strong computer science department, and the newly integrated Aarhus School of Business. Aarhus lacks, however, an engineering master degree. There is an engineering school, which only offers teaching at the undergraduate level. University of Southern Denmark[4] is a smaller fairly broad university, but had no computer science department or engineering education at the master level in the 1990s[5]. There is an engineering school, which only offers teaching at the undergraduate level. Aalborg University is the youngest of these four universities, founded in 1974. It has faculties in social science, humanities, engineering and natural science. In addition, a large computer science department has evolved from the mid 1980s.

The level of qualifications of the workforce is important for the development of the IT sector since the education level in the IT sector is higher than the average for the entire private sector. The IT sector especially demands labour with medium-term (BSc) technical tertiary education or long-term (MSc) education in the natural or technical sciences. However, demand is focused in particular on engineers in electronics and IT, and MSc's in computer science. Table 3 shows the specialization indicator of the largest Danish regions in engineering BSc's and MSc's as well as natural science candidates in 1992 and 2002.

Table 3 Specialization of the largest regions in engineering and natural science educated people 1992-2002

Region	1992				2002			
	Population Age 15-69	Engineering		Natural Science	Population Age 15-69	Engineering		Natural Science
	(persons)	BSc	MSc	MSc	(persons)	BSc	MSc	MSc
COPENHAGEN REGION	1,466,935	**1.22**	**1.75**	**1.41**	1,511,456	**1.20**	**1.67**	**1.48**
AARHUS	353,659	**1.21**	0.96	**1.90**	374,876	**1.19**	0.98	**1.67**
ODENSE	276,092	**1.04**	0.39	0.86	276,015	**1.02**	0.38	0.83
AALBORG	217,452	0.86	**1.05**	0.55	221,922	0.79	**1.27**	0.56
ESBJERG-RIBE	138,399	0.74	0.35	0.45	138,237	0.75	0.33	0.34
KALUNDBORG	102,786	0.60	0.39	0.44	104,437	0.65	0.41	0.48
FREDERICIA-KOLDING	95,436	**1.04**	0.45	0.41	98,669	**1.08**	0.48	0.38
KRONJYLLAND	94,457	0.71	0.36	0.39	93,727	0.77	0.42	0.45
VEJLE	91,907	0.99	0.42	0.69	96,312	**1.10**	0.49	0.59
HERNING-IKAST	87,943	0.58	0.22	0.30	88,385	0.68	0.23	0.25
Total (persons)	3,718,148	46,466	23,590	9,609	3,792,390	58,795	31,745	18,551

Source: Based on data from Statistics Denmark. Note: The specialization indicator is the share of people with the particular education of the total population of a given region compared with the national average. Values above 1 are marked in bold and indicate an above average share - i.e. the region is specialized.

Table 3 shows that Copenhagen is specialized in all three categories in both 1992 and 2002. The universities in this region educate approximately half of the Danish MSc's in electronics engineering. Aarhus is specialized in BSc's in engineering and MSc's in natural sciences (including computer science). The third-largest region Odense is only specialized in the engineering BSc's, since there was no local MSc education in computer science and engineering. Furthermore, the engineering BSc was not in electronics, but mainly in construction and production engineering. Aalborg University is the second Danish university that offers engineering MSc's and educates approximately half of the Danish electronics engineers. There is also an MSc degree in computer science. Aalborg was specialized in engineering MSc's in 1992 (1.05) increasing to 1.27 in 2002. Fredericia-Kolding increased its specialization in engineering BSc slightly from 1992 to 2002 and Vejle became specialized in this category in 2002. However, none of these regions was specialized in MSc's. Aarhus is close to the national average in employment share of MSc's in engineering, since they have been able to attract these from the outside.

Hypothesis 2 states that a university providing tertiary education in engineering or computer sciences has a positive effect on IT employment specialization in a region. The importance of local universities is seen Table 4 that shows the educational composition of the IT sector employees in the largest regions.

Table 4 The educational composition of the IT sector employees in the largest regions

Region	1992 IT employment 1992 (persons)	1992 Engineering BSc	1992 Engineering MSc	1992 Natural Science MSc	2002 IT employment 2002 (persons)	2002 Engineering BSc	2002 Engineering MSc	2002 Natural Science MSc
COPENHAGEN REGION	10,782	**1.17**	**1.26**	0.97	27,177	**1.03**	**1.09**	0.93
AARHUS	2,257	0.54	0.41	**2.14**	5,910	0.80	0.58	**2.06**
ODENSE	638	**1.01**	0.52	0.54	1,558	**1.10**	0.56	0.60
AALBORG	1,070	0.71	**1.19**	0.68	2,711	**1.18**	**1.99**	0.67
ESBJERG-RIBE	108	0.85	0.00	0.40	266	0.83	0.43	0.21
KALUNDBORG	38	0.00	0.54	0.00	176	0.81	0.65	0.62
FREDERICIA-KOLDING	438	0.84	0.33	0.20	459	0.82	0.37	0.30
KRONJYLLAND	101	0.00	0.00	0.85	288	**1.31**	0.35	0.28
VEJLE	533	0.47	0.27	0.16	791	0.72	0.34	0.41
HERNING-IKAST	402	0.34	0.36	0.00	565	0.67	0.71	0.15
Total (persons)	16,367	700	805	390	39,901	3,054	2,825	1,504

Source: Based on data from Statistics Denmark. Note: The specialization indicator is the share of people with the particular education of the total population of a given region compared with the national average. Values above 1 are marked in bold and indicate an above average share - i.e. the region is specialized.

The differences in the educational composition of the IT sector employees appear to be closely related to the profile of the local universities. The impact is clearly seen for the four largest regions. Aarhus has a strong position in MSc's in natural science (mainly computer science), but a weak position in engineering. Odense has a little above average share of BSc's in engineering. Likewise it can be seen that Copenhagen and Aalborg are the only regions with a university that educates MSc's in engineering. These regions also have the highest share of MSc's in the regional IT sector. This confirms Hypothesis 2 and also helps explain the strong position of Copenhagen and Aarhus and the catch-up of Aalborg. It appears to be more than urban externalities that shapes the spatial evolution of the IT sector since the lack of local IT related university educations in Odense is reflected in the educational composition of the IT employees and offers an explanation of the poor performance of Odense's IT sector.

3.4 Diversity

Table 5 shows the diversity of the regional industrial structure of the ten largest regions. Diversity is measured by the Shannon-Weaver entropy index[6]. The mathematical maximum entropy value is 3.30. The average value for all 35 regions is 2.45, while the average for the largest regions is 2.60.

Table 5 Diversity in the top 10 total employment regions 1992

Region	Diversity 1992	Diversity Rank 1992	IT employment 1992 (persons)	IT Rank 1992	IT Rank 2002	Share of total employment 1992 (%)	IT Specialization 2002
COPENHAGEN REGION	2.54	14	11,891	1	1	39.8	1.61
AARHUS	2.58	8	2,279	2	2	9.5	1.43
ODENSE	2.66	4	798	4	4	7.1	0.54
AALBORG	2.61	6	964	3	3	5.5	1.14
ESBJERG-RIBE	2.55	10	95	11	11	3.8	0.18
FREDERICIA-KOLDING	2.68	1	435	6	7	2.8	0.38
HERNING-IKAST	2.54	13	235	7	5	2.7	0.69
VEJLE	2.64	5	569	5	6	2.6	0.54
KALUNDBORG	2.54	12	42	16	12	2.6	0.18
KRONJYLLAND	2.67	2	102	8	9	2.4	0.30
Total Denmark	-	-	18,075	-	-	100	1

Source: Based on data from Statistics Denmark

Hypothesis 4 states that regions with a diverse industry structure will benefit from Jacobs' externalities and have a positive effect on the relative size of IT employment. Jacobs' externalities can be analyzed as related variety. In empirical studies, related variety is measured as variety of industries at the level of five digit industry codes, within the two digit codes (Frenken et al., 2005). However, this approach can not be used on the IT sector, since it is measured at the two digit level (NACE 72) and 93 per cent of the employment is located in the 722 and 723 codes. The entropy based measure of the overall regional industry structure in Table 5 reveals that Copenhagen is the least diverse of the 10 largest Danish regions, while Vejle, Aalborg, and Aarhus are respectively three, four and five. There is, however, only a small difference between the regions. A closer look at the structure shows that Copenhagen and Aarhus are the only large regions not specialized in agriculture and food processing. Their industry structures reveal a high share of service employment and specialization in many service industries. However, many smaller regions also have a high share of service employment, such Aabenraa, Skagen, Aalborg and Fredericia-Kolding, while most regions are specialized in some of the service industries. The electronics industry could be related to the IT sector, but several regions are specialized: Copenhagen, Aalborg, Horsens, Holstebro-Struer, Sonderborg, Ringkobing, Thisted, Aalestrup, and Skagen. Therefore, the data are rather inconclusive about Jacobs' externalities and much more detailed data on labour mobility is needed to do an in-depth analysis. Therefore it is not possible to confirm Hypothesis 4.

4 Discussion

The evolution of the Danish IT sector 1992 to 2002 shows a clear pattern with concentration in the two largest urban regions. Copenhagen and Aarhus were specialized in 1992 and remained so during the decade. Vejle was the third functional urban region specialized in IT in 1992, but lost this status in 1997. Vejle dropped from a location quotient at 1.2 in 1992 to 0.69 in 2002. The other Danish regions remained unspecialized during the entire period except for Aalborg that became specialized in 1993-5 and 2000-2. The continued specialization of Copenhagen and Aarhus indicates the existence of MAR externalities, as stated in Hypothesis 1, but this leaves some questions unanswered, such as why Vejle experienced relative decline and Aalborg caught up.

The rapid employment growth of the Danish IT sector has created a skill-biased demand of labour. This has put requirements on the stock of skilled labour and the growth of supply, which typically come from a university in the region. This could explain why Vejle's specialization has declined steadily. It has become specialized in engineering BSc's, but lacks the MSc's in computer science and engineering. This is also the case for Odense. This lack of supply is one of the factors that have hindered growth in the Odense region. However, supply of highly skilled graduates seems to have been beneficial for the growth in Aalborg. It was not specialized in 1992, but managed to overcome this disadvantage by being specialized in engineering MSc's like Copenhagen. Furthermore, this specialization increased to 1.27 in 2002. The detailed data on the educational composition of the IT sector reveals a strong relation between the composition and the profile of the local universities. Copenhagen and Aalborg benefit from the specialization in MSc's in engineering, while Aarhus has a strong profile in computer science and Odense only is specialized in BSc's in engineering. This confirms Hypothesis 2 that a university providing MSc education in engineering and/or computer sciences would have a positive effect on IT employment specialization.

The evolution of the IT sector in Denmark shows that most regions increased their IT employment during the period. However, the spatial pattern remained fairly stable and the large cities continued to dominate. It appears that regions that were able to respond to the needs of the IT industry experienced a high employment growth. The needs of the IT sector seem to be provided by large cities that have many IT firms, a large highly educated labour force and educational organizations that supply highly qualified labour. More precisely, regions that were not able to provide these factors remained at a low level of specialization. This is not necessarily an effect of urban externalities, because the cities without universities offering MSc degrees in computer

science and/or engineering remained at a low level of IT specialization. Jacobs' externalities are often closely related to the urban externalities, but there was no effect of industrial diversity, thus it was not possible to confirm Hypothesis 4.

The spatial evolution of the IT sector in other countries have also shown that it tends to locate near cities with universities providing MSc's in engineering and computer science (see e.g. Weterings, 2006, for the evolution of the Dutch IT sector and the agglomeration near the university-town Utrecht). This study clearly shows the effect of local universities. It appears that the rapid growth race of the IT sector has favoured regions that were able to provide the needed labour. However, the location of the universities and the educations they offer are not the sole explanatory factor for the spatial evolution of the Danish IT sector. Copenhagen is favoured by being the capitol city and thus home to many large companies. In addition, the universities do not only supply labour to the local labour markets. However, the local industry might have an initial advantage since the graduates prefer to stay close to their social networks after graduation, but if they can not get a job nearby they seek jobs elsewhere in the country.

5 Conclusion

The spatial employment concentration pattern of the Danish IT sector in 1992 was moderately changed a decade later. Employment increased 130 per cent and the number of firms more than doubled. These changes could imply a shift in the industry structure, but it continued to be concentrated and the spatial specialization pattern remained fairly stable. The leading regions in 1992 have kept their position, the ranking of the followers changed moderately, while the remaining regions kept lagging behind.

The spatial evolution of the sector clearly reveals a non-random growth pattern and points towards the existence of agglomeration economies. However, it is difficult to specify whether intra-industry or inter-industry externalities have been most important for growth. The two most specialized regions continued to be specialized, which support the importance of specialization externalities, but these regions are also largest urban areas, which indicate the existence of urban externalities. There was no relation between industrial diversity and the relative size of the IT sector. The persistent employment and firm specialization in Copenhagen and Aarhus show various effects and self-augmenting processes sustain these regions at a high activity level. However, urban externalities can not explain why Odense, the third largest region remained at a low level of

specialization, while Aalborg, the fourth largest region, performed well. The IT employment specialization in Aalborg shows that a non-specialized region might be able to compensate for not having a large and diverse labour market and specialization in IT employment by having a university providing MSc's in engineering and computer science. The importance of the profile of a university for the region is also seen at a larger scale with MIT in Boston, US (Best and Xie, 2006).

The IT sector has an above average share of highly educated employees. To sustain the very high growth it benefits from locating in a region with supply of highly educated employees and thus location of universities and technical colleges educating engineers and computer scientists become important. The profile of the local university and the specialization of the region's IT sector appear to be correlated. The profile of the educational structure in the regional IT sector fits neatly with the educations offered by the local universities. The local outsourcing of internal IT service activities from companies to Danish IT firms also supports the largest IT firms located in the Copenhagen and Aarhus region. Thus, it appears that the size of the industrial base have contributed to the growth. There clearly appears to be an element of path dependency in the spatial evolution of the sector.

Future studies of intra-industry and inter-industry externalities should analyze the effect of labour mobility in more detail. The flow of labour and the skill composition of the regional labour force appear to play an important role in evolution of the IT sector. It would be fruitful to analyze where the employees come from; if they are attracted from other regions; which sectors they come from; if they come from the local university and the evolution of the skill composition in the sector. In addition, it is still unclear how the intra-industry and inter-industry externalities affect the formation of new firms.

6 References

Andersen, A. K. (2000). Commuting Areas in Denmark, AKF.

Arrow, K. J. (1962). "The Economic Implications of Learning by Doing." Review of Economic Studies **29**(80): 155-173.

Audretsch, D. B. and M. P. Feldman (1996). "R&D Spillovers and the Geography of Innovation and Production." American Economic Review **86**(3): 630-640.

Beardsell, M. and V. Henderson (1999). "Spatial evolution of the computer industry in the USA." European Economic Review **43**: 431-456.

Best, M. H. and H. Xie (2006). Discovering Regional Competitive Advantage: Route 128 vs. Silicon Valley. DRUID Summer Conference 2006, Copenhagen.

Boschma, R., R. Eriksson and U. Lindgren (2008). "Labour mobility, related variety and the performance of plants: A Swedish study." Papers in Evolutionary Economic Geography(08.09): 1-21.

Boschma, R. and S. Iammarino (2008). "Related variety, trade variety and regional growth in Italy." Papers in Evolutionary Economic Geography(08.02): 1-24.

Boschma, R. and G. A. v. d. Knaap (1999). "New high-tech Industries and windows of locational opportunity: The role of labour markets and knowledge institutions during the industrial era." Geografiska Annaler **81 B**(2): 73-89.

Brenner, T. (2004). Local Industrial Clusters: Existence, emergence and evolution. London and New York, Routledge.

Carroll, L., H. Haughton and J. Tenniel (2003). Alice's adventures in Wonderland and Through the looking-glass and what Alice found there, Penguin Classics.

Crone, M. (2004). Celtic Tiger Cubs: Ireland 's VC-Funded Software Start-ups. Institute for Small Business Affairs National Entrepreneurship & SME Development Conference, Newcastle-Gateshead.

Eriksson, C. M. (2006). The Dynamics and Organisation of the Swedish IT industry 1990-2004. Department of Technology Management and Economics. Göteborg, Chalmers University of Technology**:** 140.

Feldman, M. P. and D. B. Audretsch (1999). "Innovation in cities: Science-based diversity, specialization and localized competition." European Economic Review **43**: 409-429.

Florida, R. (2002). The Rise of the Creative Class. New York, Basic Books.

Frenken, K., F. G. van Oort, T. Verburg and R. Boschma (2005). "Variety and regional economic growth in the Netherlands." Papers in Evolutionary Economic Geography(05.02): 1-58.

Hanson, G. H. (2000). "Scale Economics and the Geographic Concentration of Industry." NBER Working Paper Series(8013).

Henderson, V., A. Kuncoro and M. Turner (1995). "Industrial Development in Cities." The Journal of Political Economy **103**(5): 1067-1090.

Jacobs, J. (1969). The Economy of Cities. New York, Vintage Books.

Marshall, A. (1920). Principles of economics. London, Macmillan.

Maskell, P., H. Eskelinen, I. Hannibalsson, A. Malmberg and E. Vatne (1998). Competitiveness, Localised Learning and Regional Development - Specialisation and Prosperity in Small Open Economies. London, Routledge.

Neffke, F. (2008). "Time-Varying Agglomeration Externalities in UK Counties between 1841 and 1971." Mimeo.

Porter, M. E. (1998). On Competition. Boston, Harvard Business School Press.

Saxenian, A. (1994). Regional Advantage: Culture and Competition in Silicon Valley and Route 128. Cambridge, MA, Harvard University Press.

Steinmueller, W. E. (1996). The U.S. Software Industry: An Analysis and Interpretive History. The International Computer Software Industry. D. Mowery. Oxford, Oxford University Press**:** 15-52.

Storper, M. (1997). The Regional World: Territorial Development in a Global Economy. New York, The Guilford Press.

Storper, M. and R. Walker (1989). The Capitalist Imperative: Territory, Technology, and Industrial Growth. Oxford, Basil Blackwell.

Tushman, M. L. and P. Anderson (1986). "Technological Discontinuities and Organizational Environments." Administrative Science Quarterly **31**(3): 439-465.

van Oort, F. and O. A. L. C. Atzema (2004). "On the conceptualization of agglomeration economies: The case of new firm formation in the Dutch ICT sector." The Annals of Regional Science **38**: 263-290.

Weterings, A. B. R. (2006). Do firms benefit from spatial proximity? Testing the relation between spatial proximity and the performance of small software firms in the Netherlands. Knag/Faculteit Geowentenschappen. Utrecht, Universiteit Utrecht**:** 1-186.

[1] Henderson et al. (1995) argues that sectors that have undergone sufficient transformation and growth could be treated as something akin to new.

[2] Related variety is often measured as the distribution of employment on three or four digit codes within the two digit NACE codes. However, the IT sector is defined at the two digit level as NACE 72. Therefore, the related variety method shows the degree of related variety within the IT sector.

[3] The number of employees is based on data from Statistics Denmark measuring employment on November 1st.

[4] Odense University merged with other organizations into University of Southern Denmark in 1998.

[5] This has, however, changed recently, although at a small scale. Some new developments are pointing towards supplying engineering at the master level at University of Southern Denmark as well as at Aarhus University.

[6] The Shannon-Weaver entropy index is defined as: $\sum_{i=1}^{n} p_i (\ln \frac{1}{p_i})$, where p_i is the proportion of employment in sector i. The entropy index is calculated on the total private employment divided into 27 sectors: Agriculture, food, textiles, wood products, refined petroleum, chemicals, rubber, other non-metallic, metals, fabricated metal products, machinery, electronics, motors, other transport, furniture, recycling, construction, trade, transportation, financial services, real estate activities, renting, IT, R&D, other business services, recreational and other services.