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EKHK31

Bachelor's thesis (15 credits ECTS)

June 2016

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The Geography of Swedish ICT Innovation

Abstract

Innovation has in recent years been getting an increasingly important role in both industrial policy and in the academic discourse. In both the United States and the European Union policy-makers have tried to kick start slumbering economies by launching new innovation policies and academics write about innovation like never before. In this environment, Sweden has become something of a role model and is often mentioned in rankings of the world's most innovative countries. A number of successful startups in Stockholm have led to a lot of attention being paid to the ICT sector and parallels are often drawn to California's Silicon Valley. Simultaneously, a development toward increased focus on the importance of geography to innovative activities within both policy and research can be discerned.

Through quantitative analysis of newly-presented data, this thesis exposes the changing geographical patterns of Swedish ICT innovation during four decades. The findings suggest that the Stockholm dominance was in fact more significant in the 1970s and 1980s than in the 2000s, and that the development of the spatial concentration of innovation output has gone from decreasing in the 1970s and 1980s to increasing in the 1990s and early 2000s.

Table of Contents

1. Introduction

> "History should be our guide. The United States led the world's economies in the 20th century because we led the world in innovation. Today, the competition is keener; the challenge is tougher; and that is why innovation is more important than ever. It is the key to good, new jobs for the 21st century. That's how we will ensure a high quality of life for this generation and future generations. With these investments, we're planting the seeds of progress for our country, and good-paying, private-sector jobs for the American people."
>
> -President Barack Obama, August 5, 2009 (Executive Office of the President, 2009, p.1)

The word "innovation" is tossed around much these days and has become something of a buzzword used by politicians, business leaders and scholars. The quote above is taken from the paper *A Strategy for American Innovation*, released by the Executive Office of the President in 2009. It identifies investments in innovation as vital to the American economy and outlines a range of different policies aimed at reigniting the innovational spark in the U.S. economy. Across the Atlantic Ocean the European Union has identified a European "innovation emergency", with too little spending on R&D and a flight of researchers and innovators to countries with more favorable conditions, and have in response launched a line of initiatives with the objective to increase spending and spur innovation (European Commission, 2015). The academic world seems to agree with President Obama that innovation is more important than ever. Within the social sciences research on the role of innovation in economic and social change has rocketed during the last few decades. In fact, between 1990 and 2004 the proportion of scholarly articles within the social sciences with the word "Innovation" in the title doubled (Fagerberg, 2005).

As a positive exception on the struggling European continent, Sweden is often pointed out as one of the world's most innovative countries (e.g. Jamrisko & Lu (2016) and The Economist, (2015)). Just like in the United States and in the European Union, innovation is identified as a vital key in Swedish industrial policy. As one of his first actions as newly-elected prime minister of Sweden, Stefan Löfven presented the Innovation Council in February of 2015 with the purpose of “developing Sweden as innovative nation and strengthen the competitiveness of Sweden” (translated from Regeringskansliet, 2015, Innovationsrådet section). Much of the recent attention given to the innovativeness of Sweden has been directed toward successful startups within the information and telecommunication (ICT) sector. With the success of tech companies such as Skype, Spotify, Mojang, King and Klarna Stockholm is often compared to Silicon Valley and has been called the startup capital of Europe (Davidson, 2015; Benwell, 2014). The sector has however held a prominent role in Swedish industry for a long time with companies such as Ericsson and Asea/ABB. Taalbi (2014) and Sjöö (2014) show that output of ICT innovations has had an increasing trend in Sweden since the 1970s, in contrast to the overall Swedish industry where innovation output has decreased. Sjöö also shows an interesting development within the ICT sector with increasing importance of software innovations at the expense of hardware innovations.

The attention paid to Stockholm’s thriving startup scene and the comparisons to Silicon Valley highlights an important feature of both academic discourse and innovation policy in recent decades, namely the influence of geography on the innovation process. In his book *The Competitive Advantage of Nations* (1990), Michael Porter outlined a theory of national, state and local competitiveness within the global economy. Within this theory so called clusters play an important role. He defines clusters as “geographic concentrations of interconnected companies, specialized suppliers, service providers, firms in related industries, and associated institutions in particular fields that compete but also cooperate” (Porter, 1998, p.197). The concept suggests that the key to gaining competitive advantage to a large extent lies outside of companies or industries themselves, and instead is to be found in the locations of the business units. Porter (1998) claims that this concept points to new roles for companies, governments and other institutions that want to spur innovation and improve competitiveness. Asheim and Gertler (2005) claim that geography matters more to the innovation process today than ever before due to increased importance of tacit, non-codifiable knowledge and interactions and knowledge flows between economic entities. In order to respond to this increasing importance of geography, they highlight the concept of regional innovation systems and the promotion of these as important for national and regional levels of government. They describe the regional innovation system as the “institutional infrastructure supporting innovation within the production structure of a region” (Asheim &

Gertler, 2005, p.299). Swedish policy-makers seem to have listened to the academics. The Swedish innovation authority, Vinnova, was founded in 2001 and in 2002 started a still ongoing program aimed at strengthening clusters and regional innovation systems (Vinnova, 2016). In a report published by Svenskt Näringsliv and Sweco, Mattsson (2013) investigates the state of knowledge of the results of the Swedish cluster policy based on information about the established cluster initiatives in Sweden. A few survey investigations have been done where recipients of support have been asked about their experiences and a few quantitative figures of amounts of new innovations from these recipients are presented. However, since no extensive studies have been made, Mattsson concludes that the state of knowledge is too weak to know whether the policy works or not.

The amount of attention given to Swedish ICT innovation, especially Stockholm software innovation, combined with the increasing focus on geography in innovation policy and research makes it interesting to investigate Swedish ICT innovation output from a geographical perspective. Is it true that geography is more important than ever to innovation? Is all Swedish ICT innovation centered to Stockholm? How have the geographical patterns changed with the changing structural composition of the ICT sector? Thoughts like these are what has led to the choice of the following purpose and research questions for this thesis.

1.1 Purpose and research questions

The purpose of this thesis is to investigate the geographical properties of Swedish ICT innovation and how they have changed during the last decades. The investigation is built around the following three research questions:

RQ 1 Where have Swedish ICT innovations originated in different time periods? Have the patterns changed?

RQ 2 How has the structural composition of ICT innovations across industries changed in different municipalities and to what extent have municipalities specialized in certain types of ICT innovations?

RQ 3 Has output of Swedish ICT innovations become more or less evenly distributed between municipalities?

The first question is answered through the development of a range of maps that in an efficient way show where Swedish ICT innovations have originated and how the patterns have changed during the almost four decades from 1970 until 2007. The second question is concerned with the relative strength of the industries constituting the wider ICT sector in different time periods and whether different municipalities have specialized in different kinds of ICT innovations. It is answered by an investigation into what type of innovations that have been most numerous in different time periods and in different municipalities. Statistical methods are also used to assess to what extent different municipalities are specialized in different industries. The third question is answered using descriptive statistical methods that make it possible to compare the distribution of the innovations output between different time periods and between different industries.

By fulfilling the purpose and answering the research questions, this thesis contributes to the understanding of the structural and geographical development of the Swedish ICT sector and the evolving geography of ICT innovation. Its findings can be used by academics as well as policy-makers to for example assess the results of regional or local innovation policies.
In an OECD paper (2010) on innovation and cluster policy the lack of robust evaluations of cluster performance and changes over time is identified as a problem. As mentioned above, Mattsson (2013) found that that the state of knowledge about the results of Swedish innovation policy is weak. Even though the thesis doesn't aim to identify and assess cluster performance per se, the fact that it presents the first geographical mapping of Swedish ICT innovation output makes it valuable for tracing both high-level patterns and development within individual municipalities or regions.

2. Theory and previous research

In this chapter general theories and previous empirical findings relating to the research questions are presented. Section 2.1 concerns research question 1, section 2.2 concerns research question 2, and section 2.3 concerns research question 3. In section 2.4 the three former sections are briefly summarized and hypotheses drawn from the theories and previous empirical findings are presented. These hypotheses are then discussed and analyzed in later chapters.

2.1 The geographical patterns of Swedish ICT innovation

Lundquist and Olander (2007) write about how new so called general purpose technologies lead the transformation of industrial patterns and how the transformation is successively spread across the regions of a country in structural cycles. A general purpose technology is such a fundamental and powerful technology that it can affect the national or global economy of an entire epoch. Historic examples are the steam engine, railways, electricity and the internal combustion engine. A more recent example, and the one that Lundquist & Olander focus on, is the integration of computer and communication technologies with the Internet revolution, that they claim is radically transforming the industrial structure of the industrial countries.

The new cycle induced by the general purpose technology starts with growth of the new industries and the older industries that are vitalized by the new technology. In common for these industries is that they are all engaged in the production or the early use of the new technology. Current examples are the industries within the ICT sector. The diffusion of the new technology doesn't necessarily go in the direction set out by competencies among the user industries or their traditional directions. It is also influenced by what opportunities the technology brings in terms of new ways of using it and might be combined with other new or old technologies to create new applications. Radical innovations can lead to imitations and incremental innovations or improvements, creating development blocks which reflect the complementarity between technologies and are the most dynamic parts of the transformation process. Subsequently, in later stages of the cycle, the new technology reaches other industries as well, thereby affecting the complete industrial structure. As the cycle goes on and the technology matures, the renewal and the force of the transformation will diminish. Investments will increasingly be directed towards rationalization and increasing efficiency to manage rising competition, and eventually production growth will go down and rationalizations continue. Wage shares will rise and profits will diminish, unemployment rises and soon the cycle ends in a structural crisis.

After describing the influence of the new general purpose technology on the structural cycle on the national level, Lundquist and Olander go on to describe what happens on the regional level. The renewal, the rationalization and the crisis start in certain regions and are subsequently spread to other regions according to predetermined patterns. These patterns are related to the phenomena of internal and external economies of scale and transaction costs. In the beginning of a cycle, transaction costs for the new and the vitalized industries are high and they need large regional home markets to reach sufficient scale. The production starts out on a small and experimental basis and subsequently develops within the large regional market. Simultaneously there is a decentralization of the older technologies' production, away from large regions toward smaller, peripheral ones. As the production within the new industries begins to standardize and transaction costs start to fall, the resource side of the large regional markets become strained. Cost of living, land and wages increase, and the new industries start to diffuse regionally. There are various drivers of this diffusion, among them imitation of products by other companies, decentralization via branches in other regions and outsourcing. In the rationalization phase of the cycle the large regional markets lose their dominant position as production becomes more standardized and moves to more peripheral regions.

Svensson Henning (2008) draws on previous work by Lennart Schön and writes about the latter's resembling theories of major technology shifts as the key to explaining economic transformation. By this model a period of dramatic technological and structural renewal in the Swedish economy started in the late 1970s with the diffusion of ICT technologies. Combined with the theory put forward by Lundquist and Olander of how regional industrial patterns are affected by fundamental technological change and national economy-wide structural cycles, the model implies that it should be possible to identify changes in the geography of Swedish ICT innovation over the last four decades. If the theory holds true, and provided that the current cycle started in the 1970s, one can expect a pattern of initial dominance of the largest regions, followed by a gradual shift toward more even distribution across regions.

After this walk-through of Lundquist's and Olander's theory which led up to a hypothesis of what kind of patterns one can expect from a mapping of Swedish ICT innovation over the last four decades, we will now turn to a review of previous efforts to map Swedish innovation. Svensson Henning (2009) presents maps showing regional redistribution of manufacturing and producer services activities in terms of value added and number of employees between the years 1978 and 2000. What makes these maps unique and interesting is that they provide a time perspective similar to that used in this thesis. Focus, however, doesn't lie on either the ICT sector or innovation output. Other efforts have to a great extent focused on identifying Porterian clusters or so called cluster initiatives within certain industries. Cluster initiatives are formally defined collaborations between authorities, firms, R&D institutions etc. with the purpose of strengthening the growth and competitiveness of a cluster (Nordensky, 2009). Lindqvist et al. (2002) used statistical methods to provide a range of "cluster maps" that identify clusters within different sectors across Sweden. The indicator used in the study to measure the "strength" of clusters is number of employees within sectors in a certain geographical area. The study was made at the request of "Nationella programmet för innovationssystem och kluster" (the National Program for Innovation Systems and Clusters) and was intended to be used by policy makers in the development of cluster initiatives. In 2009, Vinnova published a report (Nordensky, 2009) that listed all the cluster initiatives that had received support and positioned them geographically on a map. The aim of the two mappings thus differ in the way that Lindqvist et al. aims to identify organically emerged clusters while Nordensky investigates where government support to cluster initiatives has gone.

There are also a few international mappings that cover Sweden. One of the most prominent is the European Union led European Cluster Observatory that maps clusters and cluster policy in all of Europe (European Commission, 2016). The Observatory provides interactive maps where a wide range of different indicators can be chosen. One of these indicators is the Regional Innovation Scoreboard (RIS). The RIS is a comparative assessment of innovation performance in 190 regions in the EU, Norway and Switzerland including eight Swedish regions. Since 2002, when the first version was published, five updated versions have been published, of which the most recent one in 2014. It is produced in a similar way to the annual Innovation Union Scoreboard (IUS) which benchmarks innovation performance at a national level. Whereas the IUS measures innovation performance with a composite index based on 25 different indicators, the RIS index is based on 11 of these indicators due to lack of data on the regional level. The indicators are categorized into three main types: Enablers, Firm Activities and Outputs. Examples of Enablers are educational level of the population and R&D expenditure in the public sector. Firm Activities are for instance R&D expenditure in the business sector and percentage of SMEs innovating in-house. For Outputs percentage of SMEs introducing product, process, marketing or organizational innovations and percentage of workforce employed in high-tech manufacturing or knowledge-intensive industries are examples (European Commission, 2014). In contrast to the Swedish mappings of clusters described above, the RIS thus includes some output indicators. However, these indicators are still merely proxies to real innovation output and the level of detail is limited to a regional level whereas the Swedish cluster maps go deeper, to a municipal level. An exhaustive investigation of Swedish innovation output at a municipal level is still missing.

2.2 The structural composition of Swedish ICT sector innovations and local specialization

The second research question revolves around the issue of structural composition of Swedish ICT innovation output and whether certain municipalities have specialized in certain kinds of ICT innovations. Sjöö (2014) investigates the structural composition of Swedish innovation output in an analysis of the SWINNO database (SWINNO is described in detail in chapter 3). She finds that a major trend in the development during the period 1970-2007 is the decline in machinery and equipment innovations, which were dominant in the beginning of the period, and the rise of ICT sector innovations. She shows that the ICT sector went from constituting around 20 % of the innovations in the beginning of the period to almost 50 % in the end, and that the development happened in two surges. She also investigates the composition of the ICT sector innovations themselves and finds that the first surge, in the 1980s, was primarily attributable to instrument innovations and to some lesser extent software innovations. She finds that the second surge, in the late 1990s, is attributable to telecommunication equipment and software innovations. Taalbi (2014) also analyzes the SWINNO database with respect to innovation counts within different sectors. No efforts have however been made to investigate whether this development can be traced to changing geographical patterns and specialization of certain municipalities.

Local specialization within certain industries have for long been a highly interesting topic for economic geographers. A century ago Alfred Marshall investigated clustering of the English metals industry in Sheffield and South Yorkshire and his explanation of this phenomenon has dominated economic geography for a long time. His explanation is that economic benefits, or so called localization economies, comes with the co-location of firms within an industry thanks to a local pool of specialized knowledge, labor and suppliers (Boschma & Frenken, 2015a). Boschma and Frenken (2015b) discuss recent empirical studies on the subject of cluster advantages and Marshallian localization economies. These studies have often resulted in ambivalent results and what they conclude is that there is little evidence of strict such economies, while if the definition is broadened from the Marshallian to include firms in related industries there is. This latter definition follows Porter's definition of a cluster more closely. With weak empirical evidence of localization economies being the dominant explanation for local specialization and clustering, they instead introduce Evolutionary Economic Geography as a superior perspective from which to explain such phenomena. This perspective tries to explain how the spatial patterns of economic activity can be understood as an outcome of path-dependent historical processes. They claim that studies with an evolutionary approach to geographical clustering is important since they can provide an explanation as to why local specialization and clusters emerge in the absence of localization economies. The evolutionary studies on different industries that they account for indicate that clusters emerge due to spinoffs of a few successful parent companies in the region.

Feldman (1994) investigates the geographical features of innovation in the United States and uses innovation location quotients (LQs) to assess to what extent the leading innovation states specialize in certain industries. The LQs are calculated by dividing the industry's share of total innovations in the state by the industry's share of total innovations in all of the United States. If the resulting ratio is higher than 1, innovations from the industry in question constitutes a larger share of the state's total innovations than of the country's as a whole. She finds that the average LQ for the leading state (by count of innovations) in the seven most innovative industries is 2.18, indicating a high level of specialization.

2.3 The spatial distribution of Swedish ICT innovations

Drawing on the framework put forward by Lundquist and Olander, described in section 2.1, Svensson Henning (2009) writes about what kind of trends one should expect in the overall regional division of labor in terms of production volumes or employment. In the beginning of the new cycle, or the transformation phase, a shift in favor of the large regions should be expected as these attract the fast-growing early-adopters of the new technology, whereas more mature, slow-growing industries locate in smaller regions. Svensson Henning thus concludes that regional divergence therefore should be expected during the early stages of the cycle. To test his expected outcomes, Svensson Henning studies changes in the spatial distribution of economic activities across Swedish regions between 1978 and 2000. The specific indicators of economic activities that he uses are regional shares of value added and employment for the manufacturing industries and the producer service industries. Using coefficients of variation and Gini coefficients as measures of regional dispersion he finds a converging trend during the late 1970s until the early 1990s followed by a period of divergence and increased inequalities of economic activity across regions until 2000.

Olsson-Ruppel (2006) investigates agglomeration patterns within the Swedish ICT sector in terms of regional distribution of establishments. He finds that ICT sector establishments are more agglomerated than Swedish establishments on average, and that this agglomeration especially is concentrated to the three largest and most urbanized regions, i.e. the Stockholm region, the Göteborg region and the Malmö region. He also finds differences between the industries within the ICT sector. The software industry has a much higher degree of concentration in the largest regions than average, while the hardware industry is slightly more concentrated than average and the telecommunications sector is less concentrated than average.

Asheim and Gertler (2005) introduce two paradoxical characteristics of the contemporary global economy. These are that innovative activity is unevenly distributed across the geographical landscape and that the tendency toward spatial concentration has become more marked over time. They claim that this is especially true for highly knowledge-intensive industries such as biotechnology and financial services due to increased importance of tacit, non-codifiable knowledge and interactions and knowledge flows between economic entities. This contradicts predictions that increasing use of information and communication technologies would lead to decreasing spatial concentration of innovative activity. With these characteristics of innovative activity in mind they claim that geography is fundamental to the to the innovation process and that spatial proximity and concentration play a central role.

2.4 Summary and hypotheses

In the earlier sections of this chapter previous research relating to the research questions and some general theories were presented. In this section a brief summary is done and three hypotheses derived from the earlier sections are presented.

A hypothesis based on Lundquist's and Olander's theory of how regional industrial patterns are affected by fundamental technological change and national economy-wide structural cycles was put forward in section 2.1. The hypothesis is that a pattern of initial dominance of the largest regions in terms of ICT innovation output, followed by a gradual shift toward more even distribution across regions should be expected. In section 2.2 a study that showed a high degree of sectoral specialization among the most innovative U.S. states was accounted for. Assuming that this feature of innovation is not unique for the United States, a similar degree of specialization can be expected among the most innovative Swedish municipalities. Section 2.3 presented findings by Svensson Henning that regional economic activity in Sweden was in a converging trend until the early 1990s and subsequently has been diverging. He explains the divergence of recent years as a result of the structural cycle being in the transformation phase during these years. Claims from Asheim and Gertler that spatial concentration of innovative activity has become more marked over time also indicates divergence in the spatial patterns of innovation. They however explain the divergence with the increasing importance of tacit knowledge rather than cyclical behavior of the economy. Combining Sjöö's finding that software innovations have become more important with Olsson-Ruppel's finding that software is the most concentrated industry within the ICT sector gives support to Asheim's and Gertler's claim. A reasonable hypothesis therefore is that divergence in the spatial distribution of Swedish ICT innovation should be expected.

Each hypothesis relates to one of the research questions presented in section 1.1 and they are tested and discussed in chapters 4 and 5. In summary:

- Hypothesis 1. The geographical patterns of Swedish ICT innovation have changed from an initial dominance of the largest regions toward increasing importance of smaller regions as the technologies mature.
- Hypothesis 2. The most innovative Swedish municipalities show a high degree of specialization in certain industries within the ICT sector.
- Hypothesis 3. Output of Swedish ICT innovations has become less evenly distributed across municipalities.

3. Methodology and sources of data

To avoid the risk of merely joining in the aforementioned buzz, it might be a good idea to try and attach a formal definition to the word "Innovation". The OECD defines an innovation as

> "the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations." (OECD, 2005, p 46).

They thus distinguish four different types of innovations: product innovations, process innovations, marketing innovations and organizational innovations. Product innovations include both entirely new goods and services and significant improvements to existing ones. Process innovations refer to significant changes in production and delivery methods, organizational innovations represent implementation of new organizational methods, and marketing innovations concern the implementation of new marketing methods i.e. product design, packaging, pricing etc. (OECD, 2005). What they all have in common and the vital feature that separates the innovation from the invention is that while the invention is the first occurrence of an idea for something new, the innovation is the first attempt to carry it out in practice. For product innovations, which are the main focus of this report, it is therefore not until the new good or service has been commercialized that it turns from invention into innovation (Fagerberg, 2005).

There are various ways of measuring innovation. The two most common indicators probably are R&D spending and patent data. Both of them have pros as well as cons. Pros for both of these indicators are high availability of data and long time series, while cons are that neither is a direct measure of output of innovations. R&D spending only measures input to the innovation process and is therefore only a proxy indicator of innovation. Patent data measures output, but since not all patents lead to commercialization and not all innovations are patented it doesn't capture innovation output perfectly (Sjöö et al. 2014). Another indicator is the Community Innovation Survey that is conducted in all EU countries every other year. It collects information on innovative activity in enterprises with 10 employees or more (Statistics Sweden, n.d.).

The source of data used in this thesis is the SWINNO database which uses a fourth indicator, namely real output of product innovations. The database was produced primarily by Karolin Sjöö and Josef Taalbi, using the literature-based innovation output method (LBIO). With this method trade journals are systematically screened and real product innovations are recorded. The database is the first of its kind in Sweden and contains extensive information about 4145 innovations commercialized by Swedish manufacturing firms between 1970 and 2007 (Sjöö et al., 2014). The version provided to the author of this thesis has for privacy reasons been stripped of company specific data such as names, corporate identification numbers and descriptions of individual innovations. This reduces its usefulness as source of qualitative data but it still is an excellent source of data for quantitative analysis. The most important database variables used for the quantitative analysis has been the two-digit industry classification, the year of commercialization and the name of the municipality of origin. While the two latter variables are fairly self-explanatory, the two-digit industry classification can be discussed further.

In the SWINNO database SNI 2002 is used to categorize innovations into different industries. In this thesis the focus lies on the ICT sector which involves several of the 60 different two-digit industries in SNI 2002. The OECD defines the ICT sector in the following way:

> "Information and communication technology (ICT) refers to both different types of communications networks and the technologies used in them. The ICT sector combines manufacturing and services industries whose products primarily fulfil or enable the function of information processing and communication by electronic means, including transmission and display" (OECD, 2016, Information and communication technology (ICT) section).

In a similar way to how Taalbi (2014) and Sjöö (2014) defines the ICT sector in terms of two-digit SNI2002 industries, the ICT sector is considered to consist of the four industries listed in table 3.1. The total number of ICT innovations by this definition amounts to 1549 distributed across the five constituting industries, see Table 3.1.

SNI code	Description	Count
30	Manufacture of office machinery and computers	275
32	Manufacture of telecommunications equipment	342
33	Manufacture of instruments and industrial process control equipment	692
72	Software	240
Total	**ICT sector**	**1549**

Table 3.1: The four industries constituting the ICT sector.

4. Results

In this chapter the results of the quantitative analysis are presented in three sections, each corresponding to one of the research questions.

4.1 The geographical patterns of Swedish ICT innovation

In the following section a series of maps are presented for the purpose of tracking where Swedish ICT innovations have originated over the years. The section thus aims to answer the research question *Where have Swedish ICT innovations originated in different time periods? Have the patterns changed?* The time period for which there is data in the SWINNO database is 1970 - 2007. This time period has been divided into four shorter intervals of time for us to be able to spot differences in the innovation landscape between different time periods. The columns in the maps (see figures 4.1-4.4) reflect the amounts of ICT innovations originating from the municipalities where the columns are located. The highest column (which in all of the periods corresponds to Stockholm) is of fixed height regardless of absolute amounts and the height of the other columns reflect the amounts from these municipalities relative to the leading municipality's. In order to show absolute amounts, two-dimensional bar charts showing the amounts of the ten most innovative municipalities by innovation output accompany each of the maps.

The first map shows that the Stockholm region and the area surrounding Mälaren had a clearly dominant role during the 1970s. The two other larger regions, Göteborg and Malmö are far behind. The three following maps show a development of the Göteborg and Malmö regions catching up. In the last map Stockholm is still clearly in the lead but the two other larger regions also stand out. A striking feature is that it is the municipality of Lund instead of Malmö itself that drives the catching up of the Malmö region, in spite of having just about a third of the population. In the Stockholm and Göteborg regions it is clearly the main municipalities themselves that are dominant.

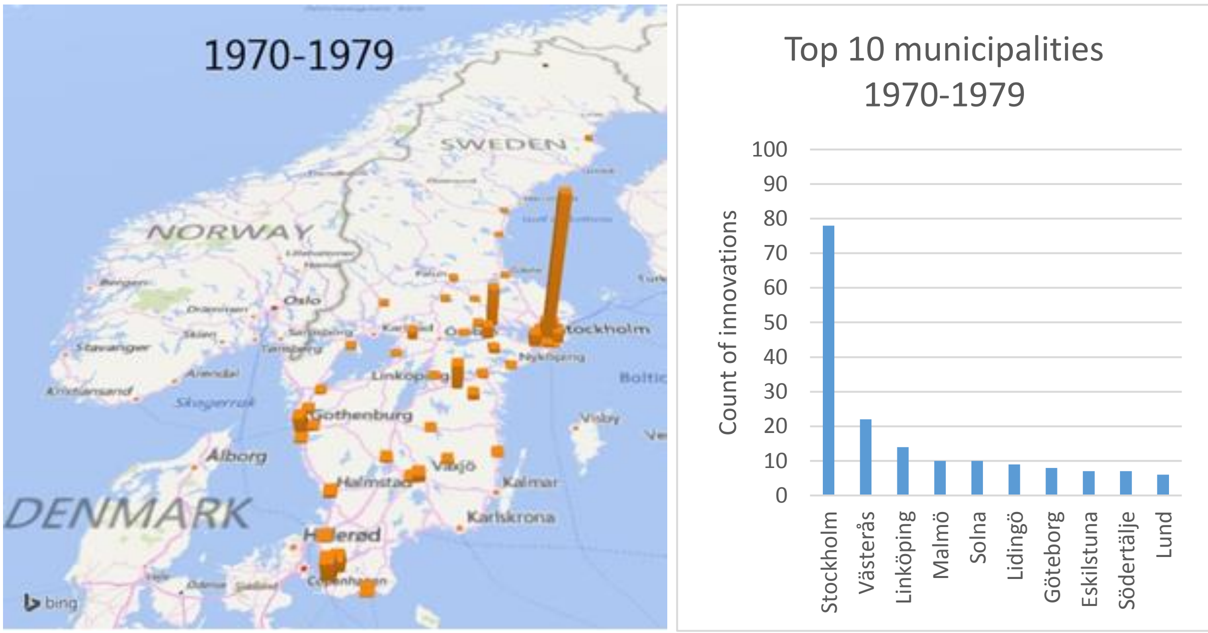

Figure 4.1: Innovation output by municipality 1970-1979.

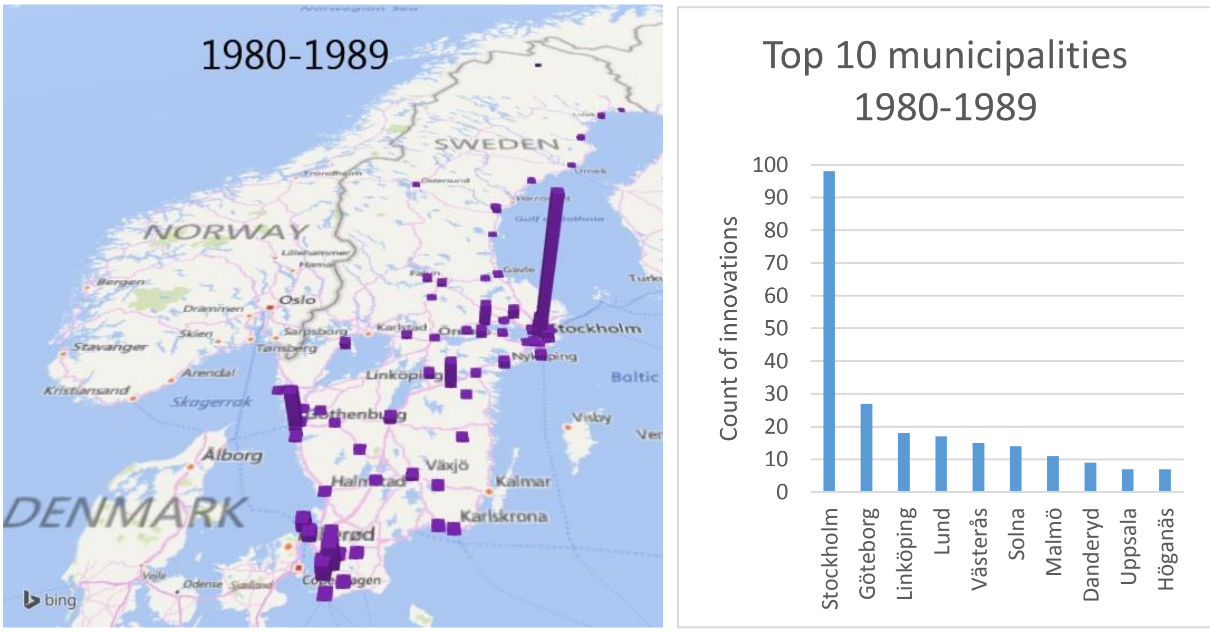

Figure 4.2: Innovation output by municipality 1980-1989.

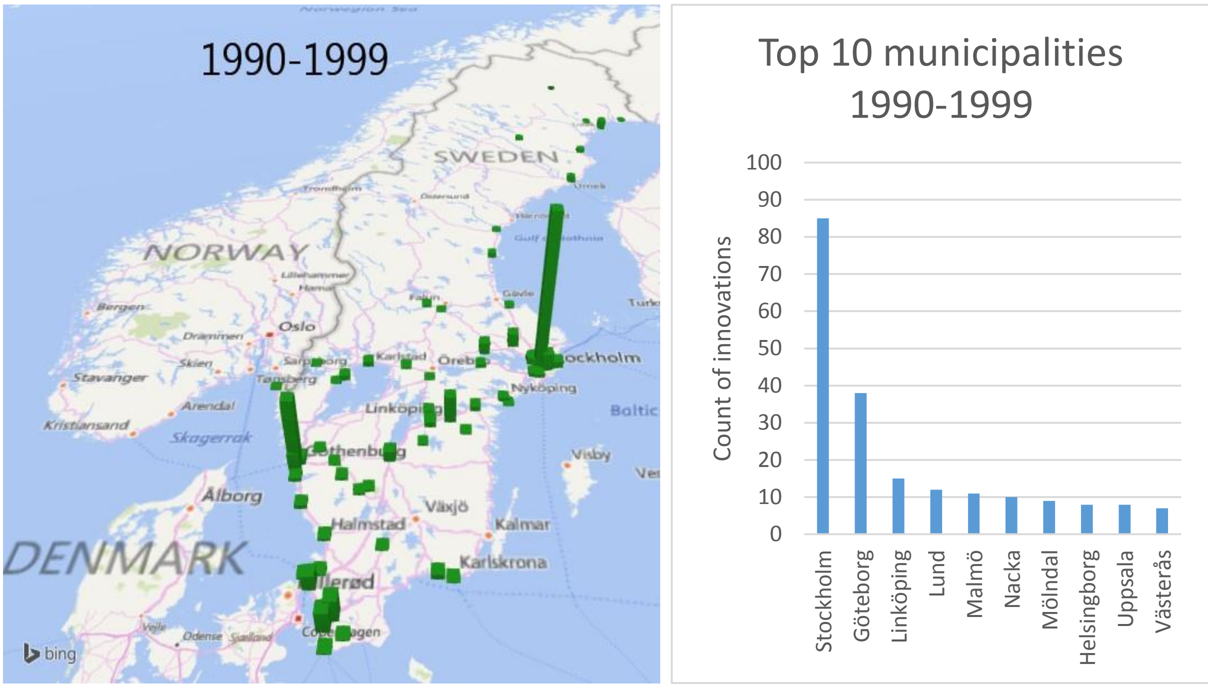

Figure 4.3: Innovation output by municipality 1990-1999.

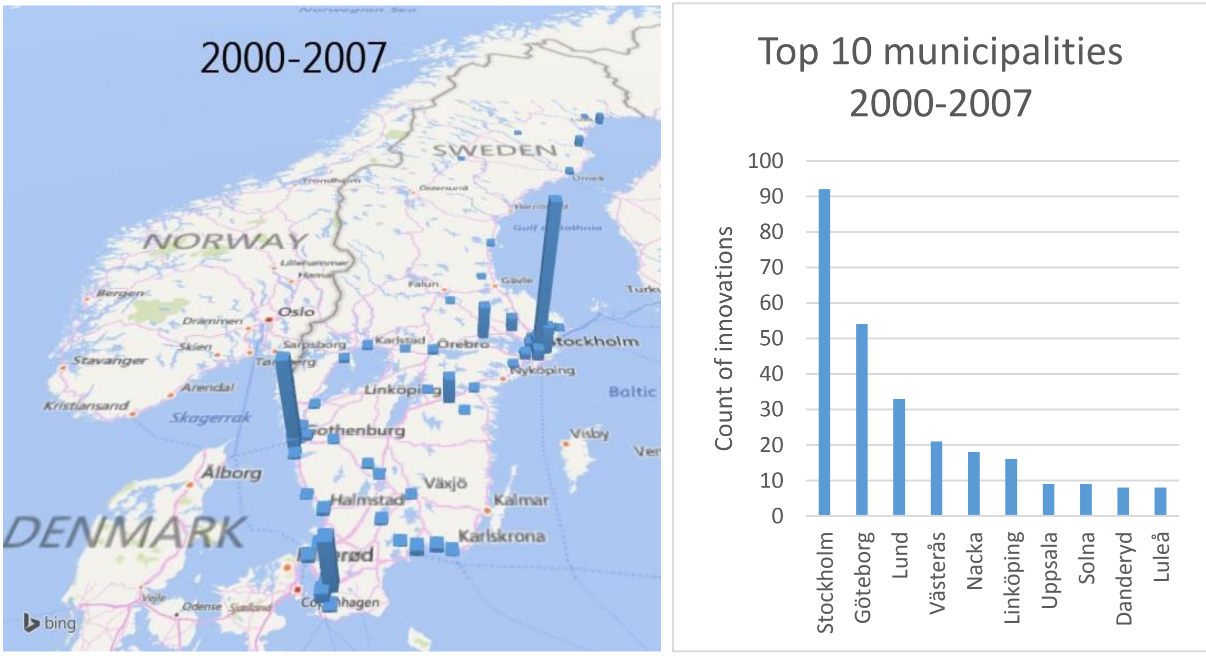

Figure 4.4: Innovation output by municipality 2000-2007.

Figure 4.5, below, shows the amounts of innovations from the top 5 municipalities during the period 1970-2007. The same development that was revealed by the maps, with Göteborg and later Lund catching up, can be seen here.

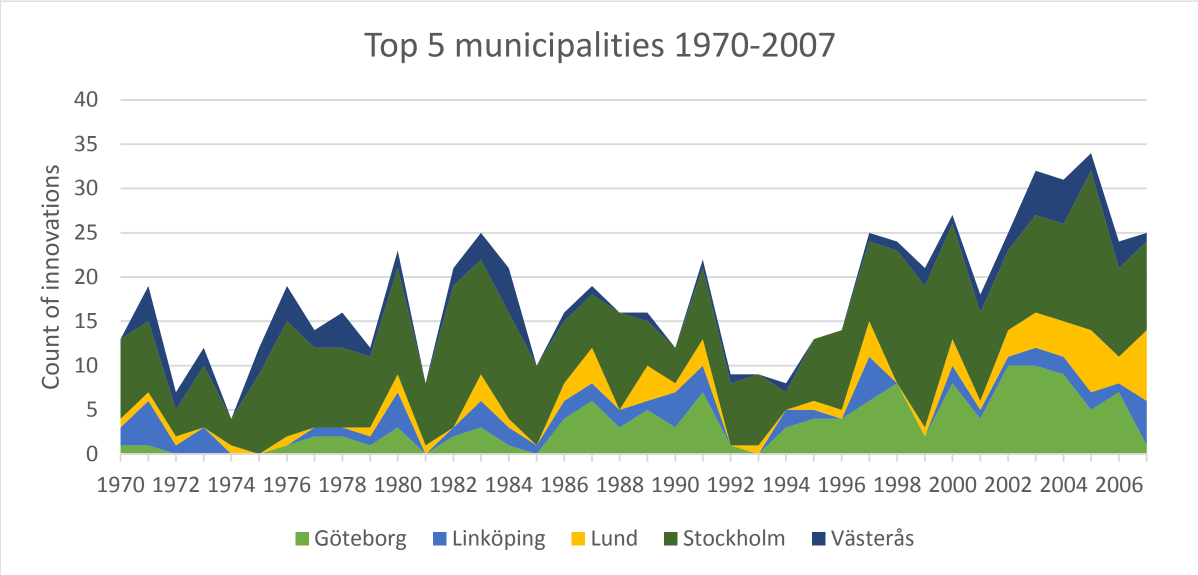

Figure 4.5: Innovation output from the five most innovative municipalities by count of innovations.

4.2 The structural composition of Swedish ICT sector innovations and local specialization

The ICT sector, as defined in chapter 3, consists of four different SNI2002 industries. Just like Sjöö (2014) found in her study of the importance of ICT sector innovation in relation to overall Swedish innovation, the sector has evolved and changed since 1970 in terms of the relative strength and importance of its constituting industries. Figure 4.6, below, shows the amount of Swedish ICT innovations stemming from each of the four industries in each year.

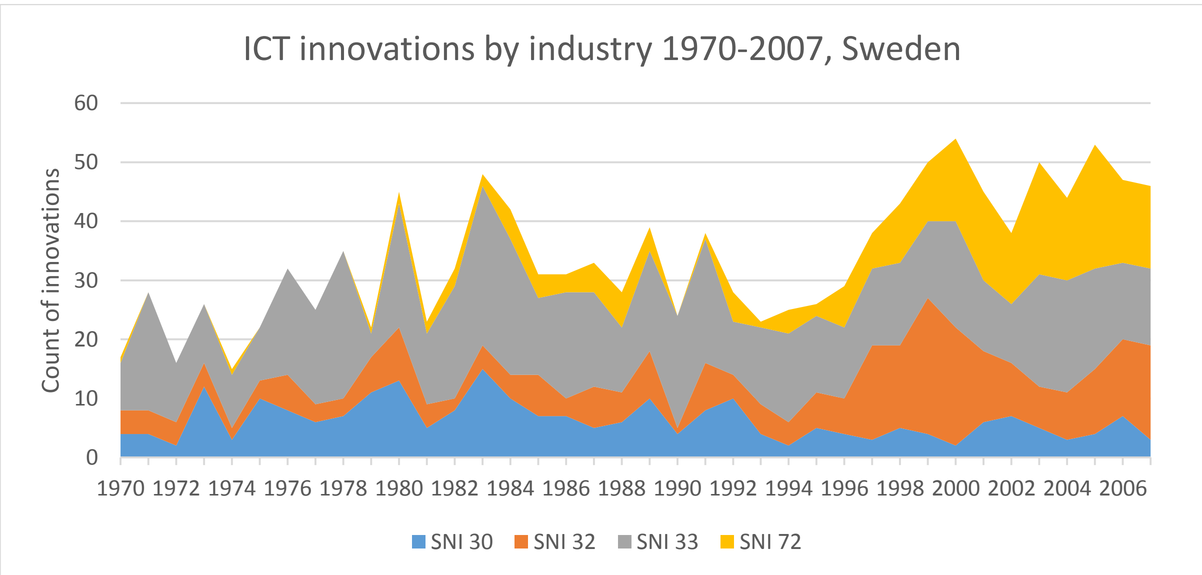

Figure 4.6: Count of ICT innovations by industry 1970-2007 for all of Sweden.

The trend in total output of ICT innovations has been upward with a clear slump in the beginning of the 1990s. Noteworthy is that the quite sharp increase in total output of innovations starting in the mid-1990s, that brought the overall trend back on track, mainly was a result of increasing output within SNI 32 and 72, i.e. manufacture of telecommunications equipment and software respectively. Up until then SNI 33, manufacture of instruments and industrial process control equipment, played a dominant role but has since the beginning of the 1990s seen its relative importance diminish, even though absolute output has been quite constant. Innovations within SNI 30, i.e. manufacture of office machinery and computers, constituted a big part of the total in the 1970s and 1980s but has diminished in both relative importance and absolute output since the early 1990s. The rise of SNI 72 bears witness to an important development in computer technology, where innovations in software has become increasingly important since the early days of modern computer technology in the 1970s. This development is especially evident in a comparison with SNI 30, where computer hardware innovations can be found.

In the previous section the development of the top five municipalities in terms of output of ICT innovations was presented. In figure 4.7 the composition of the ICT innovations is presented for each of these municipalities. The area charts reveal differences in the industrial structure of the different municipalities and changes in the structure over time. Stockholm's chart looks fairly similar to that of Sweden, witnessing about a diverse industrial structure. Noteworthy is the decline of SNI 33 innovations, that seems to have been more significant in Stockholm than in Sweden as a whole. The rise of Göteborg, as identified in section 4.1, cannot be attributed to any single industry. Instead their innovation output in recent years looks quite representative for Sweden as a whole. The rise of Lund seems to be heavily affected by innovations within SNI 32 and 72. Västerås was strong in SNI 33 innovations in the 1970s but started to lag behind Göteborg and Lund in the late 1980s and 1990s. Linköping's chart is quite patchy, and no clear patterns are distinguishable. SNI 30 and 33 seem to have been important in the early decades but have lost their dominance in the last decade. It is also clear that no municipality seems to have singlehandedly dominated any of the industries.

Figure 4.7: Count of ICT innovations by industry 1970-2007 for the five most innovative municipalities.

To assess and quantify the level of sectoral specialization location quotients (LQs) for the five leading municipalities have been calculated, see figure 4.8. The LQ for each industry in each municipality is calculated by dividing the industry's share of total ICT innovations in the municipality by the industry's share of total innovations in all of Sweden. A value of 1 means that the industry's share of total innovation output is the same in the municipality and the country, whereas a value larger than 1 means that the share is higher in the municipality and a value smaller than 1 that the share is lower in the municipality than in the country as a whole. Values larger than 1 thus indicate municipal specialization.

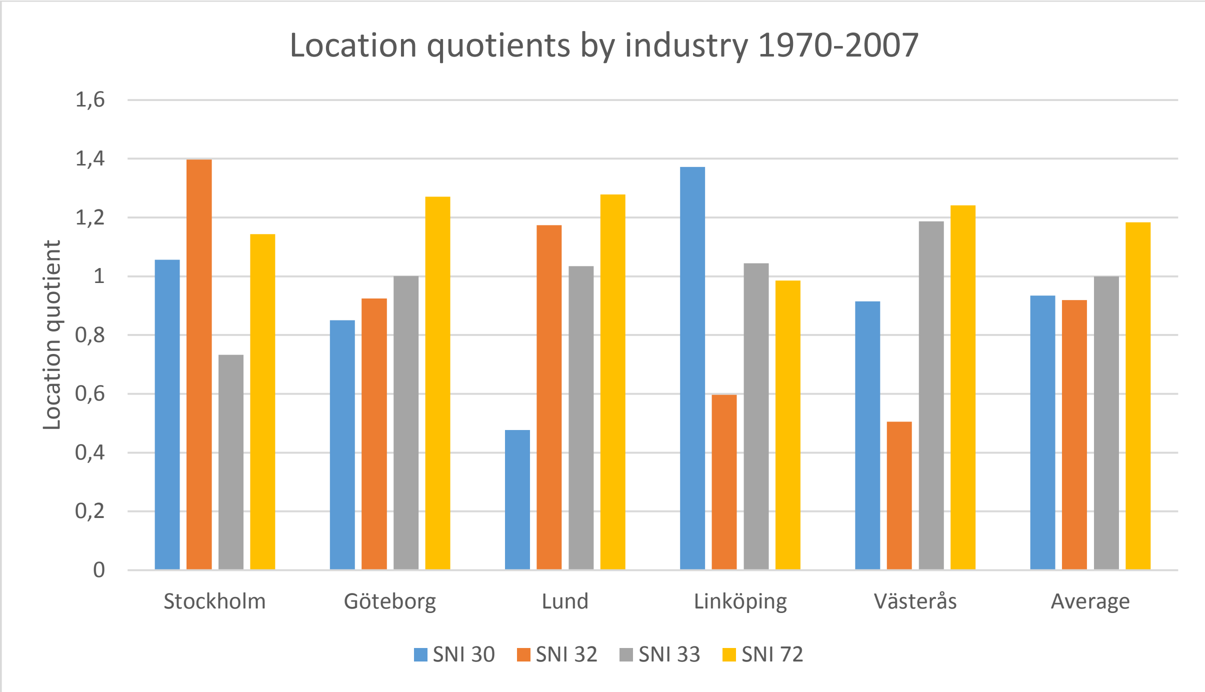

Figure 4.8: Location quotients by industry for the five most innovative municipalities.

Figure 4.8 shows that the five municipalities to some extent have specialized within different industries. Especially Stockholm, but also Lund are specialized in SNI 32. Taking a look at figure 4.7 it can be seen that this has been the case for Stockholm ever since the 1970s, whereas it is a quite new specialization for Lund. Linköping has a clear specialization in SNI 30, which has been the case since the 1980s. Noteworthy is that SNI 72 has the highest average value (1.18), indicating that it is more concentrated to the bigger cities than the rest of the industries.

4.3 The spatial distribution of Swedish ICT innovations

To answer the question whether Swedish ICT innovations have become more or less evenly distributed during the observed time period statistical methods have been used. Chapman McGrew Jr. and Monroe (2000) recommends the coefficient of variation (CV) for observing trends towards clustering or dispersal and changes in areal patterns over time. By observing how many ICT innovations that have originated from each Swedish municipality in a year, an average number of innovations and a standard deviation can be obtained. The CV is calculated by normalizing the standard deviation of the number of innovations from each municipality with the mean number of innovations from each municipality. This gives us a picture of how the spatial concentration of innovation output has changed on a year to year basis. A higher CV can be interpreted as a more uneven distribution across municipalities whereas a lower CV corresponds to a more even distribution. As can be seen from the linear trend line in figure 4.9, which includes all ICT innovations, the trend since 1970 has been one of declining CV.

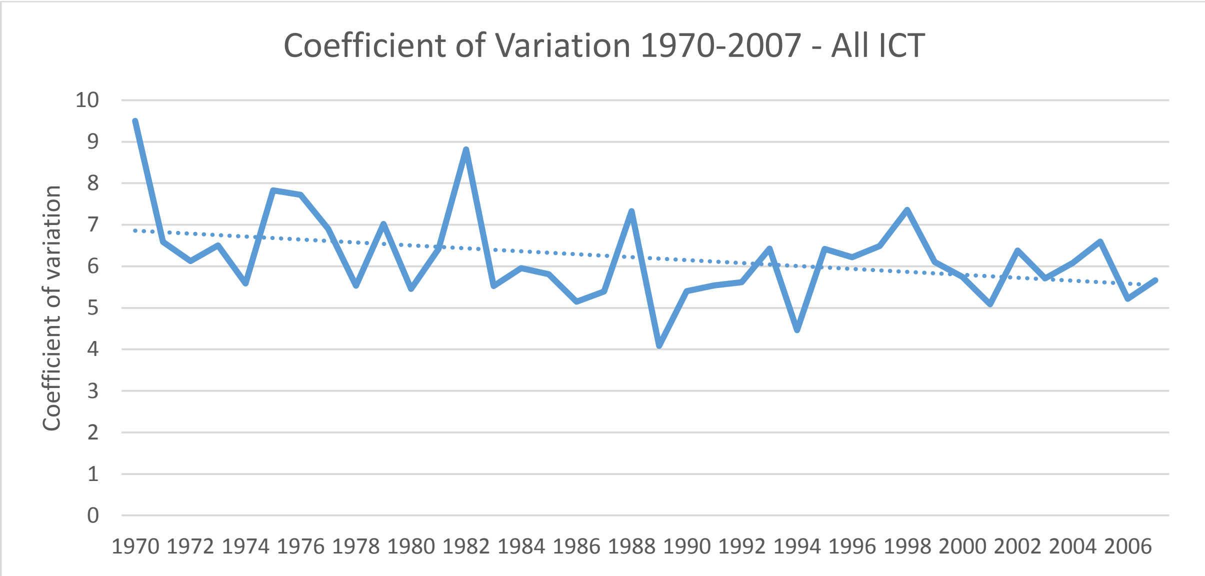

Figure 4.9: Coefficient of variation 1970-2007 for all ICT innovations.

At first sight it is not entirely inconceivable that the downward trend in CV since 1970 can, at least in parts, be explained by the increase in total output of innovations. A closer look at the graph, however, reveals an interesting break in the trend around 1990. Figure 4.10 shows that the whole decline had occurred already before the 1990s and that the trend since then has been quite flat or even slightly increasing. This contradicts that the increasing overall output of ICT innovations is a main explanation to the decrease of CV, since the increase in output of innovations has been comparably marked in both periods (see section 4.2).

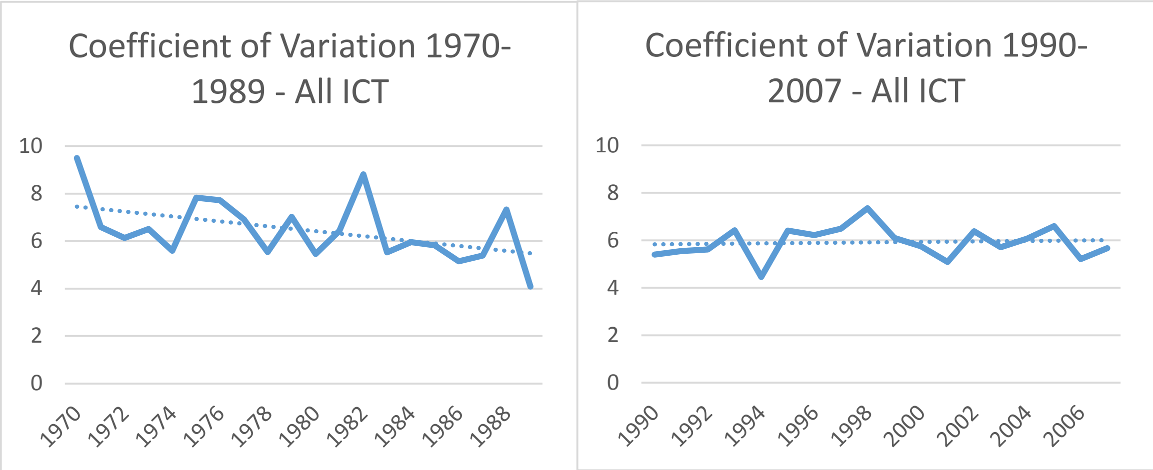

Figure 4.10: Coefficient of variation 1970-1989 and 1990-2007.

Figure 4.11 shows the development of the CV in the individual industries, with the purpose of revealing differences and similarities between them. Gaps in the graphs means that there were no innovations in that industry in that specific year.

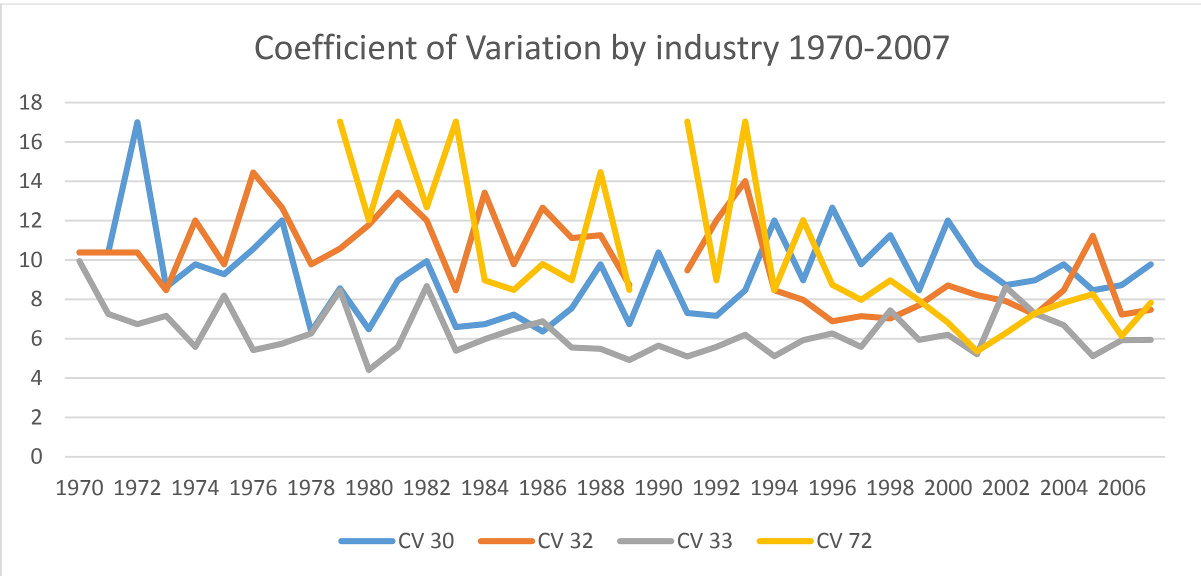

Figure 4.11: Coefficient of Variation by industry 1970-2007.

The declining trend in SNI 30 and 33, that were dominant during this period (see section 4.2), during the first two decades seem to be the cause of the downward trend in the overall ICT sector. The decreasing CV in SNI 32 indicates that the increase in innovations within this industry has not been exclusively concentrated to the bigger municipalities. Due to the low amounts of innovations in SNI 72 until the 1990s its graph has gaps and jumps up and down a lot in the earlier years. The high values in these years indicate that the few innovations that did occur were concentrated to a few municipalities. The subsequent increase in SNI 72 innovations pushed the CV values down which indicates that the increase didn't only occur in the same municipalities. Comparing the values of the different industries none of them seem to stand out from the rest to any significant amount.

5. Analysis and discussion

In chapter 2 three hypotheses regarding the research questions were presented based on general theories and empirical findings in previous research. Based on the empirical results presented in chapter 4, these hypotheses will now be analyzed and discussed.

Hypothesis 1: ***The geographical patterns of ICT innovation output have changed from an initial dominance of the largest regions toward increasing importance of smaller regions as the technologies mature.***

Hypothesis 1 is based on Lundquist's and Olander's theory of the impact on regional industrial patterns of large structural cycles led by the introduction of new general purpose technologies, and the assumption that a new such cycle was started in the late 1970s with the diffusion of new ICT technologies. Looking at the maps and their corresponding graphs in section 4.1, the first striking feature is the obvious initial dominance of Stockholm. This dominance was strongest in the 1980s, which is also the decade when innovation output in Stockholm was the highest. The second striking feature is the strong subsequent rise of Göteborg. After not even making it to the top five municipalities in the 1970s, Göteborg establishes itself as the clear number two after the 1980s. The third striking feature is the rise of the Malmö region, represented by the municipality of Lund. Lund's rise came later than Göteborg's and it wasn't until the 2000s that the former established itself as the clear number three. Västerås and Linköping, that initially held strong positions, have not at all seen the same positive development that Göteborg and Lund have enjoyed.

All in all, these findings fit well into Lundquist's and Olander's theory of how the new industries start out in the largest region and eventually diffuse downward in the regional hierarchy. The first big surge in innovation output happened in the largest region, Stockholm, in the 1980s. The second largest region, Göteborg, followed and later came the third largest region, Malmö-Lund. At that point, the time series however ends and whether the diffusion downward continues remains to be seen. Hypothesis 1 can therefore be deemed plausibly true.

Hypothesis 2: ***The most innovative Swedish municipalities show a high degree of specialization in certain industries within the ICT sector.***

While Sjöö (2014) investigated the changing structural composition of the ICT sector innovations on the national level, section 4.2 digs deeper and investigates the same thing on a municipal level for the five largest municipalities by ICT innovation output. Together with the location quotients presented in figure 4.8 this shows that the municipalities to some extent have specialized in different parts of the ICT sector. No municipality however seems to be single-handedly dominated by any of the ICT sector industries. Compared to the LQ values presented by Feldman (1994) in her study of specialization by U.S. states, the Swedish municipalities' level of specialization seems quite low. Recalling that the average LQ for the top innovation state in seven different industries was 2.18 in her study, the maximum value in this study, 1.40 for Stockholm in SNI 32, is pretty modest. Hypothesis 2 is therefore deemed partly true.

Hypothesis 3: ***Output of Swedish ICT innovations has become less evenly distributed across municipalities.***

Figure 4.9 shows that output of Swedish ICT innovations became less concentrated during the period 1970-2007. This stands in stark contrast to the notion that the tendency toward concentration of innovative activity has become more marked over time, which Asheim and Gertler (2005) claims to be a characteristic of the contemporary global economy. The results presented in section 4.3 however aren't entirely unambiguous. Figure 4.10 shows that the development toward lower spatial concentration was broken in the 1990s and that the development since then rather has been the opposite. This makes the results resemble Svensson Henning's findings about the early convergence and subsequent divergence of Swedish economic activity to a great extent.

The simultaneous development of the composition of ICT innovations, shown in figure 4.6, is characterized by a strong increase in software (SNI 72) innovations. The relative growth of software innovations and the relative decline of innovations within the manufacturing industries (SNI 30, 32 and 33) points in the direction of an increasingly knowledge-intensive and decreasingly capital-intensive Swedish ICT sector. Intuition, and neoclassical economic theory, say that a less capital-intensive industry should induce a more even distribution of output of innovations across municipalities, since highly capital-intensive production facilities tend to stay where they are. Less capital-intensive production, such as software production, can take place anywhere and thus should occur where factor costs are the lowest and thereby become less concentrated over time. This intuitive idea would entail that a sector evolving toward less capital-intensive production should see a simultaneous development toward lower spatial concentration of innovations. The fact that the spatial concentration of Swedish ICT innovation output stopped decreasing as software production took a bigger role contradicts this intuitive idea and brings support to Asheim's and Gertler's claims.

Another result that brings support to Asheim and Gertler and their claim that the most knowledge-intensive industries are the ones that cluster in the bigger cities the most is that SNI 72 has the highest average location quotient in the five most innovative cities. This is also in line with Olsson-Ruppel's finding that the software industry is the one with the highest degree of concentration in the biggest cities. Whether this is a result of the sharing of tacit knowledge in cities à la Asheim and Gertler or if it's merely a result of the software industry being the youngest in the ICT sector (which by Lundquist's and Olander's theory discussed above would mean that it hasn't yet diffused to smaller regions to the same extent as the more mature industries) might deserve a thesis of its own. Adding to the ambiguity of the results, figure 4.11 though shows that SNI 72 isn't the most concentrated of the industries in terms of coefficient of variation calculated on all Swedish municipalities.

The simple answer to the question whether hypothesis 3 holds true or not would be that it does not, judging by the development of the coefficient of variation illustrated in figure 4.9. That answer however might be too simple, since it leaves out important facts of what has happened with both the trend and the relative strength of the industries constituting the ICT sector. The fact that CV hasn't been decreasing at all since the early 1990s while the sector probably has become more knowledge-intensive brings support to Asheim's and Gertler's claims about increasing concentration of innovative activity as knowledge an innovation becomes more complex.

6. Summary and conclusions

In this final chapter the findings presented throughout the thesis are summarized and conclusions relating to the research questions are made.

Research question 1: ***Where have Swedish ICT innovations originated in different time periods? Have the patterns changed?***

The first research question is answered through a series of maps, presented in section 4.1, showing where Swedish ICT innovations have originated during the last four decades. It is the first such mapping where real product innovation output has been used as the indicator. Previous mappings, like the ones performed by Svensson Henning and Lindqvist et al. have had other aims and used input indicators such as sectoral employment levels in municipalities. The Regional Innovation Scoreboard partly uses some proxy output variables but doesn't provide information at a municipal level. What the mapping presented in this thesis also provides is a four-decade time perspective which makes it possible to spot changes in the innovation output pattern, which wasn't possible in previous mappings.

The maps reveal interesting patterns of clear Stockholm dominance throughout the studied period and strong development of Göteborg and Lund. In the last decade, the three largest regions therefore stand out in terms of absolute output of ICT innovations.

Research question 2: ***How has the structural composition of ICT innovations changed in different municipalities and to what extent have municipalities specialized in certain types of ICT innovations?***

Section 4.2 presents an investigation of how the structural composition of ICT innovations have changed over time on both a national level and on a municipal level for the five most innovative municipalities in terms of output of innovations. Important changes on the national level has been the successive rise in the relative importance of software innovations. On the municipal level the investigation reveals that no single municipality has gained total dominance of any of the industries constituting the ICT sector. The section also presents an investigation of how specialized the municipalities are in different industries based on location quotients. The location quotients reveal that all of the top five municipalities to some extent have specialized in at least one industry, but that the degree to which they are specialized is quite low.

Research question 3: ***Has output of Swedish ICT innovations become more or less evenly distributed between municipalities?***

The results in the form of declining coefficients of variation presented in section 4.3 shows that output of Swedish ICT innovations did become more evenly distributed across municipalities between 1970 and 2007. However, a more intricate development than a simple linear decline during the whole period is revealed. The whole decline happened during the 1970s and 1980s, while the trend from the early 1990s until 2007 rather was slightly increasing. The discussion in section 4.3 unveiled that there is a whole lot of ambiguity in the results and previous findings, wherefore it is hard to draw any conclusions on why the development has looked the way it does.

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