LUND UNIVERSITY
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Eco-innovations in the Swedish Context

A study of long-run national and regional patterns

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The topic of eco-innovation has gained much traction over the last decade due to its potential to improve environmental sustainability without compromising socio-economic goals. This thesis presents a descriptive analysis of the national and regional patterns of eco-innovation in Sweden using new long-run data over the period of 1970-2013 from the SWINNO database. Results show that the long-run aggregate patterns display similarities with general innovation theory, whilst regional patterns point more towards differences. The main differences include the weak effects of clustering and regional size. These findings suggest that there is potential for eco-innovation development in regions of varying sizes through regional cluster policy. Furthermore, regional performance is found to evolve substantially over time, highlighting this potential for eco-innovation development. Sweden has displayed a commitment towards sustainable growth for decades – these new findings could be of use in policy discussions regarding how to support eco-innovations and potentially, a grander sustainability transition.

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1 Introduction

The topic of eco-innovations has gained much traction over the last decade – both in the political and academic sphere. Eco-innovations are defined as innovations that "reduce the use of natural resources and decrease the release of harmful substances throughout the entire life cycle" (EUROSTAT, 2015: 57). These apply to the Schumpeterian classifications of innovation as goods, services or organizational practices. Eco-innovations provide the possibility of improving sustainability without compromising socio-economic goals. This perspective is highly attractive to governments, specifically in Europe, who have established eco-innovation as a formal strategy towards sustainable economic growth. The European Union has given environmental sustainability a large focus since the 1970's with the implementation of the first Europe-wide environmental policy strategy. Already with this first policy implementation, it was established that economic development, prosperity and environmental protection were to be mutually independent (Hey, 2001). Environmental measures have since been developed into stricter and far-reaching regulations. In 2008, the EU established the "Eco-Innovation Programme" (European Commission, 2016) – solidifying the intent to use eco-innovation as a mainstream strategy. The commitment to eco-innovations is a promising sign for bridging the gap between markets and environmental sustainability (European Commission, 2016). With increasing concern regarding environmental sustainability and climate change, eco-innovations provide a promising solution.

It is due to this increasing attention, that the academic world has shifted gears towards further understanding eco-innovation drivers and diffusion The emerging literature on the topic is still currently at a fragmented stage and includes a multitude of different perspectives. Numerous academic fields have applied their specific frameworks on the topic – from economic geography and neoclassical economics, to marketing and management theory. There is still no universal consensus of precisely what the drivers of eco-innovation are, due to the intricate combination of politics, economics and social issues that come into play when it comes to the matter of environmental sustainability. The difficulty with determining these drivers also stems from the numerous feedbacks from different actors that are complicated to map out (Bergek and Jacobsson, 2004). One suggestion that has stood out in literature thus far, has been the notion that eco-innovations are affected by the same drivers as stated in broader innovation theory to varying extents depending on other factors – however this is far from the complete picture. Regulation and policy have also been indicated as important factors, however the effectiveness of these are further dependent on societal and economic context. These relative successes at indicating the important factors in eco-innovation, has led to the understanding that painting a clear picture of eco-innovation phenomena requires the combination of different schools of thought. This was officially called for in a 2012 paper by Truffer and Coenen, who concluded that salience between various theoretical frameworks is vital for regional innovation studies, especially in regards to eco-innovations which are tied to societal matters. One perspective that is widely lacking in eco-innovation studies has been the appreciation for spatial dynamics (Karakaya et al., 2014). The inclusion of more geographical analyses has the potential to shed new light on eco-innovation, and although the tide is turning towards that direction, empirical analysis is at a largely early stage. In this regard, the use of regional eco-innovation data from SWINNO and applying this to an analysis of regional differences, makes this study a novel approach in this subject of academia.

With the increasing attention put on eco-innovations as a strategy towards sustainable economic growth, along with its relative novelty in academia, this thesis will provide empirical analysis on new long-run data of eco-innovation in Sweden that has not been applied to academic research thus far. This data has been collected for the SWINNO database – a recently developed database pertaining to innovation in Sweden spanning the period of 1970 to 2013 Sjöö et al., 2014). Specific eco-innovation data over a long period of time with regional descriptions is rare and highly valuable in potentially filing the gap of a lacking geographical perspective in eco-innovation research that was discussed earlier (Karakaya et al., 2014). Furthermore, the fact that this data is in the context of Sweden, provides further advantages since Sweden has been a leader in innovation and environmental sustainability over the last two decades especially (Eurostat, 2015). Sweden ranked second in the Global Innovation Index of 2016 due to its impressive performance in efficiency and innovation inputs and outputs. The Swedish government has also been strong in implementing environmental policy and regulation. In a global context, Sweden thus seems to be an ideal testing ground for eco-innovation as a legitimate strategy. Thus, the success of Sweden in economic growth, innovation and environmental sustainability arguably makes it an excellent context to study eco-innovations.

1.1 Aim and Scope

The aim of this thesis is to present a descriptive analysis of the long term aggregate and regional patterns of eco-innovation in Sweden. The data used in this thesis has not been applied in this manner before, thus providing new and potentially valuable insight on eco-innovation phenomena. The empirical data will be used in various methods and analysed against pre-established innovation theories and previous research. The aggregate long run patterns will be analysed against an evolutionary framework – which draws upon pre-established theories developed based on the ICT technological shift in Sweden. The ICT shift is chosen since it occurred during the same micro-electronic development block and has been well studied in the Swedish context. The regional analysis will apply a framework developed by Martin (2012), which categorizes regions by type of knowledge base. This thesis will use this framework to compare eco-innovation performance across regions by their type of regional innovation system (RIS). Due to foreseen limitations of the study, the main contribution will thus be the patterns of eco-innovation on a national and regional scale - potential driving forces are implied but should be interpreted with caution until further research can validate these findings.

The scope of this thesis will include eco-innovations with time specific and county specific locations. Variations within economic history and economic geography will be used as perspectives in analysing its behaviour, however industry and firm-level considerations will largely be omitted. The impact of eco-innovations will also be beyond the scope of this thesis since the focus will be on innovation output.

1.2 Research Questions

Although eco-innovation is a novel topic of study in academia, innovation itself has been a significant research subject since the beginning of the 20th century. It is thus appropriate to use pre-established innovation theories as a starting point when analysing eco-innovations. With this in mind, the following research questions are presented:

1) How do patterns of eco-innovation evolve over the period of 1970-2013 in Sweden?
    a. Do these patterns follow the ICT technological shift?
    b. Are clustering and regional size indicators of high eco-innovation performance?
2) Which Swedish regions are leaders in eco-innovations?
    a. Did regional eco-innovation performance differ across time?
    b. Did regional eco-innovation performance differ across different types of knowledge bases?

1.3 Outline of the Thesis

The thesis will firstly present a literature review based on the relevant theoretical perspectives pertaining to the research questions. In analysing the national patterns of eco-innovation, the evolutionary approach will be discussed. The evolutionary approach presents a paramount aspect of eco-innovation behaviour: the importance of policy and regulation in a given eco-innovation system. Although the empirical analysis does not directly involve policy or regulations, the findings of this study are potentially valuable for discussing how policy and regulation can better support eco-innovation activity. The ICT technological shift will also be discussed for the aggregate analysis, since the benefits of clustering and regional size have been well established for this topic in the context of Sweden. The comparison of eco-innovations and ICT is thus a point of comparison that will allow for a discussion regarding the importance of clustering and regional size. In terms of analysing regional patterns of eco-innovation, two alternative views within economic geography will be used: the first is concerned with the interplay of economic growth, technology and innovation, whilst the second is focused on the importance of knowledge flows as categorized by Martin (2012). The literature review is quite extensive due to the close similarities between innovation – which has been heavily researched – and eco-innovations. Thus, previous research on general innovation studies is still important to consider when discussing the empirical results of this study.

Following the literature review is the data and methods section, which is rounded off by the limitations section. The results are then presented and described in the order of the research questions previously presented. Following this, will be a discussion of the quantitative results, which will be compounded on by a qualitative case study to form a sequential explanatory research design[1]. The paper is concluded with a section summarizing the findings in respect to their given research questions and aims, along with the practical implications for future research.

[1] Sequential Explanatory Design is characterized by the collection and analysis of quantitative data followed by a collection and analysis of qualitative data. In this design, qualitative results assist in explaining and interpreting quantitative findings. (Creswell, 2013)

2 Literature Review

2.1 An Evolutionary Approach

The starting point of this study is an analysis of how the patterns of eco-innovations evolve over time in Sweden[2]. When analysing the long-run patterns of eco-innovations on a national level, it is advantageous to have a solid understanding of broader innovation systems theories. Essentially, eco-innovations share similarities with other types of innovations, rendering these pre-established theories important to acknowledge in this study. An approach to national innovation systems that stands out in the Swedish context is the evolutionary economics approach, which focuses on economic growth and technological shifts as vital in innovation processes. The interplay between economic growth and technology in innovation has been considered since roughly the mid 20th century (Verspagen, 2005). The evolutionary perspective is an inclusive approach that appreciates historical trends and allows the possibility to account for random events that do not seem to fit a given pattern or trend. This flexibility and leniency to unpredictability makes it a more appropriate approach in regards to environmental issues, than the traditional neo-classical perspective. The evolutionary approach also contributes valuably to eco-innovation analysis in other aspects – namely the emphasis on policy and regulation – which will be detailed further in this section.

Applying evolutionary theory to eco-innovations introduces different dynamics than are established in regards to broader innovations. Firstly, the assumptions made regarding the drivers of innovation in broad evolutionary theory do not perfectly fit the study of eco-

[2] Research question 1: How do patterns of eco-innovation evolve over the period of 1970-2013 in Sweden?

innovations. This brings to light the important discussion of government policy and regulation. Eco-innovation suffers from what is called the double externality problem. General theory suggests that R&D investments is restricted because of knowledge spill-overs, however this is worsened in the case of eco-innovations since the private return on investments is less than the social return if prices are not modified to reflect environmental impact (Faber and Frenken, 2009: 49). The double externality problem calls for the need to implement government policy to induce eco-innovation activities. This is more complex than it seems however, since different policies will render themselves successful in different economic climates. In a market with good opportunities and conditions to adapt to new innovations - as is the case in Sweden - firms will have stronger incentives to funnel R&D towards eco-innovations. If on the other hand, the market lacks opportunities, the incentives will also be lacking. Understanding the type of market and the opportunities available is thus important in determining what types of environmental policies to implement. For the first scenario, wherein there is an opportunity abundant landscape, price measures may work in creating more incentives to innovate. In the second scenario of less opportunity however, price measures will be less effective and need to be combined with public R&D investment that transfer public funds to research and industry (Feber and Frenken, 2009). All these factors are important when considering the types of policies and incentives to implement in encouraging eco-innovations.

The second way in which the evolutionary theory is valuable for the study of eco-innovations is in terms of the technological focus. In terms of the large role of technology in this perspective, the concept of technological paradigms is used to define different periods of economic development (Verspagen, 2005). A technological paradigm, in basic terms, is a small number of basic (radical) innovations that may dominate techno-economic developments for a long time (Freeman and Louça, 2001). The technological development of that period is thus limited by the paradigm. The technological paradigms give light to an aspect that concerns evolutionary economics significantly – that being the temporal clustering of innovations (Verspagen, 2005). This thinking stems from Schumpeter's understanding of incremental innovations following radical innovations. To this effect, certain periods in history see higher rates of innovation than others. The culmination of such conceptualizations have resulted in the idea of "long wave" economic growth and the emergence of long term patterns between economic growth, technological shifts and innovation. Eco-innovations are subject to these technological paradigms as well – take for example the electric car, which has only become a possibility due to the electricity development block.

The technological paradigms have been more closely studied and applied to concepts such as the 'technological shift' cycles by Schön (2012a) and development blocks by Dahmén (1988). These forms of technological transitions have been of interest to environmental policy makers who aim towards a grander sustainability shift (Feber and Frenken, 2009). Development blocks are similar to the idea of technological paradigms as they are "formed by complementary activities around innovations" (Schön 2009: 3) as established by Dahmén (1988). Studies have found different stages in these blocks – Schön (2009) differentiates between transformation and rationalization phases whilst others refer to them in different terms such as formative periods followed by market expansion (Bergek and Jacobsson, 2004). The consensus is that there is a more difficult period in the beginning when new technology is introduced, followed by a wide diffusion of its use in the market. This perspective has been applied to general innovation theory as well as eco-innovations. When specifically discussing renewable energy technology, this perspective can be of particular insight. Renewable energy technology in the wider context of a sustainability transition can be considered one of these technological shifts or development blocks. Firstly, the energy sector is extremely large, meaning that any transition into a massive use of different technologies will take a significant amount of time (Bergek and Jacobsson, 2004; Bruckner et al., 1996). Secondly, new markets for energy technology are difficult to develop due to the double externality previously mentioned (direct benefits are larger for society than an investor) (Bergek and Jacobsson, 2004). Linked to this is the fact that established technologies are usually subsidised and benefit from low prices. Lastly, there are powerful supporters of keeping established energy systems who block the attempts at an energy transition (Bergek and Jacobsson, 2004). The two phases as suggested by Bergek and Jacobsson (2004) are the formative period and expansion period. In the formative period, the market for new technology is rather small and the uncertainty is very high. During the market formation stage, niche markets are explored and support is built up. The key determinant in all this goes back to government policy and regulations that protect the development of new sustainable technologies (Bergek and Jacobsson, 2004). It has been pointed out that knowledge creation, protection of early markets and cumulative causation are important to the diffusion of environmental technology (Bergek and Jacobsson, 2004). It is thus paramount to create conditions that allow for cumulative causation to occur for new energy technologies.

Swedish Context

The EU and its preceding form – the European Commission – started its environmental policy implementation with an ambitious programme in 1972. Even then, Sweden was already a significant advocator of sustainable development in Europe (Hey, 2001). Into the 1990s, there was a wave of increased environmentalism – although met with certain resistance from member states, the increasing concern for climate change and sustainable development has allowed for environmental concerns to be incorporated into other policy areas (including transport, energy and agriculture) (Hey, 2001).

Sweden's relative success at eco-innovations has been aided by various factors. Firstly, is the avid commitment to policy and regulation in the matter. The oil crisis of the 1970's has been referred to having been a catalyst for innovation during this time. In regards to eco-innovations, this is of special importance since the crisis lead to an economically viable focus on alternative sources of fuel and energy. This sustainability push coincided with the beginning of the micro-electronic development block in the 1970's. This lead to the diffusion of micro-electronic technology and biotechnology during that decade and into the 1980's (Taalbi, 2014). This was followed by the large-scale diffusion of electronics and greater opportunities due to ICT and the internet. The introduction of these new technologies changed production processes in Sweden drastically, and furthermore, with the coinciding of the oil crisis, these changes included alternative fuels and reducing dependency to oil (Lundquist and Olander, 2010; Taalbi, 2014). Apart from technological and economic pressures, a general shift towards environmentally conscientious action occurred. Between 1960 and 1970, the foundation of Sweden's environmental strategy was laid out in the form of three laws: the Nature Conservation Act (1964), the Environment Protection Act (1969) and the Hazardous Products Act (1973) (Sweden's Environmental Problems, 2011). These were three very important pillars in establishing Sweden's sudden shift towards sustainable growth. Into the 1990's, the Swedish strategy has been to 'green' every aspect of society – the ultimate mainstreaming of environmental sustainability (Sweden's Environmental Problems, 2011). Investments in environmental R&D also had a large role during these times. During the 1970's the government spent heavily on investments in direct environmental measures. In the 1990's investments increased once again with a focus on cleaner energy to help reduce climate change.

These efforts toward sustainability have reaped benefits in Sweden's environmental markers. The SWINNO database portrays an increased activity in targeting environmental issues since the 1970's. Empirical data also shows that energy consumption and emissions in Sweden increased in absolute terms until 1970, at which point consumption emissions actually declined whilst energy consumption became relatively stable (Kander, 2002; Taalbi, 2014). Previous research has also established the understanding that political and institutional changes were also paramount in spurring eco-innovations – evident by the large number of innovations developed even prior to the oil crisis (Taalbi, 2014). Examples of these innovations include process innovations targeted at the pulp and paper industry to solve water and air pollution problems (Taalbi, 2014). The pulp and paper industry was heavily involved in innovating towards solving environmental problems. New paper and pulp machinery, apparatus and chemicals were utilized along with new production processes (Taalbi, 2014). Turning residue from pulp and paper industries into biofuel was another of these environmentally friendly innovations. Post-oil crisis focus was largely on alternative energy sources such as "electricity, district heating and biofuels" (Taalbi, 2014: 108). Bioenergy has been a particular focus, making it one of the biggest sources of renewable energy in Sweden. Between 1978 and 2000, the annual growth rate of biomass as a supply of energy was 3.6% (Jacobsson and Johnson, 2000; 626). Ultimately, the oil crisis of 1978, EU environmental concern in the 1970's, policy implementation by Sweden, and new technological development block were all important factors that affected the future of eco-innovations.

To summarize this section, the important concepts to consider are the evolutionary approach and the different events that have been previously suggested to have impacted innovation and eco-innovation. The evolutionary approach presents the importance of policy and regulation in any discussion of eco-innovation, as well as the potential to see eco-innovations as part of a grander sustainability shift. The different events over the past four decades, should be considered as potential forces that encouraged eco-innovation. These are important concepts to understand when discussing the first research question and analysing the empirical results of national patterns.

2.2 Regional Innovation Systems

2.2.1 Technology & Economic Growth

When analysing regional innovation systems, the type of region considered must be defined. The traditional positivist view in economic geography considers space as a bounded area filled with economic activity, one that is dependent on the industrial and technological characteristics of that area (Hansen and Coenen, 2015). It also considers historical path dependency as an important part of geographical dependency (Neffke et al, 2011). This typology of a region can be defined on different levels, however this study chooses to define its regions to counties (see methods). The study will compare the experience of eco-innovations with the pre-established ICT technological shift[3]. The importance of regional size and clustering in determining eco-innovation performance will also be analysed since these are concepts that have pervaded innovation systems studies in Sweden[4]. An example of the characteristics that contribute to better technological adaptation are illustrated in figure 1. Other frameworks consider different areas such as industry relatedness or skill relatedness (Boschma and Martin, 2010), however figure 1 is a prime example of such a framework that considers agglomeration and clustering.

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[3] Sub-research question 1A: Do these patterns follow the ICT technological shift?

[4] Sub-research question 1B: Are clustering and regional size indicators of high eco-innovation performance?

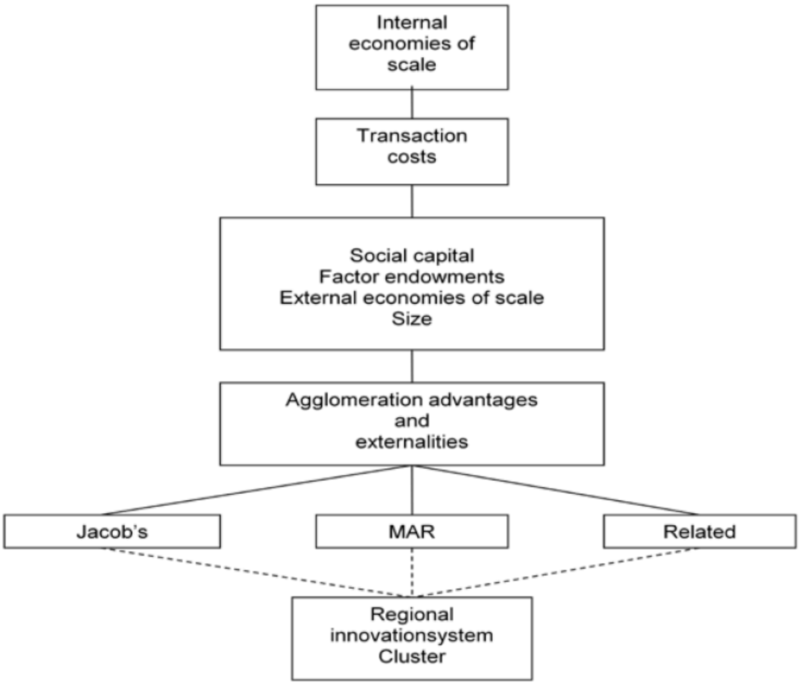

Figure 1. Characteristics that make up location advantages for different industries (Lundquist & Olander 2009: 71-78)

In Sweden, there has been significant emphasis on the interplay between regional size, agglomeration and transaction costs resulting in the clustering of innovations in predominant regions. The general pattern is described as starting with a transformation phase, wherein new industries and ones that are adapted to the new innovation, are located in the large regions, reaping the benefits of economies of scale needed when the primary cost of production is high (Lundquist and Olander, 2010). Transformation is the first phase wherein industrial structures change and resources are reallocated due to the emergence and diffusion of new basic (radical) innovations. Mature businesses and those unable to adapt to the new innovations slowly shrink, exit, or relocate to smaller peripheral regions. As the new production stabilizes in the large regions, the transactions costs decrease, followed by a strain on regional resources. This combination results in a sharp cost increase and the relocation of production processes to the smaller peripheral regions once again (Lundquist and Olander, 2010). This outsourcing is followed by the rationalization phase by which the large regions begins to lose their dominance whilst smaller regions are able to thrive due to demand-driven activities. Rationalisation is defined as the phase wherein resources are concentrated to the most productive firms whose aim is to increase efficiency (Schön, 2009). To meet future needs, these producer services follow the pattern of production into the smaller regions (Lundquist and Olander, 2010). The result of these dynamics is a high level of clustering in large regions due to economies of scale, followed by a general dispersion into smaller regions. It must be understood that these phases of transformation and rationalisation are very complex and difficult phases for an economy. On a macro level, massive restructuring is needed in the economy, whilst on a micro level, firms need to ensure their adaptability and adoptability of new technology. As a result, transformation and rationalisation are also manifested in the economy as crises. The following section will further discuss the experience of ICT technology in Sweden due to its strong characteristics and patterns – this will render itself useful for later comparison to eco-innovations.

The Swedish Experience

As previously mentioned, the concepts of regional size and clustering have been studied thoroughly in the context of the previous technological shift of microelectronics in the 1970's and how this changed manufacturing and services in Sweden. When divided into regions, it is evident that 1st tier regions (largest regions in Sweden) grew much faster and earlier than smaller regions – particularly lead by Stockholm (Lundquist and Olander, 2010), as show in figure 2. The graph illustrates the idea that older production technology moved away from 1st tier areas to peripheries, seen by the decline in 1st tier value added and increase in 2nd and 3rd tier value added between 1974 and the late 1980's. 1st tier regions experienced growth by renewed industries in the late 1980's. This is followed by immense growth in the 1990's by 1st tier regions due to a well-diffused and matured adoption of the technology. Once stabilized at a high level, growth was experienced by tier 2 regions in the late 1990's.

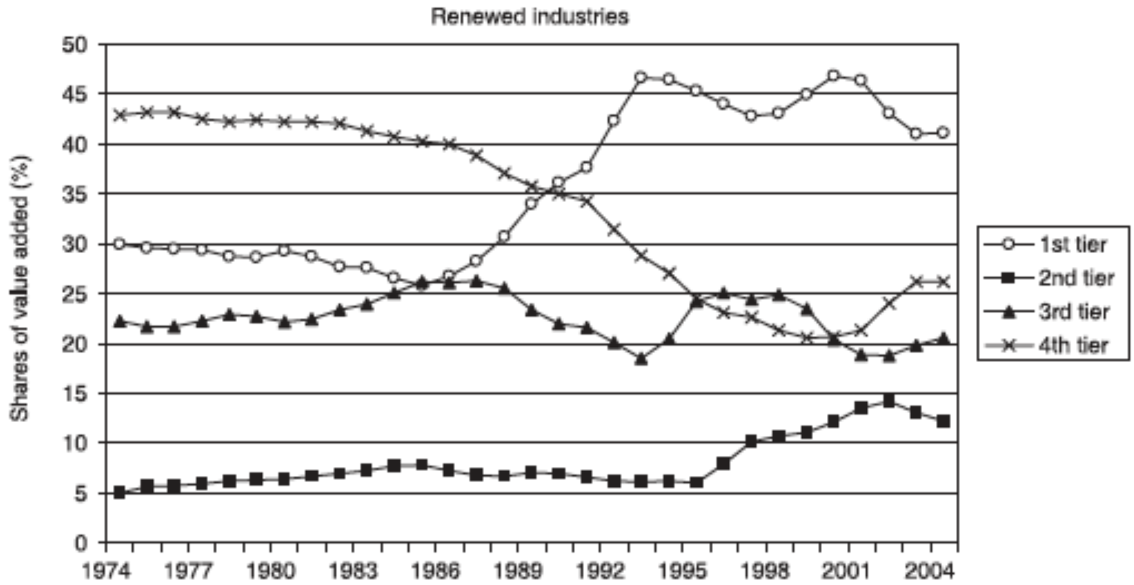

Figure 2. The development of renewed industries in regions of various sizes (Lundquist, Olander & Henning: 2008 p. 155)

Labour restructuring also supports this trend. Employment increases in renewed industries have been dominated by 1st and 2nd tier regions (Lundquist, Olander & Henning: 2008). In conclusion, it is evident that economic growth has been dominated by renewed industries in 1st and 2nd tier of a supply-driven nature. Industries that have not been able to transform have rendered themselves obsolete.

Going into the regional specifics, the first wave of technological adoption and growth occurred in the Stockholm region roughly 10 years before other regions, due to growing external economies of scale – many firms with economies of scale and high transaction costs began to accumulate in Stockholm, producing goods in the beginning of their life cycles (Lundquist and Olander, 2010: 19). The clustering of firms spread to regions close in distance to Stockholm, in an effort to benefit from the resources established there. Outsourcing from Stockholm-based firms also occurred and moved to geographical proximate regions as well. The second wave of growth occurred when the new technologies became mature and stable, allowing for independent growth in regions such as Malmö and Gothenburg (Lundquist and Olander, 2010). The mechanism of this spread can also be explained through the relationship of regional dependency and a product's life cycle. Firms that deal with products in the beginning of the life cycle were relatively more regionally dependent, however as the product matures, the firm become more regionally independent, allowing for activities to move to other regions (Lundquist and Olander, 1999). During this technological shift, Stockholm, Gothenburg and Malmö were undoubtedly the front runners of new innovation and growth – resulting in a restructuring of the Swedish economy and transformation of manufacturing and producer services. Unfortunately, this re-industrialization was not very evident in smaller regions. In regards to regional inequality, the gap between regions varied in different periods of the growth cycle. There are instances of convergence between the large and medium regions for example, which can be seen in terms of the shares of manufacturing-related industries. Large regions held 19,2% of manufacturing share in 2006 whilst medium regions had 23,8%, illustrating the lead of medium-sized regions at this point in time (Lundquist and Olander, 2010). Convergence can be seen between large and medium regions in other ways, such as value added by new and renewed industry. Unfortunately, this convergence does not include the smallest region at any point in the growth cycle. Contrastingly, this lag between regions cause a divergence between the medium to large regions and small regions. Convergence and divergence is regionally complex and dependent on what types of industry or variable is being examined, as well as which regions are being compared.

The extensive research on the diffusion of technologies in Sweden has been dominated by a focus on manufacturing and ICT. Lundquist and Olander (2010: 14) support however, that "clusters and regional innovation systems are also based on economies of scale, transaction costs and co-location advantages". It is with this understanding that the concepts of clustering and regional size be tested in the context of eco-innovations in Sweden. Other scholars have also argued for the notion that clustering promotes innovation for transitions in an environmental sustainability perspective (Bridge et al. 2013; McCauley and Stephens 2012). The development and implementation of environmental innovations is enhanced by agglomeration and economies of scale of a different kind, such as highly-educated and skilled labour, supporting organisations, universities and other forms of research institutes (Hansen and Coen, 2015; McCauley and Stephens, 2012). Universities have been suggested to have an especially important role in supporting eco-innovations depending on regional conditions – in for example, taking a lead role in addressing regional sustainability issues (Stephens et al. 2008).

2.2.2 Knowledge Flows

The advantage of size can also be interpreted in different ways, such as in terms of knowledge flows and strong networks. In this section, focus is placed on these knowledge, flows, moving away from industrial and technological characteristics of regions. Knowledge flows within regional innovation systems is grounded in the idea that innovation activity is based on knowledge. Tacit knowledge specifically, is argued to be the key determinant of innovation activity in this perspective. Tacit knowledge is information that is uncodified – meaning that it is not in a form that is easy to relay to people outside your social context or over long distances (Asheim and Gertler, 2005). The reason that this type of information is not easily codified is due to the fact that its meaning is heavily embedded in the societal and institutional context it is produced in. This concept of knowledge being tacit and understandable in a certain space is referred to as "spatially sticky" (Asheim and Gertler, 2005: 293). This understanding of regional innovation systems thus puts a heavy focus on the interactions in a region between different economic and institutional actors and the knowledge flows between them. Formal flows can occur between firms, universities, research institutions and public agencies for example. There are however, more informal flows that can also be of importance. This perspective also reinforces the importance of innovation clusters, however due to different reasoning. It is the sticky tacit knowledge, combined with localized capabilities and intangible assets that strengthen this pull towards knowledge clusters (Dosi, 1988).

This perspective puts much more emphasis on the activities and relations in a given space. After all, the transmission of knowledge fundamentally require social interaction between 2 or more actors (Bjerke, 2012). Three types of learning that can be done in a formal setting between firms and institutions include innovation, research and development and competence building (Edquist, 2005). Three different forms of interaction include competition, transaction and networking. Thus, knowledge flows in a region can be interpreted as the communication of these three types of learning by these three types of interactions. Universities have also been given special emphasis in previous literature – it is argued that they have played an increasingly important role as a fundamental source of knowledge in the last few decades (Mowery and Sampat, 2005). Since the 1970's, governments around the world have established numerous strategies to link universities to industrial activity more closely (Mower and Sampat, 2005). These strategies include facilitating the application of research done in universities into industry and firms, to bolster overall economic development. Public funded research has also been a strategy to encourage these types of flows. This gives rise to the concept of a "knowledge based economy" (Mower and Sampat, 2005). Regionally speaking, these types of policies have attempted to create regional clusters of innovative actors around universities, in the hopes of encouraging economic development in that region. Knowledge spill-overs have been found to be clustered at a regional level, which has helped certain regions create these knowledge clusters. Ultimately however, there is not much empirical evidence proving precisely that universities cause these technological clusters in a region, although there is some correlation (Mower and Sampat, 2005). Simply put, there seems to exist a relationship between knowledge clusters, universities and industry, however pinning down the precise causality is difficult due to the high complexity of variables that need to be considered. Examples of optimal knowledge clusters include Silicon Valley in California and Route 128 in (Saxenian and Hsu, 2001) – two high-tech regional clusters that have been created in a close distance to major research universities such as Stanford University and Harvard University. There is definitely reason to believe that university research plays a role in such a regional cluster, but to what extent this can be induced by policy is another question. It is thus unclear how effective government policies in encouraging these clusters through universities are.

Swedish Context

A study regarding knowledge bases in Swedish regions categorized knowledge into three different types: analytical, synthetic and symbolic (Asheim and Gertler, 2005; Martin, 2012). Martin (2012) operationalises the idea of knowledge bases quantitatively to form an analytical framework that allows for systematic analysis of different regions. This is a significant contribution since many knowledge base studies have in large part used qualitative case studies. By defining three different types of knowledge bases, it is possible to identify the types of knowledge base in a given region (Martin, 2012) and analyse if a regional economy has a specific strength in one type of knowledge more-so than another. This is done by taking the share of people with a given occupation that is linked to the three knowledge bases. When applied to the Swedish context, this framework renders fairly reliable results that can be used in different contexts (Martin, 2012).

Analytical knowledge bases are based in scientific knowledge, codified science and rational processes (Asheim and Gertler, 2005). Industries such as biotechnology and information technology dominate this type of knowledge base and are characterized by R&D

and heavy dependence on university research and other research institutions. Synthetic knowledge bases are more related to innovations through the combination of pre-existing knowledge (Asheim and Gertler, 2005). Industries usually include engineering and advanced industrial machinery, wherein R&D is less important and incremental process development more-so. Basic research in universities is less relevant, however applied R&D is still applicable (Martin, 2005). Lastly, symbolic knowledge bases include cultural production such as film and music (Asheim and Gertler, 2005). The findings from a Swedish regional analysis can be found in figure 3.

In regards to analytical knowledge bases, there is an evident relationship between regions with large universities focused on life sciences. Uppsala, Västerbotten, Stockholm and Skåne score highest in this field, in part due to their universities including Uppsala University, Umeå University, Stockholm University, Stockholm School of Economic, The Karolinska Institute and Lund university. These are combined with the large biotech industry in the Stockholm-Uppsala life science cluster, medical cluster in Umeå, and biotech and agricultural biotech in Skåne (Martin, 2012). These industrial clusters have a strong relationship to university based research. In terms of synthetic knowledge, Blekinge, Västmanland and Dalarna counties have the highest score in this category. Some of the regions that score highly also have university research activitites, however the large focus is on engineering and manufacturing – “solving concrete, technical problems” (Martin, 2012: 9). Lastly, the symbolic knowledge base is most predominant in Gotland and Stockholm – showing that symbolic knowledge does not have dominate in metropolitan regions. More generally, it is evident that there is a rather balanced specialisation of synthetic knowledge across most regions. Although it seems as though most regions specialise in one region more-so than the other, this does not necessarily mean that only one type of knowledge base exists in the region. Skåne for example, seems to have a fairly even combination of all three types.

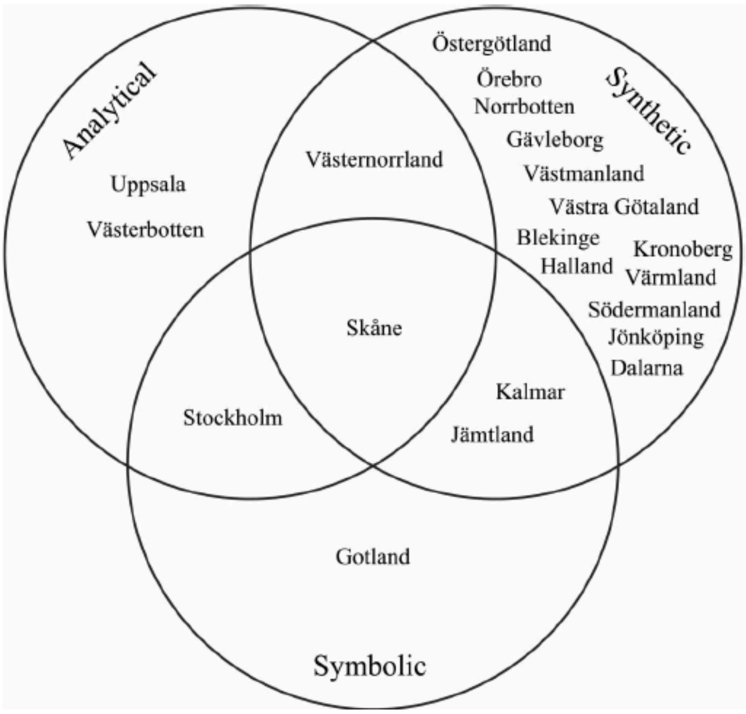

Figure 3. Knowledge specializations in Swedish regions (Martin, 2012: 73)

There is evidently some form of knowledge base clustering in certain regions. The extent to which this has been due to policy is up for debate - Sweden is at the forefront of cluster development in Europe, however has much to improve on. Cluster policies are fairly developed in Sweden, however in the case of eco-innovations, there is a lack of policy targeting their specific development. Instead, it seems as though most policy is directed to a more general umbrella of sustainable growth (Barsoumian et al., 2011). These policies do not target specific environmental industries, which results in a very fragmented cluster structure. It is also important to note that the majority of cluster policies have been set on a national level, however there has been increasing discussion regarding the importance of regional cluster policies. Although cluster formation seems to be a strategic goal for Sweden in their aim for sustainable growth, and indirectly, eco-innovations, they are not industry specific policies. It would be feasible to say that as a goal, eco-innovation is not a direct concern in policies, however that there is still evidence of the want to address eco-innovations indirectly (Barsoumian et al., 2011). Stronger and more focused policy on a regional level could improve the clustering that leads to eco-innovation. With the analytical framework presented by Martin (2012), it will be possible to identify whether there are any significant patterns between certain knowledge bases and eco-innovation activity. If so, this has the potential to guide eco-innovation cluster policy. This literature review on knowledge bases will act as the foundation for the last research question of this study which discusses the differences of regional eco-innovation performance across different knowledge bases.

3 Data

This thesis uses panel data of Swedish innovations from the SWINNO database which covers innovations over the years 1970-2013 (Taalbi, 2017). SWINNO contains extensive information about single product innovations commercialized by Swedish manufacturing firms between 1970 and 2007 (Sjöö et al., 2014), however the version used for this thesis is from an extended version that is not publicly available at this time. SWINNO is a useful source of information about Swedish innovation over time and regions; the database contains detailed information about 4104 innovations, out of which 621 are eco-innovations with country specific locations. The relatively new data gives significant opportunities to analyse technological and industrial innovation in Sweden over more than 40 years. The eco-innovations are defined as innovations stated explicitly to be developed in order to solve an environmental problem (Taalbi, 2014). Secondly, eco-innovations are also defined as innovations that are stated in the articles to have the property of improving energy economy, fuel efficiency, decrease material waste, or otherwise improve the environment (Taalbi, 2014).

The SWINNO database was constructed using the literature-based innovation output (LBIO) method. The LBIO method is an approach of having industry experts listing down important innovations in their field of study (Sjöö et al., 2014). This is done by relying on literature sources to collect this list of innovations – an advantageous approach since the literature typically comes with further details regarding the innovation, such as novelty, origin and user industry (Sjöö et al., 2014). Although the LBIO method is simple at face-value, it is rather labour intensive. In regards to the SWINNO database, several years were spent to collect the list of innovations from trade journals. The data provides detailed data of innovation with information such as: the origin of the innovation, its commercialization date and the company name. By using the specific information of the innovation, eco-innovations are identified along with the county location of the innovation. The regions will be defined using the NUTS 3 region definition by the EU – which in Sweden consists of 21 counties[5]. A qualitative case study of the Värmland region will also be presented – this data will be gathered from reports regarding higher education and innovation systems.

3.1 Methods

This thesis will include a mixed methods approach of both quantitative and qualitative data, using an explanatory sequential research design. In studying the national eco-innovation system of Sweden, time-series graphs of the development of eco-innovation will be presented. This will give a starting point of discussion by providing an overview of the long-run patterns. This is followed by the analysis of regional empirical data. The first part of this regional analysis will be focused on technology and economic growth, in which case, the specific concepts to be tested are clustering and regional size.

To compare with the ICT technological shift in Sweden, clustering and regional size will be explored. As a proxy for clustering, the study will present a test of the spread of eco-innovations over time by using the Coefficient of Variation (CV) method (formula presented below). The CV reflects the dispersion of events, and in the case of this context will reflect the spread of eco-innovations in counties throughout Sweden. A decreasing CV means that the number of innovations per capita is becoming more similar across regions, which means less concentration to one or a few regions. The CV is useful since the value is calculated based on the mean of the data, resulting in a measure of the relative variation instead of the absolute variation. Furthermore, trends will be evaluated by comparing the CV pattern of eco-innovation and the CV pattern of ICT innovations.

$$Coefficient\ of\ Variation = \frac{Standard\ deviation\ of\ all\ innovations\ across\ regions}{Mean\ of\ all\ innovations\ across\ regions}$$

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[5] See Appendix A for the Swedish NUTS 3 map

To further develop the analysis of clustering and regional size, eco-innovations per capita will be compared over regions to identify whether the performance of eco-innovations by larger regions is greater than smaller regions. An added perspective will be the percentage share of eco-innovations out of total innovations in each region. This will portray which regions are specialized in eco-innovations relative to others. The relationship between population and eco-innovation per 100,000 inhabitants will be analysed to further examine how strong this relationship is and to what capacity population can indicate eco-innovation activity.

The number of eco-innovations will also be presented regionally to illustrate which regions are leading and lagging in various periods of time. The last aspect of regional innovation systems to be studied is the concept of different knowledge bases. The analytical framework for this analysis will be adopted from Martin (2012) which differentiated regions between analytical, synthetic and symbolic knowledge bases. To determine any relationship between knowledge base classification and eco-innovations, two separate graphs will be presented. The first will be the number of eco-innovations per region in the period of 1970-1989, and second will be the same but for the period of 1990-2013. This will allow for an analysis of each period and explore if regions with certain knowledge bases are high or low performers.

Following these quantitative sections will be the discussion of the importance of knowledge flows for eco-innovation. For this, a single-unique-case study will be presented in the form of Värmland County. Document analysis from previous reports will be collected to identify which factors may have given rise to Värmland's unique strength at creating eco-innovations.

3.2 Limitations

One limitation is that the SWINNO database is created using the LBIO method. This method has its advantages, however comes with a specific bias. With this method, independent journalists and journal editors include material if they deem it significant or of relevance. The perceptual judgment bias can include, for example, only listing innovations that one feels significant enough to add. As a result, far from every products mentioned in trade journals ended up in the SWINNO data (Sjöö et al., 2014). Another limitation of the LBIO method is that it only represents innovation output – however for the purpose of this study, it is the desired measure. The LBIO method has its advantages in measuring innovation outputs that are significant enough to be included in trade journals and be selected during data collection. Other measures such as patents and R&D do not give as complete a picture of innovation outputs as the SWINNO database does.

A limitation of the SWINNO data is that a majority of innovations captured in journals are product innovations. This criterion for innovation limits the ability to point out innovations in industries where process innovations are more significant than product innovations (Sjöö et al., 2014; Pavitt 1984). Another potential drawback is that the data found in trade journals may not give a proper representation of where the innovations were created. Especially in the case of innovations created in large firms, the location may be of the firm headquarter and not the location of the actual innovation.

In regards to the methods of manipulating the data, there are a number of limitations. Firstly, although the CV is able to show the trend of eco-innovation spread across Sweden, it is not a perfect proxy for representing clustering. Secondly, the use of Martin's (2012) typology has its limitations since the Swedish regions and their knowledge bases were categorized based on 2007 data. Using this typology does not take into account the changes regions may have underwent over the period between 1970-2013. To mitigate these discrepancies however, the analysis of innovations to knowledge base type will be divided into two periods: 1970-1989 and 1990-2013. Thus, the results for the last sub-research question[6] must be interpreted with caution, especially for the earliest period.

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[6] Did regional eco-innovation performance differ across different types of knoweldge bases?

A more fundamental limitation of studying innovation systems is the difficulty in pinning down specific causal relationships. Innovation systems are complicated and complex (Bergek and Jacobsson, 2004). It is firstly, empirically difficult to trace the magnitude of various mechanisms which encourage or limit innovation diffusion (Bergek and Jacobsson, 2004: 29). Furthermore, the complexity of the system is based on the large amounts of feedbacks, which makes certain aspects unpredictable (Bergek and Jacobsson, 2004). It would thus be beneficial for certain statistical methods to be included in future research of eco-innovations.

4 Empirical Analysis

4.1 Results

4.1.1 Long-term aggregate patterns

Long-term data of innovations has been illustrated in Figures 4 and 5. Figure 4 illustrates the long-run fluctuations of the number of eco-innovations in the whole of Sweden. Figure 5 shows the long-run fluctuations of non-eco-innovations and is presented more as a basis of comparison. It is evident in both graphs that temporal clustering is experienced at somewhat similar time periods. The polynomial trend line illustrates some similarities in the curve shapes. As established in previous studies, innovations increased rapidly in the 1970's due to the combination of various factors (see literature review). This pattern is evident in the eco-innovation experience as well. From 1970 to 1980, eco-innovation events increased by more than 200%. The number of eco-innovations was at its highest over this time period in the 1980's. The 200% percentage increase is larger than for non-eco-innovations in the same 10-year period, resulting in a more pronounced trend line. The second phase of innovation growth – as established by previous literature – began in the 1990's. This is well reflected in figure 5 and to some extent in figure 4. The experience of eco-innovations seems to be slightly more fluctuated, however the overall trend has been upwards since roughly the late 1990's. When comparing the two main temporal clusters of eco-innovations, it is clear that the earlier growth phase in the 1970's was more rapid and large in magnitude, whilst the growth period from the 1990's has been rather modest and gradual. In comparing the start and end points, eco-innovations in the year 2013 surpassed the numbers in 1970, however have not reached the peak in 1980 wherein 33 innovations were commercialized.

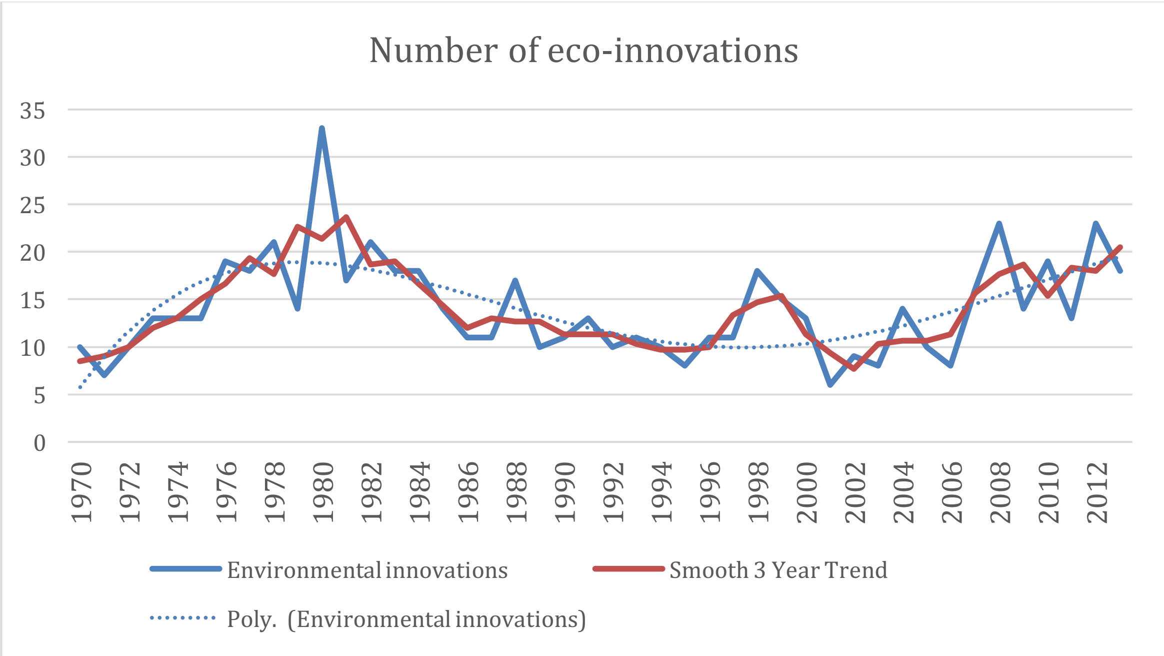

Figure 4. Number of Eco-innovation in Sweden 1970-2013

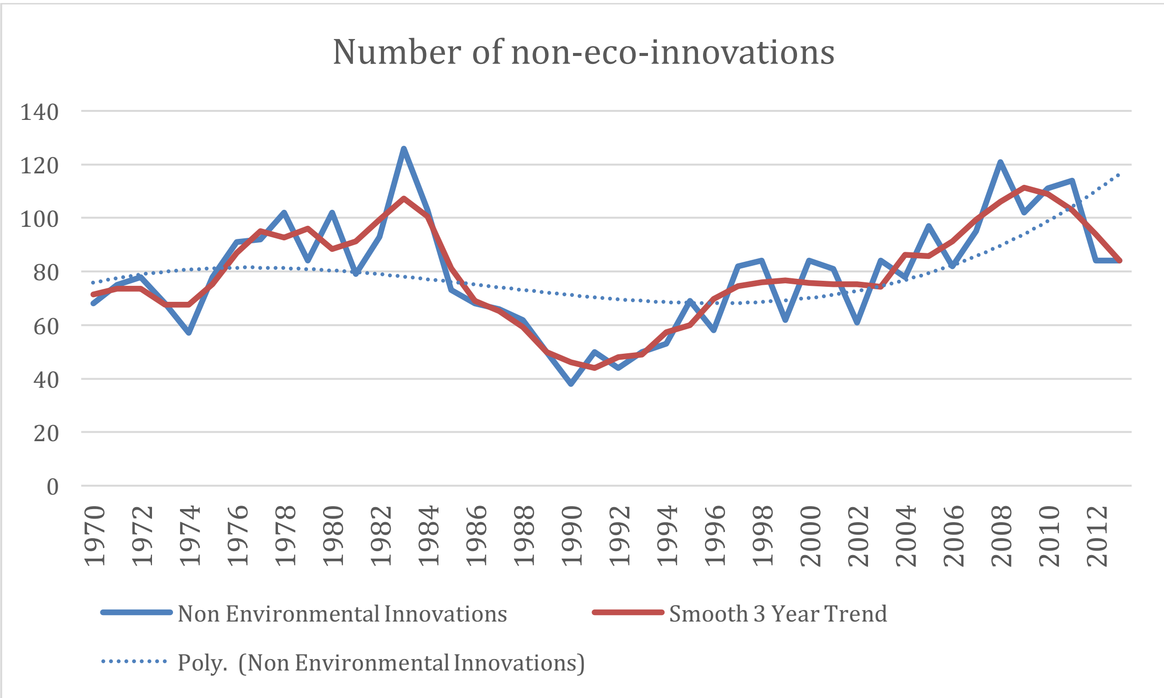

Figure 5. Number of non-eco-innovations 1970-2013

4.1.2 Regional Innovation System

Regional Size & Clustering

As a proxy to study clustering, the coefficient of variation (CV) and contribution by region is used – although the CV alone cannot portray clustering. The results of the CV approach are presented in figure 6. The CV of ICT is presented in figure 7 to be used as a starting point for comparison. This comparison is appropriate due to the pre-established studies of the strong clustering effect of ICT in the Swedish technological shift (see literature review). The ICT CV in figure 7 corroborates the pre-established studies well with less variance over time – the movement of ICT from the largest regions into the smaller regions over time is shown by the downward trend of the CV from 1970 to 2013.

The distribution shown by the CV in figure 6 illustrates that the spread for eco-innovation went from just below 2 in 1970 to roughly 1.75 in 2013. This decrease is not as large as the ICT experience, however there is a slight downward trend. As for the CV values themselves, the spread of ICT and eco-innovations are rather similar – 1.75 and 1.6 respectively. The CV for eco-innovations does not say much about clustering per-say, however it is evident that the extent that eco-innovations vary in regions has remained rather stable over the last 43 years. To build upon these findings, the regional contributions are presented in figure 8.

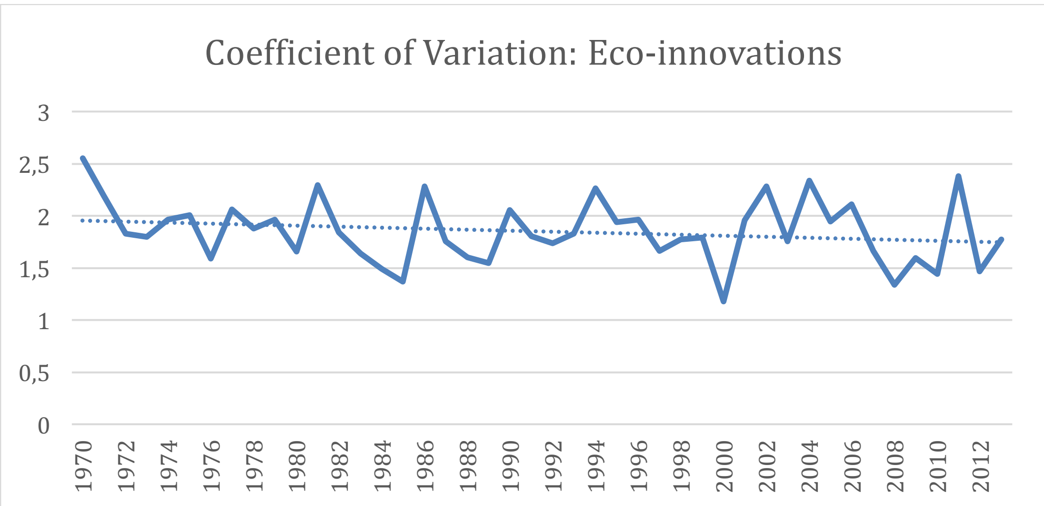

Figure 6. Coefficient of Variation of eco-innovations 1970-2013

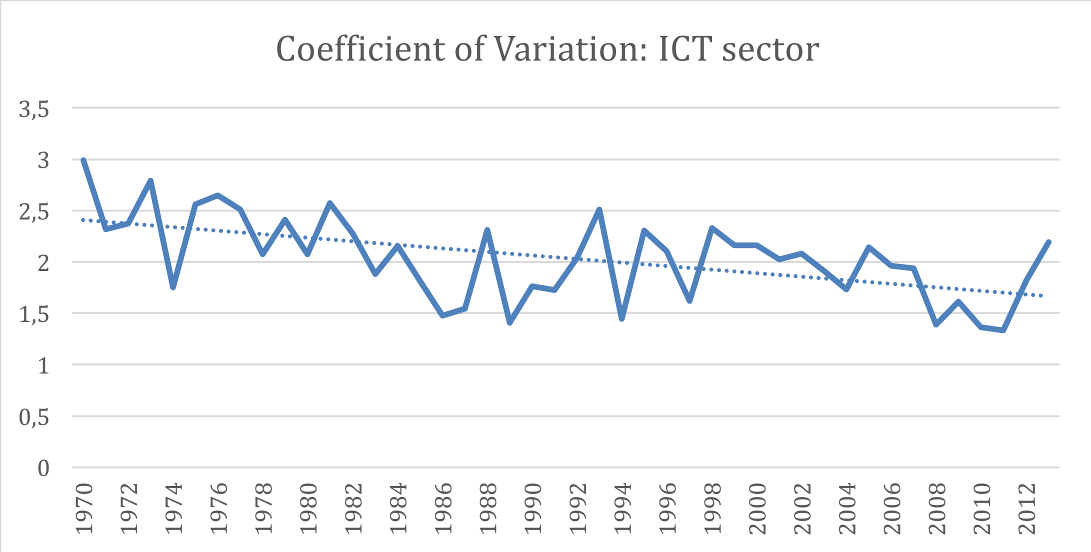

Figure 7. Coefficient of variation of ICT Innovations 1970-2013

Figure 8 illustrates the relative contributions of regions to the total amount of eco-innovations. The CV has indicated a rather stable spread of eco-innovations over the years, with a slight downward trend. There seem to be fluctuations in exactly what regions are producing these innovations in various periods of time. Stockholm has made a fairly stable contribution over the years, with the exception of the 1990´s when the region made very small contributions. Östergötland and Skåne have experienced similar patterns – with improved contributions in the 1980's, followed by a decline in the 1990's, first by Östergötland and then by Skåne. Since this decline, Skåne's contribution to eco-innovations has been rather small in comparison to earlier periods. Östergötland however, had another large increase around 2001. Västra Götaland experienced similar but milder trends to Skåne – always keeping a decent but modest contribution. Värmland is of special interest, since in per capita terms, they have contributed significantly in different periods. Between 1970 and 1980, Värmland was a high-performer, especially in comparison to the larger regions in Sweden. The performance was notable again between 1990 and 2000, and Värmland has continued to make significant contributions throughout the years. Specifically, in the latest periods of the data set – 2007-2013 – Värmland has contributed more in per-capita terms than the big regions.

In comparing the trends between regions, it is evident that whilst Stockholm declined in performance in the 1980's, Skåne and Östergötland faired quite well and became the largest contributors. At most points in the data set, Stockholm has not been the largest per-capita contributor, however they have made steady contributions. In regards to the other regions, their contributions have fluctuated through the years. At various points, the regions belonging to the "other" group have also been able to make significant contributions. The five regions depicted in the graph however, have contributed between 30-50% of all eco-innovations at which is not unprecedented considering that these 5 regions make up 57% of Sweden's population.

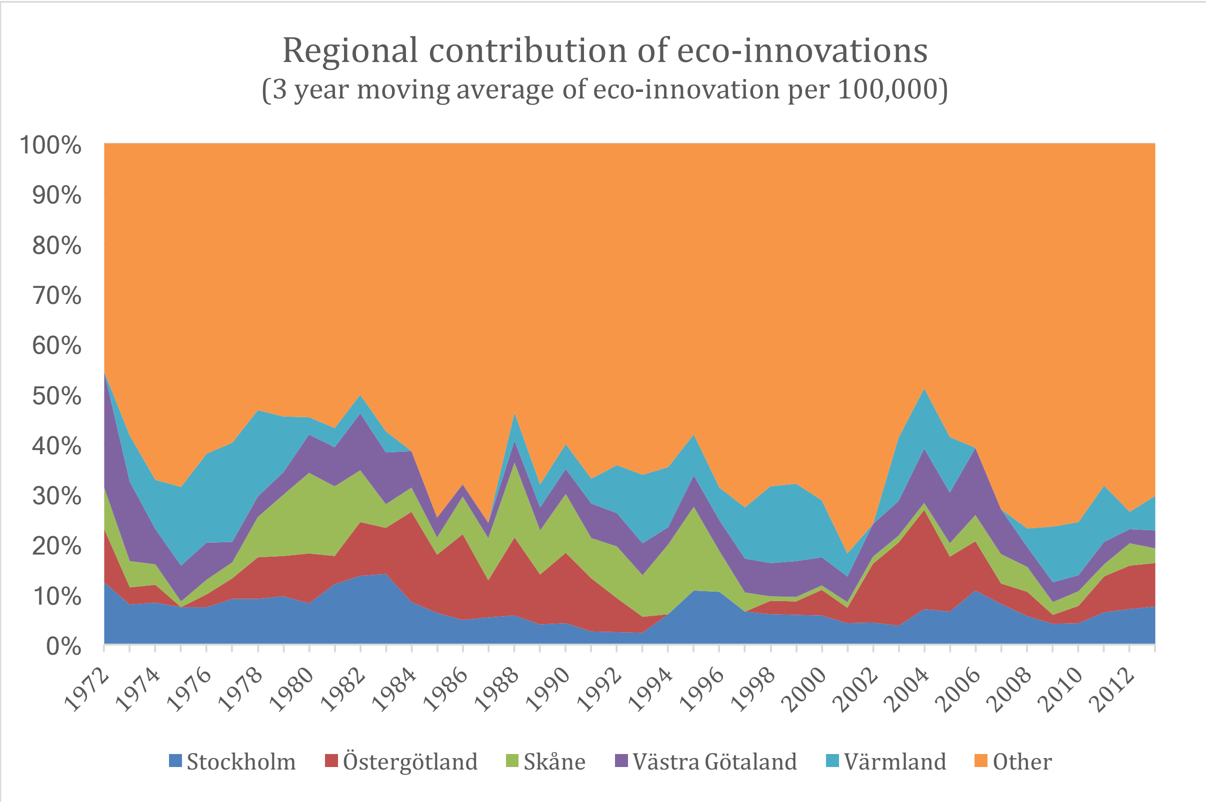

Figure 8. Regional contribution of eco-innovations (1970-201)

The following results aim to analyse the effect of different types of knowledge bases on eco-innovations. The following figures also present the leading and lagging regions in terms of innovations per capita over different time segments. Firstly, a legend is presented in Figure 9 which presents the different colours and types of knowledge bases they depict. For more information regarding these categories, see the knowledge base section of the literature review. What is evident is that the type of knowledge base does not necessarily correlate with the size of a region. The Synthetic regions for example, range from the 2nd largest region in Sweden to the 19th largest. The region labels in the graphs include a number which indicates their regional size ranking during the period of time the graph refers to.

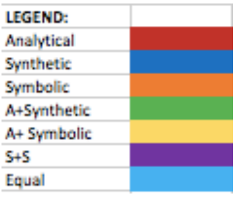

Figure 9. Legend for figure 10, 11, 12. (A+Synthetic: the overlap between analytical and synthetic), (A+Symbolic: the overlap between analytical and symbolic), (S+S: the overlap between symbolic and synthetic)

Figure 10 ranks the eco-innovations per capita in the period of 1970-2013. Värmland is the highest performer in this period, followed by Västmanland, Östergötland, Stockholm and Västernorrland in the top 5. Interestingly, the top two regions have quite small populations – Värmland has the 8th biggest population and Västmanland has the 12th biggest population. The largest regions seem to be spread across the top-middle portion of the chart, rather than being direct leaders. The smallest regions, Jämtland and Götland are concentrated at the end of the table and have the worst rankings. In terms of knowledge bases, the regions with synthetic knowledge bases are fairly spread across the board. The synthetic and symbolic regions (S+S), are at the end of the table, whilst the symbolic region is also at this lower end. Analytical knowledge bases are found in the middle of the ranking, whilst the A+synthetic, A+symbolic and Equal are all found spread around the first half of the table.

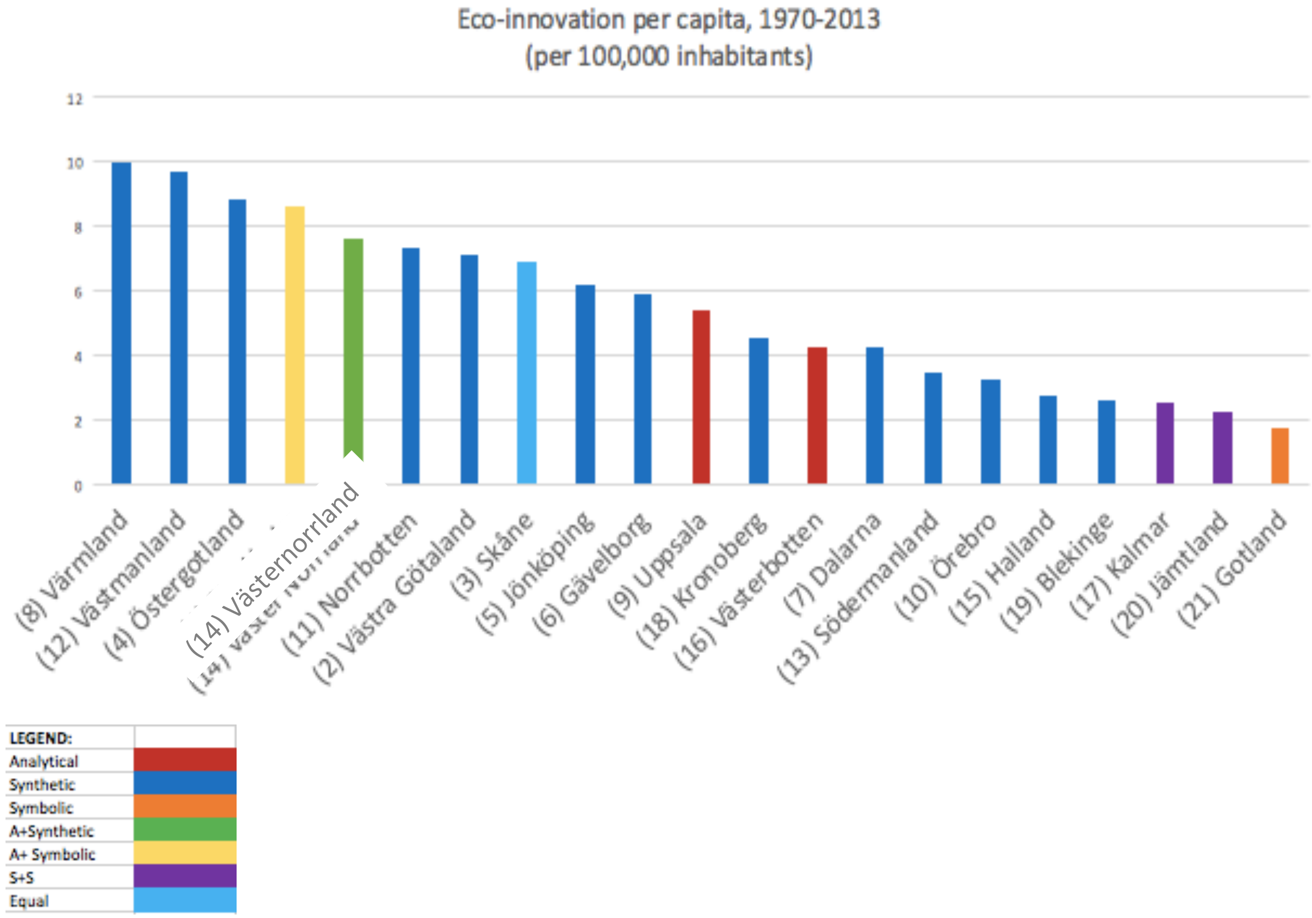

Figure 10. Eco-Innovations per capita, 1970-2013

When the data set is divided into the period 1970-1989, and 1990-2013, the results differ. In the period of 1970-1989, Östergötland – the 4th largest region during this period is the highest performer of eco-innovation, with other large regions such as Stockholm and Skåne following in 3rd and 4th position. Västmanland is the stand out region in this time period, ranking 2nd whilst having the 12th largest population. Värmland follows in 5th position and the 8th largest population. Similar to figure 10, the synthetic knowledge base regions are quite evenly spread out across the board. The S+S regions fair slightly better in figure 11, whilst Gotland – the only full symbolic region – isn't able to contribute anything to eco-innovations. The A+Symbolic and Equal regions fair quite well, especially in comparison to the rankings in figure 10.

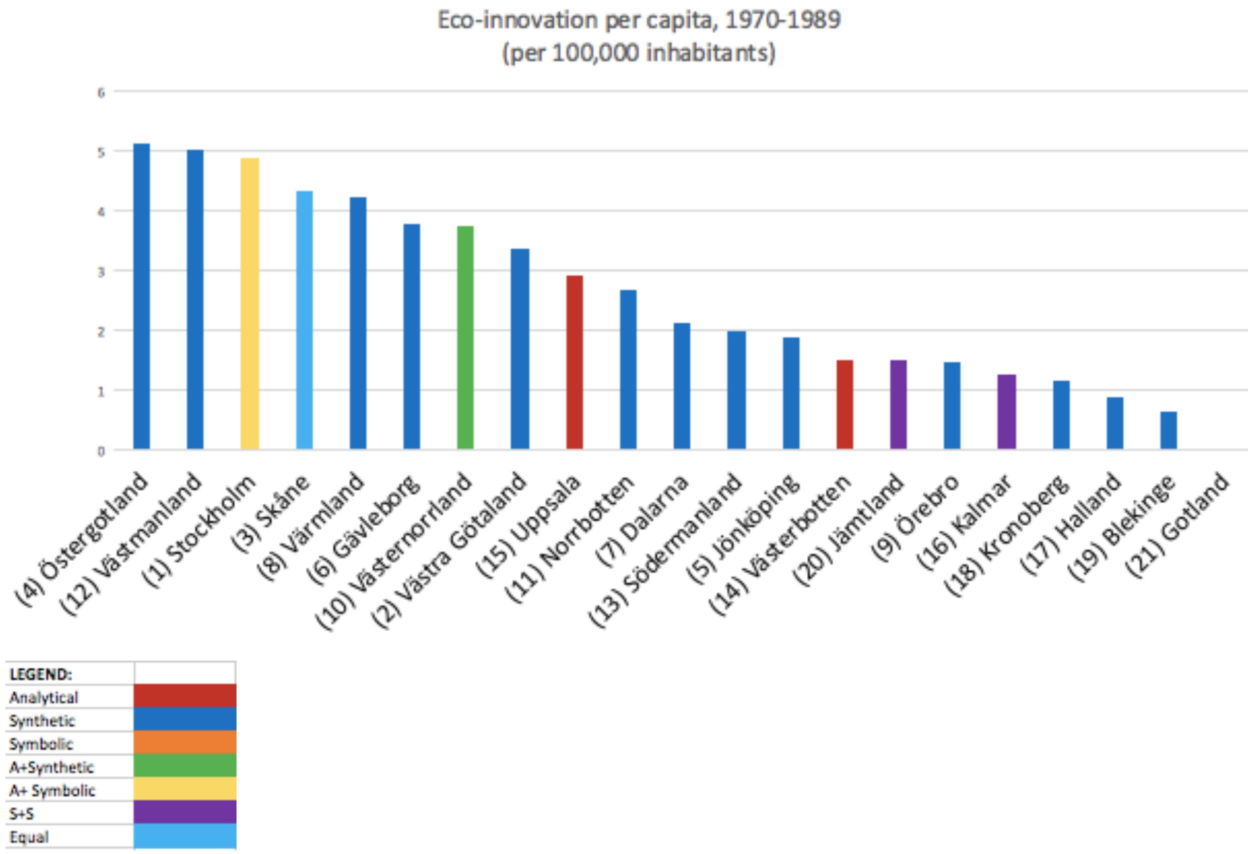

Figure 11 Eco Innovation per capita, 1970-1989

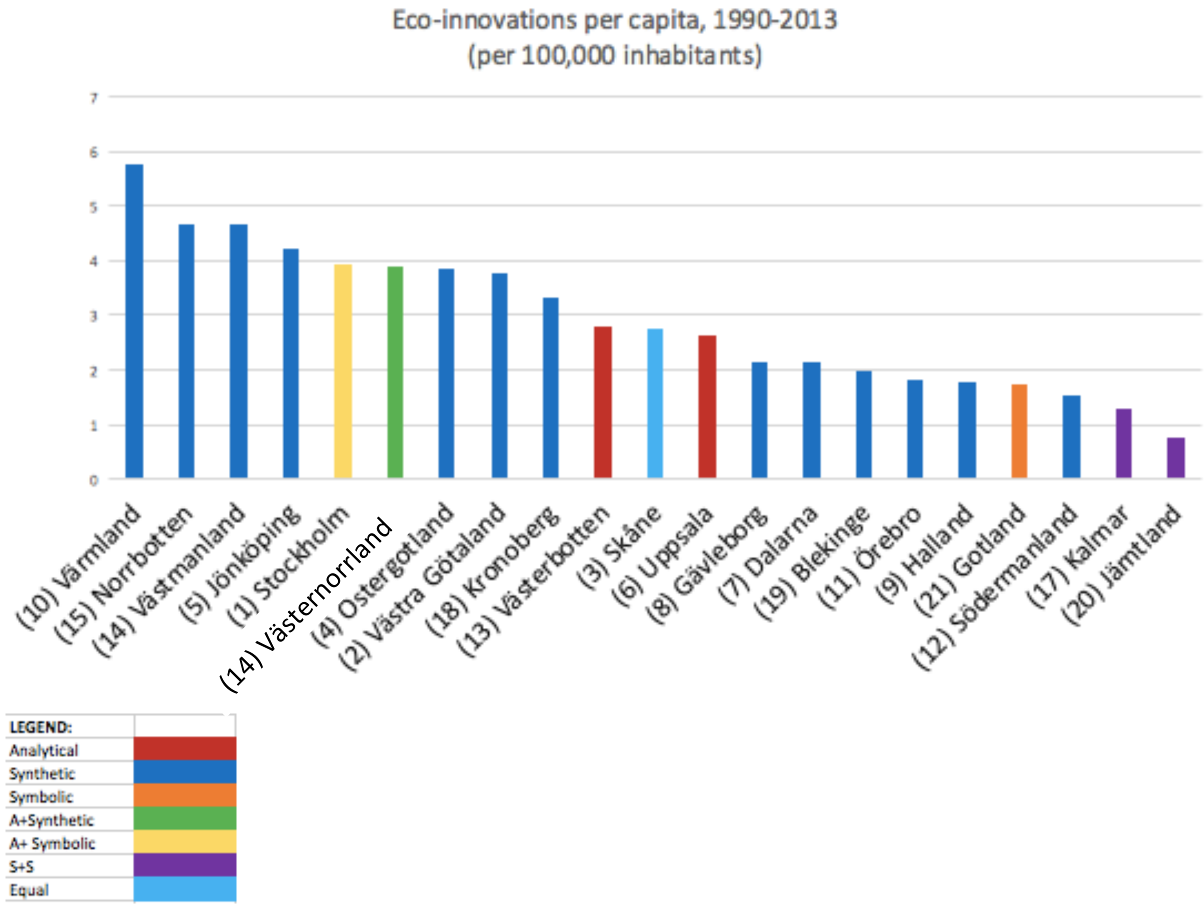

Figure 12 Eco-innovation per capita, 1990-2013

Figure 12 moves on to illustrate the data for the period 1990-2013. There are evident differences between figure 11 and 12. Firstly, Stockholm and Skåne perform worse compared to their earlier performance and compared to other regions. The leader in this period is Värmland, which has the 10th largest population in Sweden. Gotland – the only full symbolic region – improves ahead of 3 other regions in this period. Skåne however, worsens quite drastically. What is evident when comparing figures 10, 11, and 12, is that the performance of different regions changes to great extents over different periods. Region size and eco-innovation performance seems to have an unclear and weak relationship. The success of different types of knowledge bases in terms of eco-innovation also varies between different periods. In figure 10 (1970-2013) the top 3 regions are all synthetic, followed by A+Symbolic and Equal. In figure 12 (1990-2013) the top 4 regions are all synthetic followed by A+Symbolic. In all graphs, the S+S regions and regions with some of the smallest regions, lag at the end of the rankings.

These findings are compounded on by figure 13 which illustrates the share of innovations that are eco in each region. At the low end of the scale, are Södermanland, Västerbotten and Blekinge – all of which have mid-to-small populations. A interesting finding in this lower end is the inclusion of Stockholm – suggesting that Stockholm is not specialized in eco-innovations, despite producing the most number of innovations in general. Gotland ranks 1st, however this needs to be handled with caution since in total Gotland contributed three innovations, out of which one was an eco-innovation. The relevance of this finding is rather debatable. Alternatively, Värmland ranks 2nd – 27% of all the region's innovations are eco – which is quite impressive considering the region's relatively small size. It should be noted that the regional contribution of eco-innovations is measured in shares of total number of eco-innovations resulting in that the specific regions shares are tied to overall performance of other regions.

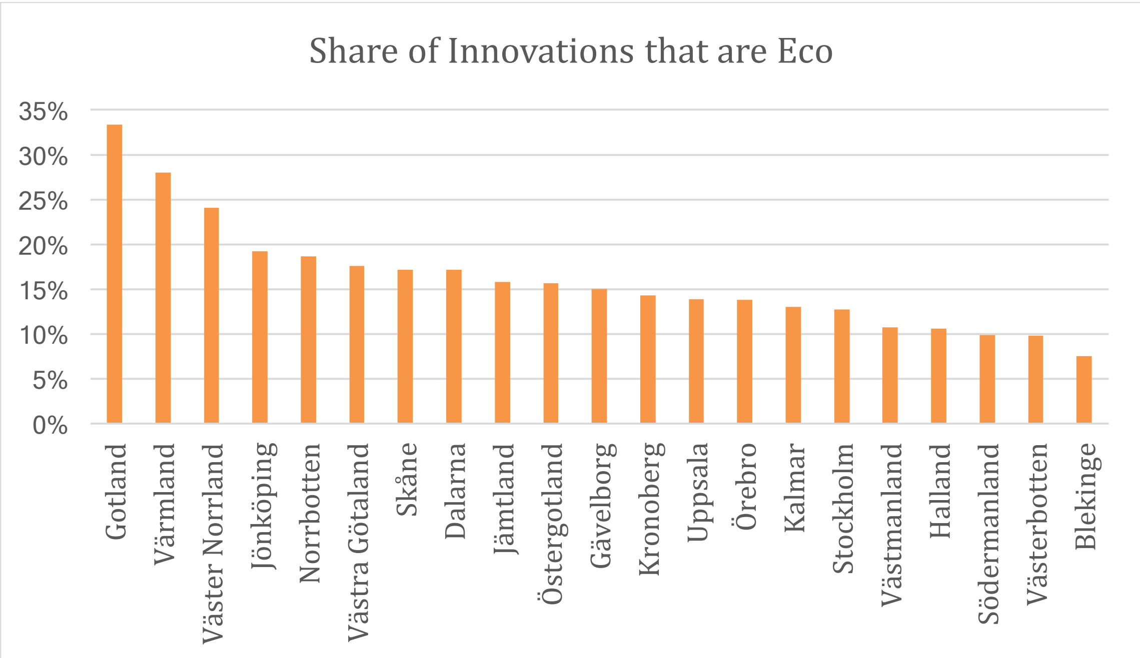

Figure 13. Share of Innovations that are Eco

A more specific analysis of the role of regional size is depicted in figure 14 which represents the relationship between population and eco-innovation per capita. The trend line suggests a positive correlation, however this correlation is rather weak – depicted by the R^2 value of 0.19. The biggest regions are Stockholm, Jämtland and Skåne, which all perform quite well but are not the leaders of eco-innovation per capita. Alternatively, Värmland, Västmanland and

Östergötland all take the top three positions whilst being drastically smaller in population than the aforementioned regions. The positive correlation is supported by the smaller regions however – these smaller regions rank quite low in terms of eco-innovation per capita and are thus situated on the lower left corner of the graph.

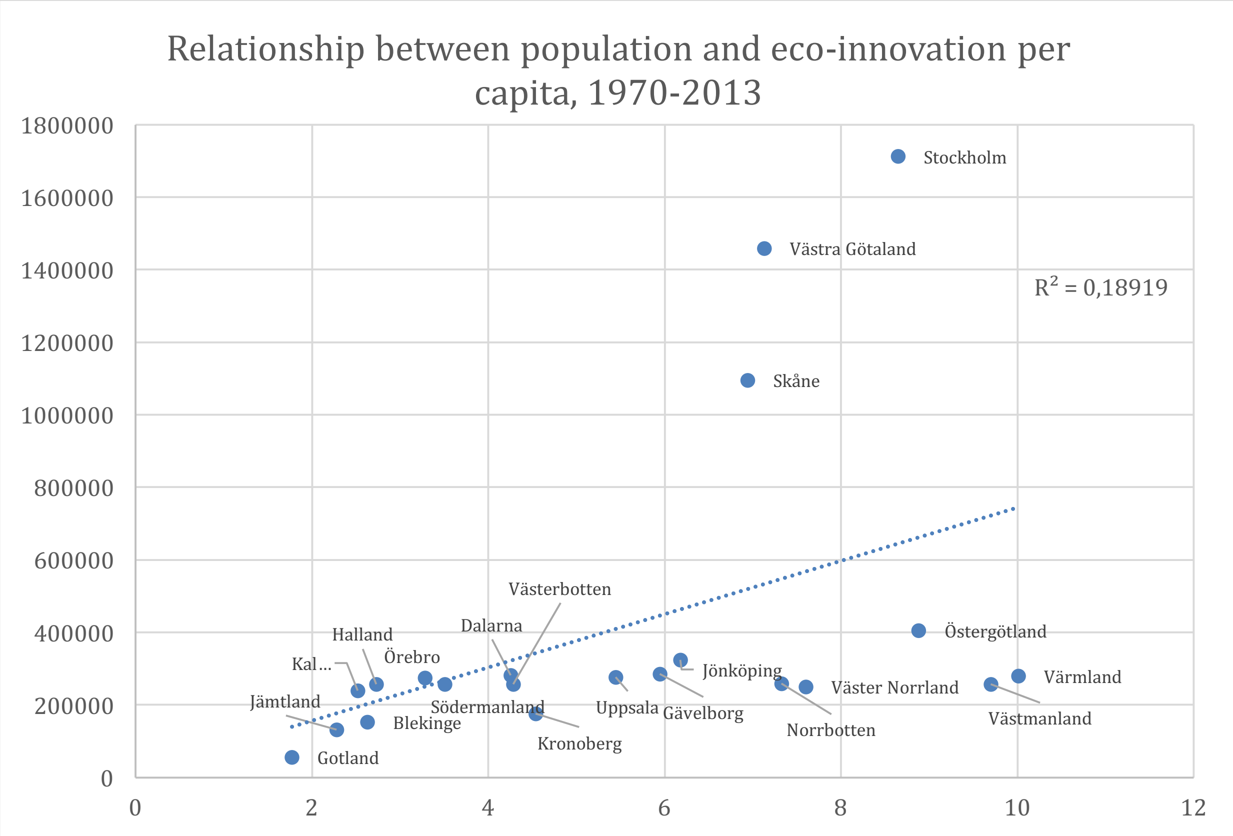

Figure 14. Relationship between population and eco-innovation per 100,000 inhabitants

The case of Värmland

Due to Värmland's interesting results in the quantitative analysis, this section will continue with a qualitative analysis of Värmlands knowledge flows in the hopes of shedding light on the previously mentioned findings.

Värmland has repeatedly ranked well in regards to eco-innovations per capita throughout different periods and in terms of the share of the region's innovations that are eco. These are significant points to note since Värmland is Sweden's 10^{th} largest region. Värmland also has largely a synthetic knowledge base, meaning that it is engineering based (Martin, 2012). In these types of knowledge bases, innovation stems from applying or combining existing knowledge in new ways and collaborating with customers and suppliers. In terms of knowledge stickiness, synthetic knowledge is partially codified, with a strong tacit component. Synthetic careers include architects, engineers, computer professionals, technicians, inspectors and many more (Martin, 2012). Although Värmland is specialised in synthetic knowledge, it is important to acknowledge the situation of other types of knowledge – the full rankings are as follows (Martin, 2012: 69-71):

Synthetic: 1.11
Analytical: 0.84
Symbolic: 0.89

To give perspective, the highest number achieved by any region in any type of knowledge is Gotland's symbolic base which scored 1.6, however a high score is generally between 1.22 and 1.43. Although synthetic knowledge ranks the highest in Värmland, symbolic and analytical knowledge are not far behind. In all types, Värmland ranks somewhere in the middle when compared to the other regions. Generally, Värmland seems to have quite average scores for all types of knowledge bases.

Historically speaking, Värmland's economy has been based on its rich natural resources. The main industries of the 1950's and 1960's included paper and pulp, iron and steel industries. These industries are still very important in the economic landscape, however they employ fewer and fewer people as labour shifts towards the service sector and people migrate out of the peripheral region. One interesting finding in regards to knowledge flows is the importance of the relationship between Karlstad University and industries. Karlstad University needs to be given special mention in regards to environmental sustainability. Not only are they a vital resource for research for regional governments and firms, they are also as an institution, aiming to contribute to an "economically sustainable development of society" (Karlstad University, n.d.: 1). For many years, the co-operation between university and industry has created important research and resulted in numerous innovations within paper, pulp and printing technology (Vught et al., 2006). Värmland county and Karlstad university also work together in developing energy, IT and environmental engineering innovations (Vught et al., 2006). These developments have also been supported by private actors. It is thus evident that Värmland has very strong formal and informal networks between three very important actors: industry, regional government and the university. This has been attributed to Värmland's small size and thus the ease at which connections can be made.

Another significant characteristic of Värmland is the abundance of different types of purposeful clusters. The "Paper Province" is an example, including paper and pulp companies; the "Graphic Valley" "Compare" and "Packaging Arena" include the IT and packaging industries (Vught et al., 2006). There also exists clusters belonging to the older types of industry, including steel and engineering. The result is an intricate and elaborate system of clusters, innovation initiatives and knowledge hubs around the Värmland region. The highly connected actors, along with this focus on clustering has resulted in a strong network that has thrived despite an ageing population and emigration (Vught et al., 2006).

5 Discussion

This discussion section will summarize the main findings as they pertain to the research questions of this study. To re-iterate, the research questions of this study are as follows:

1) How do patterns of eco-innovation evolve over the period of 1970-2013 in Sweden?
    a. Do these patterns follow the ICT technological shift?
    b. Are clustering and regional size indicators of high eco-innovation performance?
2) Which Swedish regions were leaders in eco-innovations?
    a. Did regional eco-innovation performance differ across time?
    b. Did regional eco-innovation performance differ across different types of knowledge bases?

In regards to the aggregate long-run patterns, eco-innovations in Sweden follow a similar pattern to non-eco-innovations when analysing trend lines and periods of temporal clustering over the period of 1970-2013. This suggests that eco-innovations are not completely dissimilar to other innovations, with a high probability of being affected by some of the same macro-economic and technological drivers. The findings in the empirical analysis are supported by much of the studies mentioned in the literature review. The combination of events in the 1970s (i.e. oil crisis, climate concern, manufacturing restructuring) may have been institutional necessities that supported the high level of eco-innovations into the 1980's. The political and social landscape at this time seemed to portray a "hype" surrounding environmental sustainability – it was a new concept that with the oil crisis, made monetary sense. Since then however, eco-innovations have not reached the same levels they did in the 1980's. This is not to say necessarily, that there is less focus on eco-innovations, however the maturation of this technological shift may also mean that new innovations are more difficult to develop. In the 1970's for example, during the transformation phase of the micro-electronic development block, manufacturing and production were changed significantly (Lundquist and Olander, 2010). This change created opportunities for more sustainable practices to be developed, especially since use of any alternative energy to fossil fuels was largely insignificant prior to this time period. In more recent years, complex environmental innovations such as electric cars have been developed, however these complex innovations require more high-tech complementaries and a multitude of incremental innovations (such as a sufficient battery for these cars) to fully develop. It may be that although the innovations are less, they are still significant.

Secondly, the long run patterns of eco-innovation do not follow the patterns of ICT diffusion - which is seen in the lack of clustering and relation to regional size (figures 6, 7 and 8). When looking at the regional contributions of regions, the relative contributions between them fluctuate over time. There does not seem to be a single region, or number of regions that stand out as having had a significant increase in clustering of eco-innovations. This finding, compounded by the CV findings, suggests that the spread of eco-innovations actually decreased over time, meaning that eco-innovation per capita became more equal amongst regions. This is due to the fact that smaller regions increased their eco-innovation outputs whilst larger regions decreased or stabilised their eco-innovation activity. Furthermore, the 5 biggest contributors of eco-innovations combined contribute 30-50% of eco-innovation and make up more than 50% of the population in Sweden, which arguably suggests that their contributions are not drastically out of proportion. Certain periods are, of course, more impressive than others, especially when considering the sizes of some of the high-performing regions such as Värmland. Other regions that are not necessarily leaders in eco-innovation have also increased their share of contribution over time slightly. Ultimately however, there is no indication of a strong clustering effect occurring over 1970-2013. The opposite can actually be observed – with less clustering in leading regions and increased contribution by medium and small regions. This is corroborated by previous studies that observe that eco-innovation clusters are rather fragmented and would benefit from more clustering of activity (Barsoumia et al., 2011).

Clustering effects are related to regional size, since agglomeration usually occurs where the benefits of economies of scale are experienced. Regional size and economies of scale played a large role in the micro-electronic development block, however this is not completely true for eco-innovations. Regional size does play a part to some extent, since in many measures, the smallest regions perform the worst. However, there are further instances when medium sized regions out-perform the largest regions to a great extent. Stockholm and Skåne for example, contributed less in eco-innovations in the second half of the studied period than the first half. At the same time, Värmland, Norrbotten and Västmanland performed the best in 1990-2013 and are ranked 10th, 15th and 14th respectively in terms of region size. This finding is extremely significant in confirming that regional size is not the strongest indicator.

The discussion of regional size leads us to the next set of research questions regarding the regional performers of eco-innovations. The list of top 5 contributors to eco-innovations in the different periods are presented in figure 15:

Rank	1970-2013	1970-1989	1990-2013
1	Värmland (8)	Östergötland (4)	Värmland (10)
2	Västmanland (12)	Västmandland (12)	Norbotten (15)
3	Östergötland (4)	Stockholm (1)	Västmanland (14)
4	Stockholm (1)	Skåne (3)	Jönköping (5)
5	Västernorrland (14)	Värmland (8)	Stockholm (1)

Figure 15. Regional ranking of best contributors of eco-innovations per capita in different time periods - includes regional size indicator (i.e. Värmland is the 8th largest region in Sweden in the period 1970-2013)

What is evident by the regional sizes is that the top regions in the overall period range from the largest region to the medium-small regions. When divided into the two different time periods (1970-1989, 1990-2013), it is clear that in the later period, size matters even less. Värmland ranks 1st overall, due to its good performance throughout the time periods. Västmanland and Stockholm also remain in the top 5 throughout the period. Norrbotten improved dramatically between the two periods, jumping from 10th best contributor in the 1970's to 2nd after the 1990's. When analysing the types of knowledge base of high and low performers, the results are rather ambiguous. A majority of regions are classified as synthetic knowledge bases, which have ranked all across the board in various periods – from being the top 4 in one period to being the bottom 3 in other periods (figures 11 and 12). It is not possible to say that the fact a region has a synthetic knowledge base can alone, indicate a good or bad eco-innovation performance. What can be said however, is that regions with equal amounts of synthetic and symbolic knowledge bases perform quite badly during both time periods. Skåne – which is the only region with equal amounts of all knowledge bases – decreases quite significantly in performance in the later half. The ambiguous results overall make it difficult to obtain a distinct relationship between a certain knowledge base and eco-innovation performance. This suggests that there is potential in exploring other factors such as industry and other measurements of regional networks. The inconclusive findings regarding knowledge bases must be handled with care however, since as discussed in the limitation section, the typologies are likely to be more accurate for the later periods.

The suggestion that industry and networks may play a role is justified by the case study of Värmland. This region has been a consistently high performer in eco-innovation whilst being characterised by an average level of all three types of knowledge bases. Through the case study analysis, it is evident that Värmland has a high level of clustered and specialized industries. These industries include pulp and paper as well as packaging – both are industries that have been pointed out in the literature review as having had a high contribution to eco-innovation performance (Bergek and Jacobsson, 2004)). Furthermore, it is established that informal and formal networks are strong in Värmland, creating linkages between the various industrial clusters. This is all supported by Karlstad University, which promotes environmental sustainability strongly. It is thus possible to argue that industry and networks are two aspects that need to be researched further in terms of their relationship to eco-innovation performance.

In summary, the main findings of the study can be presented as such:

1) The long run patterns of eco-innovations do have similarities with general innovations, indicating the propensity to be affected by some of the same pressures.
2) The potential explanations of eco-innovation suggested by previous literature (Bergek and Jacobsson, 2004; Taalbi, 2013; figure 4), are corroborated by the empirical analysis – namely the 1970's wherein the oil crisis, climate concern by the EU and environmental regulation by Sweden occurred in overlap.
3) The eco-innovation experience was rather different than the ICT experience in that there is no evidence of strong clustering over time nor the strong effect of regional size as a determinant of eco-innovation activity. In fact, over time, medium to small regions outperformed larger regions in terms of eco-innovations per capita.
4) The Swedish front-runners in eco-innovation differed over time, however Värmland, Stockholm and Västmanland were the consistent contributors in terms of eco-innovation per capita. The smallest of all regions had the tendency to be the lowest contributors as

well, however this effect was not as strong in later years. Region size importance seems to decrease over time.

5) There is no clear relationship between knowledge base typology and eco-innovation performance – except for the finding that the fully symbolic and symbolic + synthetic regions have performed quite badly.
6) Industry typology and regional networks are two aspects that should be looked into further in their relationship with eco-innovations.

6 Conclusion

The aim of this research was to present a descriptive analysis of the long term and regional patterns of eco-innovation in Sweden. The implementation of new time-series data has resulted in the analysis of interesting and novel findings regarding national and regional patterns. The long-run aggregate patterns display similarities with general innovation theory, however regional patterns point more towards differences. The main differences include a lack of clustering and regional size effect. The findings are of potential use in strategizing ways to improve and support eco-innovation activity in different regions. The fact that clustering has not occurred strongly, does not mean it should remain as such. Previous literature has established the benefits of clustering and pointed out the fragmented regional environmental clusters in Sweden, meaning that regional cluster policy could be advantageous to support eco-innovation. The finding that regional size is not a strong indicator of eco-innovation performance also suggests that most regions in Sweden have potential for improvement, which should be considered in policy formation. The high performers of eco-innovation – especially in the latest years of the data set – include modest-sized regions such as Värmland, Norrbotten and Västmanland. Regional performance also evolves substantially over time, highlighting the potential for eco-innovation development. Sweden has displayed a commitment towards sustainable growth for decades – these new findings could be of use in policy discussions regarding how to support eco-innovations and ultimately, a grander sustainability transition.

This study has presented a summary of the long-run patterns of eco-innovation in Sweden and should be considered a starting point for deeper research and analysis from other theoretical perspectives. One example is to develop the knowledge base typology by Martin (2012), which could make a greater contribution specifically for earlier periods. Alternatively, a focus on industry or different measures of regional innovation systems could point to other indicators of eco-innovation performance. Generally, focusing on the qualitative detail of individual eco-innovations would also largely develop the study. These details could contribute greatly in developing a more universal understanding of eco-innovation drivers.

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Appendix A

European Union NUTS 3 Classification: Sweden
(Leydesdorff and Strand, 2013)