Creating Advantage: On the complexity of industrial knowledge formation in the knowledge-based economy

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Abstract

Knowledge as a resource and knowledge formation as a process are seen as central to providing nations and regions as well as firms with a competitive advantage. This is captured by the view that the economic and industrial landscape is currently undergoing a transformation towards a knowledge-based economy. This dissertation engages with two views that have gained great influence in the discussions – in academia as well as in policy – on this industrial transformation. This concerns the view on which types of knowledge formation processes that are seen to actually provide a competitive advantage. There is today a prevailing tendency to connect the creation of competitive advantage to research-intensive, so-called high-tech, activities. It also concerns the view on where these knowledge formation processes take place. Much inspired by innovative and high-tech regions, competitive advantage is often closely associated with the role of geographical proximity for knowledge formation. The aim of this dissertation is to develop our understanding of the role of those knowledge formation processes that currently fall outside what is captured by these prevailing views. Three research questions are addressed. First, what is the role of non-research intensive knowledge formation processes in the creation of competitive advantage? Second, how can knowledge formation processes connected to the creation of regional competitive advantage be promoted? Third, what is the role of proximity in knowledge formation processes in the creation of competitive advantage? A qualitative case study approach is adopted for the empirical part of the research, consisting of one case study where low- and medium-tech industrial activities are studied and one case study where the regional dimension of knowledge formation is studied. Personal interviews constitute the major part of the empirical material. The research findings give evidence that reveals shortcomings in theory as well as in policy practice in regards both these prevailing views. It is shown that low- and medium-tech activities are still highly relevant, not only on their own but for the industry as a whole. Further, current forces of globalisation call for an approach to regional development that includes a dual focus of strengthening regional connections as well as facilitating and promoting extra-regional connections. This is particularly important in small, open economies such as Sweden. Further, the findings are in line with those requesting a multidimensional approach to the concept of proximity – one that regards proximity not only as a concept with geographical connotation but also with reference to proximity in context, cognition or value-systems. The dissertation suggests instead that an approach to industrial activities that assumes that those firms, regions and countries that can manage complex knowledge formation processes may develop competitive advantages. It is this ability to achieve and manage sticky processes in a slippery world that is essential for the creation of competitive advantage. And we are more likely to identify these particular competitive advantages on the firm level than on the industry level. Within every industry, there are firms that can manage more suitable ‘bundles’ of knowledge bases, network connections etc, which enable them to adapt at a lesser cost (costs can for instance be measured in terms of efforts, money or time) than other firms within the same industry. This is important to acknowledge – in policy as well as in theory – in order to not exclude important parts of what contributes to industrial competitive advantage in the knowledge-based economy.
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Knowledge, and its centrality in contemporary economic activities, has come to pervade the discussions about competitiveness and economic growth in both academia and in policy circles. The industrial transformation we are currently witnessing, spurred to large extent by the increasing pace and scope of globalisation of economic activities, poses challenges to firms and nations alike. In this transformation, knowledge as a resource and knowledge formation as a process are seen as central to providing nations and regions as well as firms with a competitive advantage. Consequently, this has led to considerable focus on, and interest in, how these knowledge formation processes can be achieved and managed. This dissertation also takes great interest in industrial knowledge formation and its connection to competitive advantage. More specifically, the dissertation problematises two prevailing views in regards to industrial knowledge formation and its connection to economic development – two views that have been a dominant feature in recent discussions within academia as well as policy. The first one is (1) which types of knowledge formation processes actually provide a competitive advantage. The second one is (2) where do these knowledge formation processes take place. In the following, these two views will be discussed, along with a discussion on how these views are problematic and consequently why these in particular have been subjected to closer examination in this dissertation.

The first prevailing view that this dissertation sets out to problematise is the view on which types of knowledge formation processes that have the best potential to provide a competitive advantage in the knowledge-based economy. The creation of competitive advantage is often intimately connected to research-intensive, so called high-technology, activities. To a large extent, this high-tech focus among policy makers and academics alike reflects the idea that the transformation of modern economies is one captured by the ‘knowledge-based economy’ (KBE). The KBE is a concept that has been put forward to describe the more emphasised role of knowledge and knowledge formation in the economy (along with similar concepts such as ‘knowledge society’, ‘learning economy’ etc.). Although the concept can be criticised for being vague and not strongly connected to theory, it has become widely accepted, particularly among politicians and policy-makers (Wickham, 2008); for a review of the concept’s origin and development, see Godin (2006). In this KBE, knowledge is the most important resource and learning is the most important process (cf. Lundvall, 1994; David & Foray, 2003). The KBE concept places
knowledge at the centre of attention, and the term is, according to the OECD (1996 p 9), a result of “a fuller recognition of the role of knowledge and technology in economic growth”.

Within the European Union (EU), the Lisbon Agenda from 2000 manifested the road ahead for Europe as it put on the political agenda to make the EU “the most competitive, dynamic, knowledge-based economy by year 2010”. The agenda to reach this goal includes a broad range of policies and measures, with the focus on innovation, knowledge and education as keys to achieving this objective. Measurements such as higher education, public and business R&D, high-tech manufacturing and science and technology (S&T) workers are examples of performance indicators. This is illustrated in the European Commission’s (EC, 2005) two main indicators to measure and describe the KBE – investments and performance. Investments include R&D expenditure, investment in higher education, human resource development in science and technology (researchers and PhDs) while the performance of the KBE is described in terms of for instance patents, scientific publications and share of high-tech industries of total industry. Perhaps the most frequently mentioned goal is that of reaching a three percent expenditure on R&D of total GDP by 2010 within the EU. In accordance with the KBE view on economic development, the OECD has launched a taxonomy of industrial activities ranging industries from high-technology to low-technology. Although the taxonomy was initially launched with a number of qualifications – of which one of the main credentials was that R&D is but one indicator of knowledge content – it has evolved and developed into a taxonomy based almost exclusively on R&D expenditure (cf. Laestadius, 2006; Smith 2005).

In a European comparison, Sweden ranks high on many of these performance indicators. R&D expenditure in business and industry is among the highest in the world and in the European Innovation Scoreboard for 2007 (EU, 2008), Sweden has the highest score of all the EU27 countries1. The World Economic Forum ranks Sweden to be among the very best in the world when it comes to the ability to meet the requirements of the knowledge economy2. However, Sweden is not ahead of the EU in terms of the output performance indicators. For instance, a common indicator of the extent to which a country has a technologically advanced industry is the exports of high-tech products as a share of total exports. In Sweden’s case, this amounts to 12,8 percent of total exports in 2006, which is lower than the EU27 average of 16,7 percent (Statistics Sweden, 2008). The employment in medium-high and high-tech manufacturing (as percentage of total workforce) in Sweden is 7,03 percent, which is also slightly below the EU average of 7,10 percent (European innovation scoreboard, 2005). If we look at only the high-tech sector, 4,4 percent of the EU27 labour force is employed in this sector3. These numbers show that the

1 The innovation performance is based on five criteria: innovation drivers, knowledge creation, innovation & entrepreneurship, applications and intellectual property (EU, 2008).
3 High-tech sectors include both high-tech knowledge-intensive services and high-tech manufacturing. High-tech knowledge-intensive services include the sub-sectors of postal services and telecommunications, computer and related activities, and research and development. High-tech manufacturing includes: office machinery and computers;
high-tech sector is actually still comparatively small. So, although the KBE refers to the economy as a whole, it is in reality primarily associated with only a few number of research- or science-based activities – i.e. activities that are associated with higher levels of direct R&D, patenting and scientific publications (Hirsch-Kreinsen & Jacobson, 2008; Robertson & Smith 2008). Yet, it is the role of these high-tech activities and sectors that are highlighted and given importance in the discussions on how to secure future growth and create competitive advantage, although this excludes the major part of industrial activities.

The second prevailing view that this dissertation sets out to problematise is the view on where these knowledge formation processes take place. The creation of competitive advantage is often closely associated with geographical proximity, much inspired by innovative and high-growth regions such as Silicon Valley. Such examples have inspired many – academics as well as policy makers – to try to capture the underpinnings of the dynamics displayed by these regions. Central in this focus is to develop our understanding of what it is that stimulates knowledge formation and consequently innovation and economic growth. Such regions are used as examples of how local dynamics spur innovation and economic growth and also as illustrations of the role of geographical proximity for the creation of nurturing milieus for knowledge formation. It is argued that competitive advantage is best created and supported by the promotion of geographically proximate interactions (as accentuated in theories on clusters and regional innovation systems (RIS)). Yet, assuming that knowledge formation and innovative capabilities develop primarily on a local or regional level, spurred by geographical proximity between co-localised firms and other knowledge institutions, does not fully mirror the actual knowledge formation processes in a globalised economy. Even though the existence of social interaction, trust and local institutions has been shown to be important for the growth of competitive milieus (be they clusters, RISs, etc), this does not exclude the fact that these milieus can also rely on externally generated knowledge (e.g. Amin & Cohendet, 2004; Gertler & Wolfe, 2006; Lorenzen, 2005; Malmberg & Power, 2005).

In fact, the relative significance of geographical proximity can be seen to be decreasing as the corporate motives and goals change: there is a trade-off between a centralised organisation and the importance of new inputs from distant markets, tax reductions, learning potential, the importance of ‘being there’ in terms of where the market is, etc. This is also mirrored in an increased geographical distributedness of industrial activities, and an increase of the innovative content of those activities that are distributed (Hedge & Hicks, 2008). Consequently, this indicates that geographical proximity does not, on its own, explain what it is that enables knowledge formation. In any knowledge formation process, a minimum amount of shared knowledge or experiences is needed to achieve the common understanding that allows for knowledge to be shared and transferred. This indicates the existence of other relevant dimensions of proximity than the geographical that enables knowledge formation across geographical distance (e.g. Boschma 2005).

radio, television and communication equipment and apparatus; medical, precision and optical instruments; and watches and clocks (EU, 2008).
1.1 Aim and research questions

Introduced above are two influential views on how to create competitive advantage in the transforming global economy. As always when one perspective of a phenomenon gains a dominant position, there is a risk of missing important aspects of that phenomenon which fall outside what is enclosed by the dominant view. The assumption in this dissertation is that there are important knowledge formation processes, and which can be connected to competitive advantage, also outside what is captured by these prevailing views. We can observe that the prominent position given to the high-technology sector is not reflected in the actual industrial structure. The high-tech sector is still relatively small, and also in Sweden – which is one of the highest-ranking countries according to the KBE measures – the industry is dominated by low- and medium technology industries. We can also observe that there are apparently some knowledge formation processes going on even in the absence of geographical proximity. The increased distributedness of industrial actors is one indicator of this. This indicates that there is a need to rethink the widely held view on geographical clustering and local linkages as the primary way to promote knowledge formation. This also implies that there is a need to develop further our understanding of the role of proximity as not only a geographical concept.

It is the implications that these views have for our understanding of the economy, i.e. *which types of knowledge formation processes that actually provide a competitive advantage and where these knowledge formation processes take place*, that is the starting point for this dissertation. The aim of the dissertation is therefore to develop our understanding of the role of those knowledge formation processes that currently fall outside what is captured in the two prevailing views discussed above. The dissertation is based on two case studies focusing on industrial knowledge formation: one case where low- and medium-tech industrial activities are looked into, and one case where the geographical dimension of knowledge formation processes is focused on. By providing examples of knowledge formation processes that fall outside what is captured by the two prevailing views, but that also have the potential to provide competitive advantage, it is the intention to illustrate a greater variety in technology and innovation related knowledge formation processes. This is intended is to contribute to and advance the debates occurring about the KBE.

Thus, in order to develop our understanding of the connection between knowledge formation and competitive advantage, and to problematise the two prevailing views, this dissertation addresses the three following research questions:

**RQ1:** What is the role of non-research intensive knowledge formation processes in the creation of competitive advantage?
RQ2: How can knowledge formation processes connected to the creation of regional competitive advantage be promoted?

RQ3: What is the role of proximity in knowledge formation processes in the creation of competitive advantage?

1.2 Outline of the dissertation

The main part of the dissertation consists of five papers, of which four have been published or accepted for publication in academic journals and books, and one paper has been submitted for publication in an academic journal. All the papers address the research questions above in different ways (for an overview of how the research questions and the various papers intersect, see figure 3, chapter 4). Nonetheless, each paper is also a stand-alone academic contribution with a specific a specific research focus. Table 2 below gives an overview of the research focus in each of the five individual papers included in this dissertation.

These five papers are in the dissertation preceded by a cover essay, which in Swedish is called a ‘kappa’. This ‘kappa’ is intended to give a general introduction to the research and a methodological and theoretical background as well as a summary of the most important findings and conclusions in the dissertation. The various chapters in the 'kappa' address these different aspects. This first chapter provides an introduction to the dissertation as a whole, including the overall aim and research questions. The second chapter includes an introduction to the empirical context of the dissertation, a discussion on the methodological choices as well as a description of the research process. Chapter three provides a discussion of the central theoretical concepts for the dissertation as a whole. The fourth chapter includes a discussion of the main findings. The discussion is structured according to the three research questions formulated above, and here the findings from the individual papers are connected to these research questions. Finally, the fifth chapter presents the more general conclusions that can be drawn from this dissertation.

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<tr>
<th>Paper</th>
<th>Title</th>
<th>Research Focus</th>
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<tr>
<td>Paper 2</td>
<td>Published in: Journal of Industrial Relations, Vol 48 No 5 pp 619-631</td>
<td>From Grounded Skills to Creativity: On the transformation of mining regions in the knowledge economy</td>
</tr>
<tr>
<td>Paper 3</td>
<td>Published in: Industry and Innovation, Vol 16 No 1 pp 123-139.</td>
<td>Promoting regional innovation systems in a global context</td>
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<tr>
<td>Paper 4:</td>
<td>Accepted for publication in: Regional innovation systems: The Swedish experience of policy, governance and knowledge dynamics. (Eds Rickne et al)</td>
<td>Between the regional and the global - regional innovation systems policy and industrial knowledge formation</td>
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<td>Paper 5:</td>
<td>Submitted to Industry and Innovation (Special issue on Offshoring of Intangibles of Innovation)</td>
<td>Globalisation of corporate knowledge formation – enabling proximity through organisational coordination mechanisms</td>
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Table 2: Overview of the individual papers
This dissertation is written within the discipline of Industrial Dynamics, a discipline that is concerned with technological, organisational and structural changes in industries and firms. Industrial dynamics (ID) has its roots in seminal works of Marshall, Schumpeter, Nelson and Winter’s evolutionary theory, as well as Swedish contributions by Dahmén, Eliasson and Carlsson. As a subdiscipline in industrial economics, ID developed as a response to the need for a framework to help us understand the process of transformation and restructuring of the industry, the causes of technical change, industrial development and economic growth, and the linkages between these processes and their micro-foundations (Carlsson, 1989).

Four themes are particularly pertinent in analysing economic activities with ID spectacles on (Carlsson, 1989): (1) the nature of economic activity in the firm and its connection to the dynamics of supply, and therefore economic growth. Particularly the role of knowledge is emphasised in this context. ID views the firm as essentially a processor of knowledge (Eliasson, 1989) rather than as a transformer of physical inputs into physical products. It is less about the physical transformation of inputs into outputs and more about the content of those firm activities that involve knowledge processing, activities such as R&D, engineering and marketing. (2) The boundaries of the firm and the interdependencies among firms. (3) Technological change and the institutional framework, and finally (4) the role of policy in facilitating or obstructing adjustment of the economy to changing circumstances (domestically as well as internationally) at both micro and macro levels.

Knowledge formation is a central process in the understanding of industrial and technical transformation and development, and is as such a fundamental topic of interest within ID. The least common denominator underlying firm adaptation, innovativeness and the creation of competitive advantage is knowledge and the process that enables firms to create new knowledge. The ID approach has implications for the questions explored and the way the world is perceived in the dissertation. The context of industrial dynamics – not least in times of globalisation – is the question of how firms can confront the competition, e.g. how can firms create and maintain competitiveness in innovation and production on a global level. The interdependence between firms as well as between industries is another essential building block in attempting to understand industrial transformation. This is also a policy challenge: which activities should
be promoted in order to secure future competitiveness and growth, and how can policy assure that essential parts of those globally organised industrial activities remain regional and/or national.

2.1 The empirical context

This dissertation is primarily supported through a research project funded by the Swedish Research Council. The research project – ELIT (Experiences and learning in technology) – focuses on knowledge formation in technology intensive activities. Through empirical studies the intention of the project is to study knowledge formation processes connected to innovative behaviour. The ELIT project consists of two subprojects, one that focuses on The transformations of technical and vocational training: a 20-year perspective and one that focuses on Learning and knowledge in technology intensive practices – and the results of the latter project is reported on this dissertation. Within the scope of this project, two larger case studies have been carried out upon which the discussions are based. These are briefly introduced below, and more thorough accounts of the findings from these two case studies are reported on in two working papers (Gustavsson & Laestadius, 2005; 2006).

2.1.1 The LMT case study

The focus in this case study is on firms in the low- and medium-technology (LMT) industries. This case study was carried out in connection to a wider European research project called PILOT (Policy and Innovation in Low-Tech). PILOT, financed within the EU’s 5th Framework Programme, is a collaborative project with members from eleven universities and research institutes in nine countries. The project comprises in total 43 case studies of LMT firms, of which the main findings are summarised in Hirsch-Kreinsen et al (2005). The aim of the project was to create new ways of thinking in regards to economic growth through innovations. As already discussed briefly in the introduction – and which will be dealt with more in depth in chapter four – much focus is on the high-technology industries when economic growth is discussed and consequently a large amount of the policy measures aimed at promoting growth are focussing on supporting the emergence and development of high-tech sectors.

In each member country, four studies were carried out in small and medium sized firms within the LMT sectors. The criteria for the selection of firms to be studied were that they had a minimum size (> 40 employees), were economically successful and technologically innovative. This dissertation builds primarily on the Swedish study of four small and medium sized LMT firms, although findings from the PILOT project as a whole support the discussions also. The four Swedish firms are Lammhults Möbel AB – a design-focused furniture manufacturer; Bahco Tools AB – a manufacturer of hand-tools; Ostnor AB – a domestic market leader in water taps; and Hallsta paper mill (a part of Holmen AB) – a producer of
newsprint and improved paper qualities. The results of this case study are discussed in paper 1 and 2. Within this LMT case study a minor detour to the mining district of Kiruna in Northern Sweden was carried out. This is mainly a conceptual exercise reported on in paper 2.

2.1.2 The Robot Valley case study

This study concerns a sector in the medium-high tech segment of the industry, i.e. robotics and robot-related automation\(^4\). This study was carried out in two steps where the first part of the case study generated the questions explored in the second part of the case study. The results of this case study are discussed in paper 3, 4 and 5.

Part 1

The first part of this study focuses on a Swedish regional innovation systems policy initiative. The initiative – Robot Valley – is part of a policy programme called Vinnväxt (Regional Growth through Development of Dynamic Innovation Systems) initiated by VINNOVA (The Swedish Governmental Agency for Innovation Systems). Robot Valley is an initiative that aims at making the region of Mälardalen in Central Sweden an internationally competitive, and even world leading, region within the field of robotics\(^5\).

In focus for this study is to analyse the regional innovation systems policy initiative at an initial stage and identify the opportunities and challenges for the initiative to promote the creation of a world-leading region within the robotics industry. Thus, the study is not intended to provide a comprehensive evaluation of the initiative per se, but rather to selectively focus on the initial prerequisites for ‘an innovation system in the making’, with a particular focus on the regional knowledge infrastructure. A number of Swedish research groups have studied several of the Vinnväxt initiatives, of which this study has been a part\(^4\). The results of a number of these studies are collected in Laestadius et al (2007).

Part 2

\(^4\) Primarily SNI2002 29 (292, 294 and 296). SNI (Svensk Näringsgrensindelning) is the Swedish Standard Industrial Classification which classifies companies according to the activity that is carried out. SNI2002 29 is the manufacture of machinery and equipment n.e.c.

\(^5\) Paper 3 in the dissertation discusses the Robot Valley initiative along with another Vinnväxt initiative, Triple Steelix. Triple Steelix is an initiative that aims at creating a world leading, regional innovation system based on the steel industry in the region of Bergslagen in Sweden. The empirical data from this initiative was collected by PhD Cali Nuur and Professor Staffan Laestadius and of which I take no credit (cf. Laestadius & Nuur, 2006)

\(^6\) This research was financed by the Dahmén Institute (DI). DI is a research organisation bringing together researchers from many fields of the social sciences. Its activities are primarily concerned with policy research, information and knowledge management and the process support for regional and national development processes. The name of the institute gives tribute to Erik Dahmén and his contributions in the field of industrial transformation and dynamics.
The second part of the study includes a closer look at one of the major industrial players in the Robot Valley initiative and within the robotics industry. This company’s development is interesting as it, in the midst of the regionally focused Robot Valley initiative, shows a development in the opposite direction. Shortly after the initiation of Robot Valley, this MNC moves its head quarters to Shanghai, China, and also starts building up a strong research unit there as part of a strategy to globalise the R&D activities of the company.

This case reveals a firm strategy that differs quite substantially from how policy organises for knowledge formation. Obviously, there are different objectives behind the organisation of knowledge formation processes if we look at the company on the one hand (proximity to a growing market, proximity to manufacturing facilities, transaction costs etc) and a policy actor as VINNOVA (strengthen regional industry and institutions, build regional infrastructure etc) on the other. However, if we focus on knowledge formation, it still indicates two different views on the knowledge formation process: one where the process of knowledge formation is strongly related to the geographical dimension (within the region) and another where it is related to the organisational level (within the company).

2.2 Case studies as a research strategy

When approaching a research question, the researcher is confronted with an abundance of proven research methods – each particular one pertaining certain advantages and disadvantages – but applied appropriately all may be used to successfully contribute to knowledge. The suitability of a specific research method may be determined by pragmatic concerns such as time restrictions, availability of and access to data etc., but ultimately it is the suitability of the research method, in connection with the research design, to scrutinize the research questions that is central. Thus what should be sought is a method that is well suited to the phenomenon that is to be investigated, or put differently, when applied the research method allows for the inclusion of all relevant factors that affect the phenomenon that is being studied.

A case study methodology builds primarily on a qualitative research strategy, although it can be based on a combination of qualitative and quantitative evidence (Yin, 1994). Some characteristics of a phenomenon are better captured with a quantitative approach – such as the magnitude of a specific phenomenon or with which frequency it occurs – whereas other characteristics can better or even exclusively be captured by a qualitative approach. A particular advantage of a qualitative case study methodology is that it allows for a holistic approach. While quantitative methods are used to investigate a specific phenomenon with a large amount of observations, the case study methodology employs a limited number of observations, but the in-depth studies can illuminate several aspects of the phenomenon under study. As such, the case study as a method of inquiry can cope with situations that have many variables of interest (Yin, 1994).
In real-life, phenomenon and context are often not easily distinguishable, and a strength of the case study method is its inclusion of the context in which a phenomenon is studied. The contextual conditions play a very large role – Lincoln and Guba (1985, p. 39) refer to this as the natural setting of the entity or phenomenon in focus, and argue for the contextuality by saying that “realities are wholes that cannot be understood in isolation from their contexts, nor can they be fragmented for separate study of the parts”. Because of its empirical richness, an important function of the case study is to detect the misconceptions or inconsistencies in generalised theoretical statements or conventional wisdoms. Whereas quantitative research tends to focus on descriptions and testing of derived hypothesis, a key purpose of qualitative research methods is to construct explanations and gain insights (Ghauri & Gronhaug, 2005). Thus, in qualitative methods, the emphasis is on understanding rather than on testing or verification.

The most important reason for a qualitative case study approach in this dissertation is that a quantitative approach would not allow us to see the phenomena under study here. In order to fully understand knowledge formation processes we need to go beyond quantitative data such as patents or R&D data – the kind of data that is often used to describe the technology intensity of firms and industries as well as regional and national performance. This type of quantitative data can capture inputs and outcomes of certain types of knowledge formation processes (for instance R&D as input and patents as outcome) but they do not capture all knowledge formation processes. Particularly as the focus is on capturing the complexity and variety in technology- and innovation-related knowledge formation processes, a case study approach is better suited. In the best of cases, we should have a stepwise development where qualitative research influences successive quantitative research and so on. The combination of quantitative and qualitative methods can be very forceful. To be able to interpret and understand quantitative data, it is necessary that the researcher has an understanding of the context and reality in which the data is collected. Mintzberg argues that quantitative data gathered from a distance should be supported by anecdotal data, or as he puts it (1979, p 587) “We uncover all kinds of ‘hard’ data, but it is only through the use of this ‘soft’ data that we are able to ‘explain’ them, and explanation is, of course, the purpose of research”.

2.3 The research process

The major stages in a research process are normally the formulation of a research problem, the construction of a theoretical framework, collecting and analysing empirical data and finally reporting the research results. These different stages are, in reality, often not conducted in strict chronological order. During the research process, new experiences and insights are gained, which lead to an increased understanding of the phenomenon under study. This normally influences the different steps of the research process. This is certainly descriptive of this study, and the empirical and theoretical research has to a large extent been an iterative and interactive process where the empirical findings have served as
inspiration for further – theoretical as well as empirical – studies. Consequently, the conceptual framework has evolved continuously. Below, I will describe this research process briefly.

I will start by a reflection on the role of the researcher. This is important to mention in the conduct of qualitative research. The researcher is the primary instrument for collecting, interpreting, categorizing and presenting data. In this process, the researcher is highly selective. As the collected data in qualitative approaches can be quite unstructured and unwieldy, the researcher must provide some coherence and structure to large sets of data while at the same time not losing the accounts and observations from which these are derived. In this collected material – often too vast to allow for the inclusion of all the aspects that the data illuminate – the researcher selects some aspects that are dealt with further and reported on. The researcher’s own understanding and prior knowledge affect this selection process. However, it is not only the selection process that is affected by the researcher. The analysis stage is also affected by the researcher’s interpretation of the data. It is through interpretation that the researcher makes sense of the collected data, and this process is naturally influenced by background and prior knowledge of the researcher. From my perspective, my background as a mechanical engineer from the Royal Institute of Technology has naturally influenced how I perceive of the world, and what aspects that have caught my interest. Basically, a genuine interest in industrial processes and activities lies at the core of the studies presented in this dissertation.

The overall research problem – to gain a better understanding of technology and innovation intensive practices – was known at the outset, but the actual research questions have developed gradually. As a consequence of this, the theoretical framework has also developed over the course of the work with the dissertation. At some instances, the empirical research was even performed before a theoretical framework was developed. This is particularly the case with the Robot Valley case study. Here, the empirical findings served as inspiration to go further down some theoretical avenues that were not visible at the outset of this research journey.

2.3.1 Selection of cases

Focus has been on selecting cases that offer the opportunities to learn as much as possible about the studied phenomenon rather than cases depicting some unique or extreme situation. Of course the selection of cases was also determined by a) the selection criteria of the PILOT project discussed above, and b) as a consequence of the research project financed by the Dahmén Institute to study an innovation system in the making (i.e. the Robot Valley). Focus throughout all case studies has been on firms involved in technology and innovation intensive activities. In some cases these activities can be located in the R&D department, which is the situation of the MNC in the Robot Valley case study, but these activities may just as well not be concentrated to an R&D unit, which is the situation in the LMT case study. In common for all industry sectors covered by the case studies is that they are all established sectors in terms of having
longstanding positions as part of Sweden’s industrial tradition. All can also be considered mature – even the fundamentals of robotics rely on technologies developed 30 years ago, although this industry just as in the pulp and paper industry or the furniture industry for instance constantly needs to integrate newer technologies and/or scientific findings.

2.3.2 Data collection

A large part of the empirical data collection has consisted of interviews. Personal interviews were chosen as the preferred strategy before for instance interview by phone or e-mail. Personal interviews allow for open-ended questions, which enables an understanding of the world as it is perceived by the respondents. Further, visiting the firms provides a better understanding of the activities carried out within each firm. All interviews have been tape-recorded and a majority of them also transcribed. Table 2 below shows the number of interviews and the time period during which the data collection was carried out in the two case studies.
Table 2: Number of interviews and time period for data collection in the two case studies.

<table>
<thead>
<tr>
<th>Case study</th>
<th>Number of interviews</th>
<th>Time period of data collection</th>
</tr>
</thead>
<tbody>
<tr>
<td>The LMT case study</td>
<td>31 semi-structured interviews</td>
<td>2003-2004</td>
</tr>
<tr>
<td>The Robot Valley case study Part 1</td>
<td>18 semi-structured interviews</td>
<td>2004-2005</td>
</tr>
<tr>
<td>Part 2</td>
<td>11 semi-structured interviews</td>
<td>2006-2007</td>
</tr>
</tbody>
</table>

In the LMT case study, a total of 31 in-depth interviews have been carried out at the four companies. Interviews were semi-structured and lasted between 1-2 hours with representatives from different hierarchical levels and from different functions within the company. Each visit also included a tour of the facilities including production and development departments of the companies. Each firm also completed a standardised questionnaire. This data was complemented with secondary data such as annual reports, company presentations, etc. Within the PILOT project, a common methodological basis was used with both a standardised questionnaire and a structured interview guideline.

The first part of the Robot Valley case study is based primarily on two sources. Firstly, 18 semi-structured interviews were conducted between 2004 and 2006 with industry, government and academia involved in the initiative. Secondly, the principle of public access has been exercised to obtain official records and applications, plans of action and other documents submitted by the initiative and by VINNOVA. The data was collected at an initial stage of the policy initiative.

Part 2 of the Robot Valley case study builds on the findings from part 1 of the Robotics case study, but with a focus on one of the MNCs in the Robot Valley. Thus, further data collection at the MNC was carried out for this part of the study. The research is based on a set of eleven semi-structured interviews, carried out primarily in 2006-2007, at two of the R&D sites of the studied company – one R&D unit in Västerås, Sweden, and the newly set up R&D unit in Shanghai, China. Interviewees were selected at managerial level, operational level and on Group level, on the basis of their overall knowledge of the workings within the organisation and insight and personal experiences from the international cooperation between the R&D units. Secondary data has also been collected such as company documents in order to obtain background description of the company, financial results and internal structure.

Different aspects of the empirical material are presented in the papers included in this dissertation. However, the format of journal papers often limits the possibilities of more elaborate case descriptions.

7 In contrast to the other parts of my case studies, the findings from this part of the study are not reported elsewhere.
These more in-depth case descriptions are instead collected in the two working papers referred to earlier (Gustavsson & Laestadius, 2005; 2006). The case descriptions in this dissertation can be characterised by a midrange approach somewhere between ‘thick descriptions’ that are often characteristic in for instance ethnographical and anthropological studies, and a distant analytical approach, more typical for studies based primarily on a quantitative approach. This is a reflection of the chosen research approach – the aim has been to gain an understanding and insight into the practices of the respondents and not to closely capture how these practices are carried out in their daily routines by conducting participating observations or even by ‘going native’.

2.3.3 Analyzing data

The purpose of analysis is to understand and gain insights from the collected data. Analysis is the activity of bringing order, structure and meaning to the mass of collected data (Ghauri & Grønhaug, 2005). The analysis has in this dissertation focused on discovering trends or patterns within the case studies that can help us understand the phenomena under study. A way to bring structure and meaning to the vast collected data is by conceptualisation. Analysis conducted through conceptualisations is an important part of the research analysis and this has also been the case here. In the course of writing a dissertation, several concepts are normally used as a means to make order and meaning of the collected material. Some concepts are used already at the outset whereas other concepts surface during the course of the research process. One such concept that has surfaced as an important analytical tool is complexity. This concept was not predefined but has gradually been introduced as a tool to describe and analyse the studied phenomena. This concept makes it possible to go beyond those prevailing views identified in the discussions on what it is that creates competitive advantage in the knowledge-based economy. Analysing activities in terms of their complexity enables a more nuanced view on which activities that potentially hold a competitive advantage. Another important concept that has presented itself during the research process as an important aspect to explain the observed phenomena under study is proximity. During the progress of my research, it became clear that this concept has different meanings to different actors – which also has impact on how these actors organise for knowledge formation processes.

The material has undergone various processes of verification and validation. The papers included in the dissertation have been presented in workshops within the two larger research groups in which they have been a part. The material has also been presented and discussed with the respondents in order to verify the case descriptions and to avoid any misconceptions or misunderstandings on my behalf. The papers that have been published (as well as the paper that has been submitted and accepted for publication) have met the critical eyes of several anonymous reviewers.
This chapter includes a discussion of the central concepts used in this dissertation. These concepts have bearing on issues discussed in all of the papers that this dissertation builds on, although the concepts are not always explicitly dealt with in each of the individual papers. One central concept is knowledge formation. However, this does not mean that this dissertation includes an attempt to define the concept of knowledge per se – this is a concept with many meanings in various fields and disciplines and it could be a dissertation topic on its own to unravel the many views and definitions of knowledge. For anyone who wants a more thorough account of different theoretical approaches to knowledge in firms, a reading of Amin and Cohendet (2004, pp 3-8) is recommended. This dissertation adopts the view that knowledge is different – and more – than information in that it enables its possessor to take action, physically or intellectually (Foray, 2000). As it represents and important foundation for the discussions in this dissertation, the concept of competitive advantage is also discussed. One of the central concepts in this dissertation is complexity. This is also discussed in this chapter. This concept is introduced here with the assumption that industrial activities involving knowledge formation processes that exhibit a certain degree of complexity possess a (temporary) competitive advantage.

3.1 Knowledge formation

There are many concepts related to the analysis of knowledge and the processes that generate knowledge, of which the meanings are often interrelated and overlapping. In this dissertation, the concept used is knowledge formation (the use stems from the Swedish word kunskapsbildning, which in English can be translated into knowledge formation). This concept overlaps with for instance knowledge creation and also learning, and it cannot be excluded that what in this dissertation is referred to as knowledge formation may by someone else be considered processes of knowledge creation or even learning.

Knowledge formation is in this dissertation interpreted as knowledge formed by new combinations or recombinations of knowledge. These combinations and recombinations are typically the result of some
kind of interaction. This can be the interaction between individuals, but also the interaction of different knowledge domains or disciplines. Knowledge formation does not necessitate 'new to the world' knowledge, in a strict sense. It may well be existing pieces of knowledge combined and put together in novel ways (as pointed out already by Schumpeter (1911/1934) in his discussion on innovation). We can take the Internet as an example to illustrate this: Internet was not the result of new technological developments. All the necessary technologies existed already – for instance wireless telegraphy (Marconi), wireless telephones and radio. Instead it is a result of a highly innovative way of combining these existing technologies into novel solutions. In how it is interpreted here, knowledge formation is not seen as the same thing as learning. Learning implies obtaining knowledge already held by someone else, as when a student learns from a teacher. Hence, the knowledge formation process in focus here goes beyond what can be learnt by reading textbooks or taking a class. It can for instance be the process of incorporating new knowledge, new material or new technologies into a specific context. However, learning is often an important component in knowledge formation.

The context in which knowledge formation takes place is highly important. In this area, parts of the Japanese management literature that discusses knowledge creation closely overlaps with how knowledge formation is perceived here. In this management literature, the context of knowledge creation is referred to as ‘ba’ (which roughly is the word for place in Japanese). ‘Ba’ is defined as a shared context in which knowledge is shared, created and used. Also in ‘ba’, interaction is central – that is the interaction amongst individuals or individuals and the environment (Nonaka, Toyama & Konno, 2000).

3.1.1 Tacit and codified knowledge

Knowledge can be both codified and tacit. The distinction of knowledge into codified and tacit knowledge (Polanyi, 1983/1966) highlights the fact that not all knowledge is equally easily transferred between actors. Codified knowledge is explicit and expressible through words or numbers, scientific procedures or universal principles. This knowledge is thus characterised by greater ease of sharing or transfer. Essential parts of knowledge, however, are tacit. Tacit knowledge is often characterised by a high level of context-specificity (e.g. Nonaka, Toyama & Boysière, 2001) and as being inseparable from action (Orlikowski, 2002), and these traits of tacit knowledge make it refuse smooth codification and transfer. Skills and know-how are associated with implicit routines and procedural rules and are shared through imitation or practices rather than through explanations or manuals (Nelson & Winter, 1982). Much of this tacit knowledge is merely unarticulated – it has not yet been subjected to articulation (Cowan, David & Foray, 2000). It may concern things we choose not to articulate or say, such as trade secrets, or things that people never got around to articulating even though it concerns skills that can be articulated (Janik, 1988). Some

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8 It should be noted that tacit and codified knowledge are seldom – if ever – two neatly separable dimensions of knowledge. A central issue here is the question of whether a body of knowledge can be completely converted into codified form without losing some of its original characteristics (this is discussed by Johnson et al, 2002)
of this tacit knowledge is not articulated as it would be too “costly” to attempt to articulate certain pieces of knowledge. It is also argued that some knowledge is of a nature that is incapable of precise articulation. One kind of such tacit knowledge is knowledge by acquaintance or familiarity such as sensuous experiences of the smell of freshly baked bread or the sound of a musical instrument. The second kind of this type of tacit knowledge is based on experiences acquired through practice – knowledge that is connected to the ability to see analogies between situations and deal with unforeseen occurrences (ibid). As more knowledge and information becomes generally available, knowledge formation processes that refuse or are difficult to transfer become essential to a firm’s innovative and competitive advantage (cf. Lundvall, 2006).

Although this dissertation does not deal directly with these dimensions of knowledge, the tacit dimension needs to be mentioned. If all knowledge were perfectly codifiable, the issues under study here would not exist. In the case of non-research intensive knowledge formation processes these generally rely to a large extent on application-oriented and practical knowledge (of which essential arts are tacit), in addition to publicly available (codified) knowledge. An epistemological distinction can be made between two forms of knowledge production: ‘natural science’ and ‘engineering science’ where the former is more related to knowledge that is theoretical and universal and the latter is knowledge that is instrumental, context specific and practice related (Johnson et al 2002; Laestadius, 2000). Simon (1996) refers to the latter as ‘science of the artificial’ as different from ‘natural sciences’. Where natural science is knowledge about the natural world and what is, artificial science is the knowledge about artefacts and how things ought to be in order to attain a certain goal and in order to function within the environment in which they operate. Scientific knowledge is, without excluding the tacit dimension, to a larger extent characterised by explicit and codified knowledge. Scientific knowledge is normally manifested in for instance scientific papers or registered patents, which are examples of knowledge that has been codified. One dimension of knowledge that is important for the discussions in this dissertation is practical knowledge. Practical knowledge includes both elements of codified knowledge such as design drawings and product specifications, and elements of tacit knowledge such as accumulated experiences and verified, evolutionary routines for technical problem-solving etc. Also in relation to the role of proximity in knowledge formation, tacit knowledge is relevant. One important part of the discussions on proximity is based in the acknowledgement that tacit knowledge is difficult to transfer, whereby geographical proximity has been seen to facilitate knowledge formation processes that involve tacit knowledge. However, whether it is the geographical proximity that enables the sharing and transfer of such knowledge is a question currently engaging many scholars. This issue is also addressed in this dissertation.

3.2 Competitive advantage

How nations and companies compete is naturally a topic of continuous interest to researchers, managers
and policy makers alike. Competitive advantage can be discussed on a firm level as well as on a regional or national level. Literature on the so-called resource-based view of the firm (Penrose, 1959) argues that a firm’s resources can be a potential source of competitive advantage if they are valuable (as in exploiting opportunities and/or neutralising threats), rare, non-imitable and non-substitutable (Barney, 1991). Competitive advantage can also be provided by secured market niches that are a result of for instance a technological monopoly (e.g. through patents) or a market monopoly (e.g. through regulated markets etc) – yet it is primarily not such situations of (temporary) monopolistic competitive advantage that are in focus in this dissertation.

As mentioned above, knowledge and knowledge formation are at the core of the discussions on the creation of competitive advantage. To become industrially relevant, however, knowledge formation processes have to be transformed into capabilities of firms. The capabilities concept captures the insight that even if firms have the same repertoire, in terms of for instance knowledge assets and technological resources, some will be more successful than others. A firm with dynamic capabilities has the ability to exploit existing (internal as well as external) capabilities along with developing new ones (Teece et al, 1997). In a Schumpeterian (1911/34) line of argument, it is the creative combinations of distributed assets, which upset the equilibrium state of the economy, that provide firms with a (temporary) competitive advantage. The same line of reasoning can be applied on nations and regions alike, as these also compete with resources that, applied and exploited in innovative ways, can provide an advantage in comparison to other regions or nations (Lundvall, 1992; Porter, 1990). There is also a strong policy drive, of course, to promote processes that provide competitive advantage – sometimes on firm level but more often on regional and national level (and also on more aggregated levels such as transnational organisations as the EU).

The intimate connection between research-intensive, so called high-technology, activities and the KBE in the discussion on competitive advantage, has led to that formal R&D expenditure has become a widely used measure of technological performance of countries, sectors and of firms. This has parts of its origins in the Frascati manual (OECD, 1981), in which an emphasis was given to the distinction between novelty and routine. A result of this was a narrow definition of industrial R&D that excluded many industrial activities, such as design and engineering activities, production engineering and training. Dissatisfaction with the biased focus of the Frascati manual of R&D as input indicator of competitive strength, and the stronger focus on innovation in the discussions on economic development, which particularly empirically has been shown to not always be conducted within units that are formally entitled R&D departments (Freeman & Soete, 2009) led to a development of a new set of indicators in the Oslo Manual (cf. Smith, 2005). Particularly innovation-output indicators were developed to better capture the changing nature of the innovation process itself. It is for instance not seldom so that the locus of industrial innovation can be far upstream or downstream from the industry or firm that carried out the research. Yet, in practice the strong emphasis on R&D and related activities as an indicator of competitive advantage remains.
Further, it is often argued that competitive advantage is best supported by the existence and promotion of geographically proximate interactions and regionally embedded dynamics. As Porter argues: “anything that can be efficiently sourced from a distance through global markets and corporate networks is available to any company and therefore is essentially nullified as a source of competitive advantage” (Porter, 1998: p 77). Accordingly, it is essentially the resistance of knowledge to a smooth transfer, or an immobility of knowledge, that provides a competitive advantage. And, as Porter argues, this competitive advantage can be highly local – which is represented by the clustering tendencies that are an obvious part of the global economy. Yet, the ‘globalisation paradox’, where we on the one hand see strong tendencies of clustering and on the other an increasing globalisation of industrial activities, indicates that competitive advantage does not solely rely on locally embedded interactions.

Thus, the position taken here is that competitive advantage is essentially about those knowledge formation processes that are difficult to instantly move or replicate by a competing actor. These processes provide a situation of temporary monopolistic competition, where an actor for at least some time can have a temporary competitive advantage within a defined niche, as it will take time and effort for a competitor to catch up. This competitive advantage is not primarily defined by the level of R&D investments on the one hand or on the level of local embeddedness on the other. It is instead necessary to find additional approaches to the analysis of industrial activities and their potential competitive advantage. In this dissertation, the concept of complexity is introduced for the purpose of analysing industrial activities. It is the assumption that a certain complexity in the knowledge formation processes that underlie industrial activities leads to an immobility and resistance of transfer, which consequently contributes to a (temporary) competitive advantage.

3.3 On the complexity of knowledge

It has become rather commonplace to assert that there is an increased complexity in today’s business environment. It is also a notion that has been deployed in several disciplines, and applied on different levels (component or systems level for instance). Certainly, the world can be described as more complex in many ways. The network character of the economy increases the importance of inter-firm collaboration. For instance, innovations are more often than not a combination of several different technologies, and technologies are often a combination of several different disciplines. Taken together, innovations are increasingly the result of interactions in complex networks of interdependent actors, where many different technologies and scientific disciplines interact.
In his seminal works on complexity, Simon (1962, 1976, 1996) characterises a complex system as “one made up of a large number of parts that interact in a non-simple way” (1962, p 468). He defines complexity in systems in the following four points (Simon, 1976, p 507):

- “Systems that have many components may be considered complex relative to systems that have few. Hence the cardinality\(^9\) of a set may be taken as one measure of its complexity.”

- “Systems in which there is much interdependence among the components are generally regarded as more complex than systems with less interdependence among components.”

- “Systems that are undecidable may be regarded as complex in comparison with those that are decidable.”

- “The complexity of systems may be measured by their information content [...] By this criterion, systems with many identical components are less complex than systems of comparable size whose components are all different.”

This dissertation is not concerned with the complexity of a product’s architecture or the complexity of a highly automated production process or with the complexity of business networks etc. However, the concern is what the effects of such increased complexities have for the underlying knowledge formation processes. Following Simon’s definition of complexity above, and if we apply this definition on knowledge, a piece of knowledge is complex if it comprises many elements that interact richly. Also, the last two points indicate that a higher degree of uncertainty and greater distance between the elements in the system – in terms of the knowledge that is involved – increases the complexity of knowledge. Simon’s view on complexity can be connected to a more recent elaboration on the complexity of knowledge offered by Grandori (2001). She distinguishes between two components of knowledge complexity: computational complexity and epistemic complexity. Computational complexity refers to a system’s number of elements and the connections between these elements. Epistemic complexity refers to the difficulty to establish causal links and to observe a particular phenomenon. It also relates to the limitations in our ability to construct valid and reliable knowledge. In addition, Grandori (2001) discusses knowledge differentiation, which is an important feature in determining the complexity of the relations between different elements. In the following, these three dimensions introduced by Grandori, that can be related to Simon’s four characteristics of complexity, are discussed.

\(^9\) Cardinality is the mathematical term for the number of elements in a set. For example, the set \( \Lambda = \{2,4\} \) contains 2 elements, and therefore the cardinality of \( \Lambda \) is 2.
3.3.1 Computational complexity

Computational complexity is very close to Simon’s (1962) characterisation of a system’s complexity in terms of the number of nodes in a system and their interdependence. It refers to the number of elements or components in a system that is required and their connections (Grandori, 2001).

“Systems that have many components may be considered complex relative to systems that have few…”

This is highly relevant in today’s business environment where a higher degree of specialisation of the single firm results in decentralisation and vertical disintegration. As firms are specialising their activities more and more (which is popularly referred to as focusing on the core competence), they are consequently buying more parts, components, and services from outside. This leads to a distributedness in terms of where the knowledge necessary for a certain activity is located as it becomes more commonplace to draw from knowledge developed within other firms and even within other industries. Also, many industries incorporate technologies derived from a large number of different disciplines: the pulp and paper industry is including nanotechnologies to improve paper qualities; the transformation of the mining industry from an industry relying on manpower to an industry relying on autonomous, remote-controlled machines; and robots are developed to not only operate in industrial settings but also to function in close interaction with humans – from domestic robots that assist with cleaning and maintenance in people’s homes to robotics for healthcare with robots that can even perform surgical procedures – which requires the integration of for instance sensory and navigation systems as well as artificial intelligence (AI). Thus, a greater number of nodes in the system in terms of the involved scientific or technological disciplines can be considered a source of increased computational complexity.

Also the actual number of nodes in a system – as in the number of organisational units for example – affects the computational complexity. Globalisation has enabled, but also in many cases necessitated, a global presence of firms. Two major factors are often mentioned as underlying this globalisation of firm activities: liberalization and deregulation of trade and investments, and the rapid development and diffusion of ICT. However, also the need to decrease time-to-market through reduced product development time and product life cycles as well as the acquisition of specialised external capabilities are influential factors. Hence, there are many reasons why the traditional home-centred organisation is moving towards a more distributed organisational set-up. The rationale behind this increased global presence has shifted from market customization to access to foreign technology developments and to regarding foreign units as important sources of innovation (Hedge & Hicks, 2008). This globalisation process is evident also among many Swedish firms. For example, the share of R&D performed outside Sweden increased from 22 percent to 43 percent between 1995 and 2003 (UNCTAD, 2005). Thus, a
greater number of nodes in the system can also be considered a source of increased computational complexity.

“Systems in which there is much interdependence among the components are generally regarded as more complex…”

Yet, it is not only the number of nodes in the system that is relevant when we discuss computational complexity. If we have many nodes in a system, but the nodes are not really interdependent, the complexity of the knowledge formation process of the individual unit is not necessarily greater. This can be the typical situation of loosely-coupled corporate networks where there is vertical specialisation and each unit is developing relatively stand-alone products (Birkinshaw, 2002). However, in many cases there is interdependence between the activities of different nodes. And given the above discussion about vertical disintegration and globalisation, this interdependence is not restricted to an intra-organisational or intra-regional or national perspective, but can also exist across company borders as well as geographical borders. Complexity can thus be defined in terms of the level of interdependence inherent in the subcomponents of a piece of knowledge (Simon, 1976). “A high degree of interdependence indicates that many ingredients influence the effectiveness of others so that a change in one may dramatically reduce the usefulness of the recipe […] Low interdependence implies small cross-component effects and a corresponding opportunity to adapt and change ingredients independently” (Sorensen et al., 2006: 998).

Globalisation is a term used throughout this dissertation, and it calls for a brief clarification of how this term is perceived here. It is a concept that has its supporters as well as its sceptics. The ‘hyper-globalists’ argue that we live in a borderless economy where nation-states have lost their importance. Global corporations with no loyalty to a certain place or community reply to a homogeneous consumer demand by providing standardized global products. The ‘sceptical internationalists’ question the ‘newness’ of the current situation. They argue that we do not live in a global economy but in an international one. In such an economy, the nation state still plays an important and influential role. Therefore, the ‘sceptics’ prefer to talk about internationalisation rather than globalisation (Dicken, 2007; Vertova, 2006). It does not fall within the scope of this dissertation to determine which of the two positions that is closest to the truth in regards to recent economic development. What is emphasised in the use of the term globalisation here are the qualitative changes in the global economy – in terms of where and how production, distribution and consumption of goods and services take place. If economic integration has historically to a larger extent been characterised by arm’s-length exchange of goods and services between independent firms, which can be referred to as a shallow integration, today’s economy is to a greater extent characterised by deep integration – i.e. complex and integrated networks of actors with a greater geographical distribution (Dicken, 2007). Thus, globalisation can be seen as a process that is wider and deeper and with a higher degree of interdependence. This implies that even if the level of internationalisation is constant (for instance, the number of geographically dispersed nodes is unchanged), increased globalisation would imply that there is
a higher degree of interdependence between the nodes. Thus, a higher interdependence between the nodes in industrial activities can also be considered a source of increased computational complexity.

3.3.2 Epistemic complexity

Epistemic complexity deals with the notion that we need to understand a set of things or situations – i.e. we need prior knowledge and experience – in order to understand a complex situation. This dimension refers to the difficulty to develop valid and reliable explanations and models of action, due to the unobservable nature of certain phenomena (Grandori, 2001). Such complexities can be captured in for instance some organisational routines – as resident in certain interactions that correspond to the successful solution to a given problem (Nelson & Winter, 1982). It also refers to the difference between knowing and communicating a fact and Polanyi’s (1983/1966) famous words that “we know more than we can tell” which is how he describes the tacit dimension of knowledge. Epistemic complexity is closer to what Simon says about undecidable systems which are more complex compared to systems that are decidable (Simon, 1976):

- “Systems that are undecidable may be regarded as complex in comparison with those that are decidable.” (Simon, 1976, p 507)

This means that the complexity increases if the set of potentially useful combinations from a wide set is difficult to decide upon. The classical model of rational choice “calls for knowledge of all the alternatives that are open to choice. It calls for complete knowledge of, or ability to compute, the consequences that will follow on each of the alternatives. It calls for certainty in the decision maker’s present and future evaluation of these consequences, no matter how diverse or heterogeneous, in terms of some consistent measure of utility” (Simon, 1979, p 500). However, in many situations we do not have the full knowledge and cannot predict the exact outcomes of a particular action, or it would be too time or effort-consuming to decide upon the most rational choice out of a large number of options. Often, as Simon argues, processes of decisions are better described as situations where “the consequences of choosing particular alternatives were only very imperfectly known both because of limited computational power and because of uncertainty in the external world, and the decision maker did not possess a general and consistent utility function for comparing heterogeneous alternatives” (ibid, p 501).

Technological problem solving is often characterised by situations of such undecidability and uncertainty. The early phases of searching for the solution to a problem are characterized by high uncertainty, and the design and characteristics of the final solution are only vaguely defined. In the end, among a variety of ideas or solutions, all but one will be eliminated. In this phase, chance and trial-and-error processes may play a very influential role in the events that lead up to the point where one solution is selected before
others (Abernathy & Utterback, 1978; Utterback, 1994). Epistemic complexity can thus be interpreted as a dimension of complexity that lies close to engineering science or ‘science of the artificial’ where the determination of cause-effect relationships is facilitated by experience and an understanding of the contextual conditions.

3.3.3 Knowledge differentiation

Knowledge differentiation is a central feature in determining the complexity of relations between nodes. Differences in technological orientation, educational background, organisational affiliation and cognitive alignment can result in diversity in terminology, differences in how we perceive of a particular situation, and which knowledge and practices we use (Grandori, 2001). Such “cognitive distance” (Nootenboom, 2000) can decrease the mutual understanding and the ability to identify, absorb and apply knowledge of others – what Cohen and Levinthal (1990) call the absorptive capacity of an organisation. Complexity increases if the elements and interactions are widely different. Accordingly, a system in which there are several different types of knowledge bases interacting is more complex than a system based on one type of knowledge only. This relates to Simon’s last point on complex systems:

- The complexity of systems may be measured by their information content […]. By this criterion, systems with many identical components are less complex than systems of comparable size whose components are all different.” (Simon, 1976, p 507)

An increasing knowledge differentiation is then a source of increased complexity. It can increase both the computational and the epistemic complexity. In a system with many interdependent nodes, a greater cognitive distance between the involved actors makes the interaction more complex. A system with high uncertainty – i.e. it displays an epistemic complexity – is also more complex if the involved knowledge disciplines are highly different – this requires a greater amount of experiences and prior knowledge from several disciplines instead of only one.

However, this complexity can be reduced if the involved actors share some contextual dimension, such as the same organisational context, industrial experience or educational background. Actors who share a common knowledge base can more easily communicate and share knowledge as well as access and incorporate knowledge from one another. The context of knowledge formation has already been pointed out as a central aspect in understanding the process of knowledge formation. Space as a contextual dimension has in recent years gained increased attention, and if the idea of space was initially geographically defined, this is gradually changing as “evidence comes to be offered of innovation and learning based on distant networks and communities linked through cultural ties, travel and sophisticated
communications, in the travel of ideas and knowledge, and in the links of localized clusters with sites many thousands of miles away” (Amin & Cohendet, 2004: p 86).

This makes our understanding of space much more complex but also more interesting. The idea of space need not take its analytical point of departure in the geographical dimension. For instance, Amin and Cohendet (2005 p 465) define space as “a network of both contiguous and non-contiguous relation of various length, shape and duration”. Such spaces are essentially ways in which actors organise themselves in order to pursue a particular corporate goal. This can be in the shape of task teams, face-to-face encounters, global networks etc.” This also relates to the concept of ‘ba’ which describes the context where interactions take place, but without defining this place as a geographical dimension primarily. The corporate organisation, for instance, can be such a space that offers a common frame of reference, (ideally) shared goals and vision, and common organisational terminology and routines that enable the sharing and transferring of knowledge across geographical distance. This means that if we include the role of knowledge differentiation as a central attribute in defining the complexity of certain relations and interactions, we see that it is not necessarily so that increased geographical distances only and always imply increased complexity. If the actors in the various nodes share a common knowledge base they may well be able to interact and share knowledge (also complex knowledge) across great geographical distances. A common example to illustrate this is the academic community, where international networks and international conferences are often the forums where interaction takes place and knowledge is shared.

There is a distinct causality between these concepts introduced above (i.e. knowledge formation, competitive advantage and complexity). The complexity of knowledge influences the knowledge formation process, which in turn impacts the competitive advantage that a certain activity may possess. Activities characterised by knowledge that involve an epistemic and/or computational complexity rely on many interdependent nodes or on the involvement of many different types of knowledge or where the expected outcome is only vaguely defined. This results in more complex knowledge formation processes, as interactions between more individuals or knowledge disciplines are needed in order for knowledge to be formed. And in turn, activities characterised by a high degree of complex knowledge formation processes have a potential competitive advantage over activities based on less complex knowledge formation processes. As argued above, competitive advantage is based on an ability to manage a network of many dispersed nodes, or managing a technology that relies on many different knowledge disciplines. In the end, it is those activities that exhibit some complexity in terms of their knowledge formation processes that are of interest in defining which activities that provide a firm or a region, for instance, with a competitive advantage.

The position taken here is that the complexity of a process or an activity is an empirical question: it is not best determined on account of its connection or not to the high-tech sector or its demonstration or not of
geographically proximate connections and interactions. And the following chapter presents some of the most important findings from the empirical studies related to this.
This chapter includes a discussion of the central findings in the five papers that this dissertation builds on. Each paper obviously contains findings and conclusions that are directly linked to the research focus of each individual paper. However, these five papers also have common issues that crosscut the individual focuses of the papers, which are addressed within the three research questions that this dissertation sets out to study. This is illustrated in Table 3 below. The first research question is the role of non-research intensive knowledge formation processes in the creation of competitive advantage. The second research question concerns the issue of how knowledge formation processes connected to the creation of regional competitive advantage can be promoted. The third research question addresses the role of proximity in knowledge formation processes in the creation of competitive advantage.

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Table 3: Overview of which papers that address the three research questions.

4.1 What is the role of non-research intensive knowledge formation processes?

The OECD taxonomy defines a high-technology industry as one where the ratio of total R&D expenditure over total turnover exceeds five percent. Industries that qualify within this category are for instance the aerospace industry, pharmaceuticals, computers and electronics-communications. Medium-high tech industries (R&D intensity between 3 - 5%) are for instance electronic machinery, motor vehicles, chemicals and non-electrical machinery. Medium-low tech industries (R&D intensity between
0.9 - 3%) include ship-building, fabricated metals products, rubber and plastic equipment etc. Low-tech industries (R&D intensity below 0.9%) include petroleum refining, ferrous metals, paper and printing, textiles and clothing, and wood and furniture (OECD, 2001).

The division of industries into categories depending on the varying R&D intensity represents, however, a narrow view on industrial activities and a narrow view on knowledge. The KBE is often connected to the growth of high-technology sectors, such as ICT, biotechnology, pharmaceuticals and computers, or with knowledge-based services such as software, R&D or consultancy (Cooke et al, 2007). When the future prosperity and growth of Europe – and Sweden – is discussed, little emphasis is placed on the so called low- and medium-tech sectors. However, the high-tech sectors still constitute a small part of the Swedish (as well as the European) economy (as shown in chapter 1). Primarily focussing on high-tech sectors implies the exclusion of large parts, or in fact the major part, of economic activities. The high-tech sector is (still) small and it is therefore difficult to argue that this should/could be the only real driver in the economy. Low- and medium-tech industries are important and will most probably continue to be so also in the future.

The aim of this dissertation is to add to our understanding of the characteristics of industrial knowledge formation processes and their connection to competitive advantage. A problem with the current approach to classifying industries in terms of high- to low-tech is that it is based on one indicator - internal R&D expenditure. This measure misses out on at least two important, and interrelated, issues related to knowledge formation (cf. Hirsch-Kreinsen et al. 2005; Smith, 2002). First, R&D should not be regarded as the only relevant measurement of knowledge formation activities. It represents a very narrow view on the cognitive characteristics of knowledge as it includes only knowledge formed through activities carried out through the R&D departments. Output in terms of R&D expenditure is one dimension of knowledge formation, but much knowledge is formed also outside the R&D departments.

There is also a great variety in how innovation and development expenses are reported as not all firms have an R&D department or a special R&D account. This adds to the incompleteness of using R&D as measurement. In the LMT case study this was the situation in two of the firms where substantial investments in the development of new machinery was not at all, or only minor parts were, reported and accounted for as R&D. In the case of Hallsta, a paper machine investment amounted to costs of about 200 MEUR but none of the acquisition and development expenses were accounted for as R&D (cf. paper 1; Gustavsson & Laestadius, 2005; cf. also Laestadius, 1998). Another example of significant development work within firms is carried out in close collaboration with customers and suppliers. LKAB develops refined iron ore products that are customized according to each customer’s requests, which requires close interaction with the customer in the development process. This does not show in the R&D expenditure of the company, even though it is a significant contribution to the company’s competitiveness (Rönnberg, 2009).
However, regardless of various fashions of reporting R&D and what is included in the different R&D budgets, the main argument here is that it is not the only relevant measurement of the level of technology- or innovation intensity. The LMT case study shows that also firms categorised as low- or medium-low tech can be highly technology- and innovation-intensive. In fact, the cases that displayed the most intensive use of advanced technology in their activities were those that are found at the very bottom of the OECD technology ranking of industries, namely paper production and mining. In both cases, the production process is highly automated and the task of operators is to a large extent the control and supervision of autonomous or remote-controlled machines. The mining company LKAB was actually voted ICT company of the year in 2005 in the province of Norrbotten in the northernmost part of Sweden.

Second, R&D expenditure as the sole indicator excludes many of the ways in which knowledge is formed. Most firms rely on a variety of knowledge bases/types/sources for their activities. Some of this knowledge is formed within R&D departments, some of it is formed in other parts of the company and additional parts of it is generated outside the company. The ability to source knowledge from outside has become increasingly important as a result of factors such as specialisation, more rapid technological change, increased development costs and an increased complexity of technology etc (in paper 1 this is referred to as a company’s networking capability). For small companies such as the four PILOT firms, collaboration is often key to the development of both processes and products. This is partly because these are all relatively small firms and partly because of the distributed character of technologies and knowledge underlying most innovations today.

Generally, the case study firms show a great dependence on firm-specific experience and know-how acquired through learning-by-doing, trial-and-error experiences and apprenticeship systems. However, they also show a reliance on additional knowledge disciplines, both scientifically based knowledge as for instance materials research, nano- and biotechnologies as well as basically non-scientifically based knowledge within design, logistics and marketing (cf. paper 1 and 2). There is also evidence of changing requirements on the skills and knowledge of the personnel. In the mining case, there has been drastic changes in the requirements of the miner, where it is no longer a dirty and heavy job carried out hundreds of meters below the ground, but it is a job that requires skills in ICT and computer-controlled operations in order to handle drilling, loading and hauling by remote control from above ground (paper 2).

In paper 1, this ability to combine technologies and disciplines is referred to as a company’s integrative capability, i.e. how good a company is at creating complex systems out of dispersed knowledge bases. This can involve for instance the integration of a more engineering-based knowledge, such as advanced machine knowledge and automation expertise, with more science-based knowledge. Examples of this ability to combine different types of knowledge are Ostnor’s water tap which is equipped with advanced
flow control systems and temperature regulation, Hallsta’s paper which can be used in new applications as a result of scientific findings in, for example, chemistry and biochemistry, and Lammhults that produces new chairs through a revolutionary technology where wooden fibres are pressed together under high pressure giving a material that can be manipulated and shaped in similar ways as plastics. This is also discussed in paper 2, as a challenge but also potential opportunity for a region based on a traditional industry such as mining.

However, this is not something exclusive to the LMT sectors. Also within the Robotics case study we can trace a multitude of disciplines that have impact on the development of robot-related technology. Inputs from engineering such as hydraulics, mechatronics and industrial control systems is combined with science-based disciplines such as computer science, optics and laser technology and geographic information science and more social science based disciplines such as cognitive science, human-machine interaction and interaction design (Gustavsson & Laestadius, 2006).

What is of interest is not the passive receiving of technologies developed elsewhere. It is a question of a capability to transform acquired technologies in order to fit the specific processes or products of the company. In fact, the ability to adapt external knowledge to suit their respective activities is important to all PILOT firms, much due to the, in many cases, highly firm-specific technologies and equipment developed internally, by incremental improvements and over the course of many years. Thus, purchasing turnkey solutions “off-the-shelf” is often not an option for these firms. This is discussed in paper 1 as a company’s transformative capability, i.e. the ability to transform generally available knowledge into plant- or firm-specific knowledge, and the ability to transform conventional technologies into firm-specific high-performing processes and products. The aforementioned acquisition of new machines at two of the PILOT firms is a good example of the importance of an ability to combine various scientific disciplines and transform these into an application suitable for the particular activities and requirements of the company.

Not only is it important to look at the non-research intensive sector on its own. It is also important to highlight the interdependency between high-technology and low-technology sectors. It is obvious that R&D as indicator does not capture the important cross-border – i.e. distributed – character of knowledge formation today leading to an in- and outflow of knowledge and innovation between firms and between industries as innovation often takes place in cooperation with external actors (other firms, institutions, universities etc). Further, this cooperation is not necessarily restricted to occur within a specific industry, on the contrary; innovation is often a result of the interaction and collaboration across industry sectors. LMT firms are the most important users and consumers of high-tech products. This influence on the development of high-tech products is overlooked in the current R&D-based classification of industries (cf. Robertson & Smith, 2007, Hirsch-Kreinsen et al, 2006). As high-technology customers, LMT firms are important drivers of the technological development both in regards to the development of new
machinery (as in the cases of Hallsta and Bahco) and new materials technologies (as in the case of Lammhults) (as discussed in paper 1 and 2).

To summarise this section, it should first be emphasised that industries should not be treated as black boxes. Variety in terms of the knowledge formation processes, their potential complexity and possible contribution to competitive advantage should be analysed not at the industry or sector level but at the firm level. In a similar line of reasoning Kirner et al. (2009), in an empirical analysis of the German industry, demonstrate the large heterogeneity of firms within the same sector (high-, medium- or low-technology sectors). Consequently, it is incorrect to equate low-technology sectors with low-technology firms. High-, medium- and low-tech firms can be found within all technology sectors. Equally, we can find successful as well as not so successful firms within all sectors. Within the PILOT project a large number of successful LMT firms were identified and studied throughout Europe (cf. Hirsch-Kreinsen et al, 2006). Moreover, it is misleading to define high-tech countries as high-growth countries (Hirsch-Kreinsen & Jacobson, 2008). The impressive growth rates of both China and India as well as several Eastern European countries, which has up until quite recently been most associated with non-high tech activities, although shifts in focus can be seen here with growing high-tech innovation in China for instance (cf. Laestadius et al, 2008). By this follows the important recognition of the relative importance of the LMT sectors. Despite its sometimes not so flattering reputation or neglect in the discussions on future economic prosperity and growth, the LMT sectors dominate the economies of both developed and developing countries (whether measured in output, capital investment and employment). The LMT sector account for more than ninety percent of output in the European Union as well as in the U.S. and Japan (Hirsch-Kreinsen et al 2006; Robertson et al, 2009).

What the findings presented in this section has provided examples of are primarily two things. First, we have seen evidence of complex knowledge formation processes taking place also in LMT sectors. The effective use and combination of internal and external knowledge in knowledge formation is highly typical of many LMT firms. To be successful, this requires an ability to identify, integrate and transform general knowledge into highly firm-specific solutions. A recent Special Issue on innovation in LMT industries in Research Policy (Robertson et al, 2009) provide evidence in line with the findings presented above. It points to the role of adaptation as technologies developed elsewhere must be customised locally. Further, the special issue highlights the role of diffusion of innovation to LMT firms, as these firms have the important role of adopting, as well as placing strong demands on the development of, high-technology solutions. This is in line with the second main finding discussed in this section, namely the important interdependencies between sectors. There is not only an increasing need but also an increasing opportunity in making innovations through the interactions between scientific knowledge and non-scientific knowledge. These interdependencies are mutually beneficial – LMT firms depend on high-technology developments for both product and process innovations, and consequently these LMT firms, as consumers, contribute to economic growth of high-technology firms.
4.2 How can regional competitive advantage be created?

The relationship between specialised knowledge and geographical concentration is not a newly acknowledged notion (it was discussed already by Marshall (1916/1920) in his work on industrial districts). This pairing together of knowledge formation and geographical proximity has emerged from theoretical developments on the economics of agglomeration and localised learning – i.e. that firms build their competitive advantage on and in interaction with localised capabilities. Recently, it has gained renewed interest, much influenced by the developments of high-technology districts such as Silicon Valley (e.g. Saxenian, 1994) and regional growth based on more traditional industries, e.g. the design-intensive and craft-based industries of Third Italy (cf. Putnam, 1996) and Gnosjö in Sweden (cf. Wigren, 2003). As a result, concepts such as clusters (cf. Porter, 1998) and regional innovation systems (cf. Asheim & Gertler, 2005) have emerged. The argument underlying this view on geographical proximity is that it is seen as promoting the trustful relationships between actors (through for instance a common language and shared values and norms which can facilitate communication, provide shared frames of reference etc). This, in turn, facilitates the establishment and upholding of informal channels of communication and knowledge exchange, and particularly the exchange of tacit knowledge. Also a common institutional setting, in terms of norms, corporate practices, labour markets and financial institutions, is relevant and beneficial for knowledge formation and innovation (Cooke et al, 2007).

Somewhat paradoxically, globalisation has reinforced the interest in the regional level. Regional innovation systems theory has been adopted by regional policy makers, and is an approach that rather reinforces the geographical dimension and its role for knowledge formation (as discussed in papers 3 and 4). This despite the fact that the early theoretical developments on the innovation systems concept (e.g. Lundvall, 1992) explicitly argues that even though many important features of the system in focus are localised, it is important to view the innovation process as open and transregional/transnational (cf. paper 3) and that knowledge formation processes are becoming more international and the knowledge networks more global.

Thus, globalisation has, to a large extent, contributed to the increased focus on the geography of industrial activities. We see on the one hand a high level of geographical concentration of firms and certain places emerge as specialised clusters or centres of excellence. Although the current globalization of activities implies that certain, previously localised, production factors will become more generally available, and the technology necessary for industrial activities is internationally available on a general level – hence weakening former technological advantages – there will still be distinctive infrastructural, social or institutional features that lead to the agglomeration of activities in certain locations and the varied growth patterns of regions (cf. Malmberg & Maskell, 2005) and an uneven distribution of innovation and its
related activities (e.g. Asheim & Gertler, 2005; Coenen, 2006). On the other hand, we see the importance of international presence and international collaborations in technological activities, for instance, and these are not limited to occur within a specific geographical region or area (paper 3 and 4). Firms scan globally for favourable combinations of production factors and factor prices.

This globalisation paradox is perhaps best understood by seeing dynamic milieus as – probably more often than not – distinguished by an ambiguous character of closeness and openness (as discussed in paper 3 and 4). Some of the former advantages of clustering or geographical proximity can be offset by the advantages of decentralisation or dispersion: advantages such as proximity to foreign production units, closer to suppliers and customers, the access to specialised knowledge in other clusters etc (as discussed in paper 4).

However, despite theoretical reservations as to the sufficiency of a geographically defined place such as the region as locus of knowledge formation and innovation, which is discussed in paper 3 and 4 (cf. Amin & Cohendet, 2005; Lundvall & Borrás, 1997; Malmberg & Power, 2005 among others), this view has gained much influence in policy circles. There are various reasons as to why policy actors find the regional approach so appealing in the design of technology and innovation policy. The example of successful dynamic regions such as Silicon Valley, Third Italy and Gnosjö is perhaps the strongest reason. Further, by breaking down the level of analysis to a less aggregated one – for instance from the national to the regional – it may be easier to identify the system’s components. And lastly, the view that important parts of knowledge is ‘sticky’, despite advances in information and communication technology, has also contributed to an increased focus on the region as a locus of innovation and growth creation. This has led to what we can call a regionalisation of innovation policy (as discussed in paper 3).

This regionalisation of policy is studied in the Robot Valley case study. The regional innovation systems policy initiative Robot Valley, in the region of Mälardalen, is focused on strengthening and promoting a world-leading region within robotics-related industries. This is one of eight initiatives within the Swedish policy programme Vinnväxt, a programme that builds on the concepts of Triple Helix (which holds that knowledge is best generated through the interplay of industry, academia and public institutions) and RIS. This case provides examples of some of the challenges as regards what to include within the boundaries of an innovation system; challenges that are particularly tangible in relation to a downscaling of the innovation systems approach from the national to the regional level. This is something that becomes highly evident in small open economies such as Sweden, where regions may be comparable to the size of cities in many other countries (and Sweden with a population of approximately nine million can be comparable in size with many regions in other countries). A first challenge is directly related to defining the borders of the innovation system – the system’s domain (Laestadius, 2007) – that is to be promoted. For instance, even though Swedish robotics industry has a strong industrial base in the region of Mälardalen in Central Sweden, it is not necessarily so that all relevant actors participating in the innovation system of
robotics-related activities can be found within the region. These may have a wider distribution across (and outside) Sweden. Thus, the system’s domain is actually wider than that of Mälardalen, even though Mälardalen is an important node in that system. However, the domain refers not only to the geographical reach of the system, but to the industrial and innovative properties of the system.

Another challenge related to defining the borders is that of establishing functionally defined regions. A functional region should reflect the actual behavioural and mobility patterns of resources, and not the administrative, geographically defined, borders of a municipality or county. Despite that the clear intentions and explicit condition of Vinnväxt is to promote functional regions, these initiatives in practice display a very strong geographical boundedness, conditioned and constrained by the financial inputs from municipal and county actors. Hence, one practical implication of the programme design is a regional lock-in as the local co-financing creates strong incentives for locating projects and activities within the own region and difficulties and reluctance to go beyond the own administrative region.

A challenge that follows this problem of regional lock-in is that of the regional knowledge infrastructure. A strong innovation system depends not only on an agglomeration of interacting firms in the same or related industries. What differentiates the innovation systems concept from the cluster concept is that the former milieu depends also on, in addition to inter-regional co-operation between firms, the involvement of academia and public institutions in the innovative co-operations (cf. Isaksen, 2001). As such, an innovation system depends not only on the strength of the business sector but also on a strong university sector and on public organisations and institutions that support innovation in the regional industry. Then there is a problem if the regional universities are not (yet!) strongly positioned on the research map within the specific sector (as discussed in paper 3). The challenge of the sufficiency of the regional knowledge base is further studied in paper 4, and where the role of extra-regional links in creating competitive regions is further explored.

To summarize the findings discussed in this section, it is certainly so that the uneven distribution of innovative activities implies that the geographical location has an important role. However, that role is not a result of geographical proximity and regional attributes only, but more in the sense of Amin and Cohendet (2004) as nodes or hubs where various kinds of knowledge communities and networks intersect, and with local concentrations of knowledge providers such as universities, research organisations, and firms “from which various kinds of knowledge spillovers and knowledge links emanate” (Cooke et al 2007 p 46). Thus, also in regions that display strong clustering tendencies within a specific sector it is not necessarily so that interactions are primarily regionally bounded. For instance, the Swedish biotech-pharma industry is highly clustered, yet studies have shown that regional, and national and international knowledge collaborations all occur in the case of collaborative R&D deals (McKelvey et al, 2003; McKelvey, 2004) Co-location in the same region, or even in the same country, did not characterise the knowledge collaboration, and this was particularly the case for firm-to-firm collaborative
deals. In a report on another Vinnväxt initiative on Biomedical Development in Western Sweden, Laage-Hellman et al (2007) have shown that even if there is collaboration between many regional partners, business relationships partners (e.g. customers and suppliers) are usually located outside the region. The role of the region and the importance of geography and/or space is also explored in a recent special issue in Industry and Innovation (Asheim et al, 2009).

Policy initiatives are important to mobilize regional actors to collaborate, and can play an important role in spurring innovative activities. This is also what is found in the study of Robot Valley. Yet, the focus here is rather on how these initiatives could be further strengthened. It seems that in today’s global economy, a competitive advantage lies in being an important node or hub in an innovation system that may have links that feature a combination of regional, national and international connections. To be an industrially relevant region, in a wider perspective than the sub-national, it is necessary to have links that reach outside the region – to access knowledge developed elsewhere and also to attract knowledgeable actors to the own region. Understanding the role of regional and non-regional knowledge links – and the multiple geographies of knowledge – is particularly important if the regional knowledge base is insufficient, as in the Robot Valley case. Then there should be stronger efforts to connect the regional knowledge to external knowledge sources in order to strengthen the regional knowledge base (as discussed in paper 3 and 4). Policy needs to be able to handle this balance between the regional and the extra-regional. Industrial excellence is rarely built on a regional level only, particularly in a global industry such as robotics. As such, the creation and support of regional excellence within such an industry should be promoted by global linkages to other regions with similar or complementary knowledge assets.

The importance of promoting external links has also been emphasised by others. Lundvall & Borrás (1997) point to the risk that geographically closed networks can obstruct rather than fuel innovation, for which reason the role of public policy to promote external networking is important – at both the regional, national as well as the European level. Thus, in order to build strong regions, it is important that policy not only supports intra-regional links but also supports and promotes knowledge links that exceed the borders of the region; if there is important knowledge outside the region the focus should be on accessing this. A policy aim should be to build a strong node in a wider industrial network – a network with regional, national and often also international reach. This does not only involve the need for a wider geographical reach in terms of knowledge links. This applies also to a wider approach that exceed sector boundaries. Robotics is a complex knowledge field that brings together competences from several different scientific and engineering areas.

4.3 What is the role of proximity in knowledge formation processes?
It follows from the discussions above that globalisation and regionalisation seems to be two concurrent forces in industrial organisation today. The global distribution of activities has led to an increased interest in the geography of knowledge formation, as well as a need for an increased understanding of how these processes take place. This development challenges some of the intellectual underpinnings that argue that localised processes of knowledge formation are very different from non-localised processes. For instance, seeing tacit knowledge exchange as a local phenomenon and codified knowledge exchange as global is one such assumption that is being challenged. The increased distribution of activities most likely implies that some knowledge formation processes occur also when the geographical distance is greater.

As discussed in the previous section, a core notion in the arguments on the advantages connected to co-location is the notion of proximity. However, this is not a concept that should/can be understood only in terms of its geographical dimension. If we regard knowledge as a social process – a result of interaction within some type of community – we can talk about proximity in terms of offering a nearness, mutual understanding or frame of reference between actors. As such, proximity also entails meanings without a geographical connotation, for instance proximity in context, cognition or value-systems (Cooke et al, 2007). In addition to geographical proximity, we may for instance talk about organisational, cognitive, social and institutional proximity as relevant for understanding knowledge formation processes (Boschma, 2005). This is important since it indicates that it is not only the geographical proximity that enables knowledge exchange of a more complex character – or that even geographical proximity should be enough to enable joint knowledge formation.

It seems as somewhat of a paradox that whereas companies in many cases are becoming increasingly global, as is the case of the MNC studied in paper 4 and 5, policy tends to become more regionalised. This indicates that there are two quite different strategies to knowledge formation. Policy regards knowledge formation as a process that is essentially a geographically sticky process, whereas the MNC does not necessarily depend on geographical proximity in its organisation of knowledge related processes. Of course, it is what defines a multinational company that it has activities in multiple countries. Even so, the strategy of MNCs is changing towards globalising activities more directly related to innovation (ITPS, 2006).

With this follows a necessity to better understand the role of proximity in knowledge formation processes. It is not only important for policy to develop a multi-dimensional approach to proximity. It is, on the firm level, important to understand how such proximity can be created or supported by the organisation. Following the organisational set-up of the MNC, it seems that is not necessarily geographical proximity that is the main or necessary dimension of proximity. Thus, other dimensions of proximity seem to play a role in enabling knowledge formation in a distributed company. The way to approach this in this dissertation is by studying how different organisational coordination mechanisms can create/support different dimension of proximity. This study (presented in paper 5) supports the idea that there are
dimensions of proximity, other than the geographical, that can be as important or more important to overcome barriers posed by geographical distance. Actually, many of the challenges related to the new distributed organisation were not primarily related to the geographical distance. For instance, the exchange of experience-based knowledge was more related to a lacking cognitive proximity in terms of shared educational background and industry-specific working experience. Communication difficulties due to differing terminology between units, as well as more informal discussions is primarily related to a lacking organisational proximity characterised by a high degree of shared relations, integrated projects and strong inter-unit ties. However, geographical proximity is important as it can facilitate knowledge formation primarily by strengthening the other dimension of proximity (Boschma, 2005). The case study shows that this is particularly the case for the more informal discussions.
This final chapter aims to summarise the key findings with reference to the research aim and specific research questions presented in chapter 1. The aim of this dissertation has been to problematise two prevailing views on industrial knowledge formation and its connection to economic development that have influenced much of the recent discussions on the creation of competitive advantage; both in academic and policy circles. Complexity has been introduced in this dissertation as an important analytical tool in understanding knowledge formation processes and their connection to competitive advantage. By providing examples of the complexity of industrial knowledge formation processes of the sort that fall outside what is captured by the two conventional views, we can include a greater variety of technology and innovation related knowledge formation processes that can be connected to competitive advantage.

The chapter begins with a reflection on what a study of this sort really can say about the phenomena under study, i.e. what is the reach of the conclusions. Further, the implications of introducing complexity into the analysis of industrial knowledge formation are discussed. Finally, the implications of this research in connection to the three research questions are discussed as well as suggestions for further research.

5.1 Reach of the conclusions

A case study methodology is primarily concerned with the study of the particular and not the general. To what extent can more general conclusions – based on the dissertation as a whole – be drawn then? Even though it is not the primary purpose of these case studies – or qualitative case studies overall – to make generalisations, this does not exclude the possibility to draw more general conclusions from findings obtained through a case study methodology. Case studies can produce results that are generalisable and transferable to other phenomena or situations with similar contextual settings. Stake (2000 p 22) refers to this as naturalistic generalisations which are arrived at “by recognising the similarities of objects and issues in and out of context and by sensing the natural covariations of happenings”. Such generalisations stand in contrast to rationalistic, propositional and law-like generalisations, a type of generalisations that have never been the intent to produce within the work of this dissertation. However, an important contribution from results obtained by case studies can be to challenge conventional wisdoms that direct the
progression of knowledge by revealing shortcomings in theory as well as in accepted assumptions or generally held wisdoms. This has indeed been an objective of this dissertation.

Two such general and important conclusions can be drawn from this research project, where the findings presented above give evidence of the shortcomings in the prevailing views that this dissertation set out to problematise. The findings provide empirical examples that challenge both the conventional wisdoms on the high-tech – low-tech distinction as well as the view on proximity. These findings illustrate important knowledge formation processes that are not captured in the current dominating focus on research-based (i.e. R&D-intensive) activities. Further, the findings show that knowledge formation processes need not – and often do not – rely only on a proximity offered by localised (in this case regional) knowledge interactions. Thus, the empirical evidence in this dissertation aligns with those requesting an approach to competitive advantage that does not a priori assume that it is a question of (promoting) R&D intensive activities on the one hand (as discussed by Hirsch-Kreinsen et al, 2006; Robertson et al., 2009), or that activities that provide a competitive advantage are best promoted on a geographically defined (often the regional or the national) level (as discussed by for instance Amin & Cohendet, 2004; Lagendijk & Oinas, 2005) on the other.

5.2 The complexity of industrial knowledge formation

How can we, then, connect the findings from the five included papers to the complexity discussion? Complexity in industrial activities can be a result of an increasing number of components that build up a specific technology or the number of nodes in an innovation system – nodes that can also be distributed across various places in the world (i.e. computational complexity). This is for instance identified in the networking and integrative capabilities in the LMT case study, as well as in the capability to incorporate different technologies and scientific findings in the Robot Valley case study, where the development of new robots involves the integration of several different knowledge disciplines. Complexity in industrial activities can also be a result of the unobservability or uncertainty of a phenomenon or a situation (i.e. epistemic complexity). This normally requires prior knowledge and a contextual understanding are required to understand a situation or solve a particular problem. This is for instance identified in the transformative capability displayed in the LMT case study. In general, many of the processes in the LMT case indicate a high degree of unobservability and reliance on practical knowledge (which relies to a large extent on experience- and routine-based knowledge). Hence, assuming that those firms, regions and countries that can manage complex processes may develop competitive advantages in niches on all technology levels makes the complexity concept a core issue.

Knowledge differentiation is an important feature in determining the complexity involved. Both the computational and the epistemic complexity increase with increased knowledge differentiation. For
example, in a system with many interdependent nodes, and the nodes are widely different in terms of knowledge content, this system is likely to be more complex than if all nodes share the same knowledge. Equally a system with a high degree of uncertainty becomes more complex if there is a high level of knowledge differentiation in the system. This discussion is highly relevant in the Robot Valley case study and has implications for our view on the role of proximity for knowledge formation. It is important to not presuppose that geographically distributed knowledge formation processes exclusively or always lead to increased complexity. This depends on the knowledge involved – if actors share the same professional experiences or have a common educational background there is assumably less complexity than if actors have widely different understanding and knowledge bases. It may well be so that regional actors have more separate knowledge bases than actors within the same industrial context or academic network etc in different parts of the world.

5.3 Sticky processes in a slippery world

What can, then, the focus on complexity in our analysis of industrial activities tell us about the competitive advantage. Competitive advantage is in this dissertation understood as provided by those activities that in some way refuses a smooth transfer. Those activities, or more precisely the knowledge formation processes underlying these activities, that are not easily available to another actor through global market contracts or wireless connections are the focus of this dissertation. We can say that what is of interest here are those knowledge formation processes that are in some sense sticky. Stickiness is a concept often connected to Markusen (1996). She likens stickiness with fly tape – it has the ability to attract as well as to keep. It is the conjecture here that complex knowledge formation processes create a certain stickiness to an activity, and this stickiness, in its turn, can provide a (temporary) competitive advantage. This stickiness is not primarily related to a geographical stickiness, but to the complexity of the knowledge formation process.

With the complexity approach, the prevailing view on which types of knowledge formation processes that actually provide a competitive advantage can be challenged. Analysing activities in terms of their complexity challenges the classical high-tech – low-tech dimension. Drawing on the findings from the included papers, we can apparently find more or less complex knowledge formation processes in the low- and medium-tech sectors. Thus, we cannot a priori assume that research-intensive, so-called high-tech, activities are necessarily more complex than non-research intensive, so-called low-tech, activities. By this follows that it is not as simple as to say that research-intensive activities are better equipped to resist global pressures because they are more complex. A technology that depends on many interdependent knowledge nodes for its development may be difficult for a competitor to replicate and thus this technology possesses a certain amount of stickiness. A production process that depends on practical knowledge is also sticky in that it depends on specific, accumulated experiences and routines. These examples are not mainly indicative for
the research-intensive end of the industry – in fact these examples are actually very typical for activities in LMT firms.

The complexity approach also challenges the prevailing view on where knowledge formation processes take place. Rather than being a question of regionalisation versus globalisation, many knowledge formation processes depend on both regional and non-regional knowledge links. We should not a priori assume that local relations are best suited or equipped for coping with complex knowledge formation processes. It is more a question of the knowledge involved in these knowledge formation processes. Actors who share a common knowledge base can more easily interact than actors where the knowledge differentiation is great. This is in many cases not a variable dependent on geographical proximity but can relate to other dimensions of proximity such as cognitive, organisational, institutional and social proximity. This challenges the understanding of knowledge formation as primarily a geographically sticky process. As Amin and Cohendet (p 102-103) argue, knowledge is not fixed to particular sites, and “if there is a boundedness to the knowledge generated in each site, it is a feature of its entrapment and nodal position within specific actor networks of varying spatial composition and reach, not a feature of local confinement”. Consequently, knowledge formation is not a process confined to a certain location but the stickiness depends on the entanglement of knowledge in a specific setting that make up the everyday practices of an activity.

In the end, the creation of competitive advantage is essentially about the ability to achieve and manage these sticky processes in a slippery world – a world were much knowledge seems to become increasingly footloose. And it is important to emphasise that we are more likely to identify these particular competitive advantages on the firm level than on the industry level. Individual firms – although belonging to the same industrial sector – will display different patterns of complexity. Within every industry, there are firms that can manage more suitable ‘bundles’ of knowledge bases, network connections etc, which enable them to adapt at a lesser cost (costs can for instance be measured in terms of efforts, money or time) than other firms within the same industry. An industry level approach will not reveal these comparative advantages that individual firms display – only a firm level analyses will.

5.4 Implications and suggestions for further research

From the findings presented in this dissertation some main implications – theoretical as well as policy related – can be drawn in connection to the three research questions. In regards to the first research question, the findings give evidence of the important role that non-research intensive knowledge formation processes have in industry. Consequently, in our knowledge-based economy we cannot neglect those knowledge formation processes. There are several reasons as to why it is difficult to make a clear distinction of the importance of high-tech versus low-tech when we want to understand which activities in
our economy that can provide a competitive advantage. One is the interdependency – or symbiotic relationship – between high-tech and non high-tech sectors (Robertson & Patel, 2007). Another is the fact that there is no real evidence that the economy is undergoing an all-embracing transformation from old technologies to new technologies (Hirsch-Kreinsen & Jacobsen, 2008). As problematic as the one-sided focus of policy on research-intensive activities is, this is reinforced by the coarse division of industry that the high-tech – low-tech categorisation represents. The bottom line is that, at least with the current categorisation, an industry approach does not sufficiently well inform us of which activities that will resist the global pressures of increased competition. Yet, the possibility to measure industrial performance is important and it is a delicate task to develop indicators that are sensitive enough to allow for the necessary variety that characterises industrial activities. It has not been the purpose within this dissertation to engage in the difficult task of developing such indicators, notwithstanding that this would be an interesting path for further studies. In this context, the complexity approach could perhaps be one additional entryway to a more sensitive set of indicators, although this remains a question for further research.

The second research question is concerned with the creation of competitive advantage on the regional level. As it has been pointed out above, this is of central concern to many policy makers today. However, one important contribution in this dissertation is that it points to the necessity to balance the forces of regionalisation with the forces of globalisation. It is a question of dealing with a strategic coupling of the regional assets (in terms of regional knowledge base, infrastructure etc) and wider, even global, networks. Consequently, policies to strengthen regional economies should not only promote intra-regional interactions but also encourage and facilitate extra-regional knowledge links. It should be the aim of policy to assure that the own region is an important node of a wider, national or international, innovation system. What the findings in this dissertation have shown is that this dimension is not captured in current regional innovation systems policy. It is suggested that policy needs to adopt a two-fold approach of strengthening the regional innovation system in focus and enlarging the collaboration with the wider technological system through extra-regional links. And these extra-regional links need to be actively promoted and supported. As shown in the Robot Valley case, the actors within the initiative are quite busy establishing the (in many cases novel) collaborations between various actors within the region.

Here, our understanding of space as not necessarily an issue of varying geographical scales is valuable. Space can for instance refer to organisational space (which in the case of an MNC for instance stretches across various geographical scales) or a technological space (which also can connect various actors within the same technological fields in different places in the world). The domain concept (Laestadius, 2007) also captures this non-geographically defined context in which industrial activities take place. As Robertson and Smith (2008) suggest, there is a need for a multilayer approach including different layers of innovation networks. These individual innovation networks may be defined on sectoral, technological or regional levels. Thus, developing such multilevel policy packages is a great challenge and important subject for further research. This requires at least two things – a theoretical and empirical development of the
concept of space, and the development of policy measures that can incorporate these various spaces/levels.

Further, and related to the third research question, the findings in this dissertation contribute to our understanding of proximity as a concept with many dimensions. When knowledge formation is concerned it is not necessarily the geographical proximity that is important. This connects to the role of knowledge differentiation, and that proximity in some cognitive sense is the essential component for any knowledge formation process to take place. Thus, proximity – interpreted as a multidimensional concept – can assumable help reduce the complexity caused by distributed and ever more interdependent knowledge nodes. In order for proximity to be important in that respect, it is important that we can understand better how, and which dimensions of proximity, that matter for knowledge formation. This has implications for policy as well as corporate management. However, the connection between different dimensions of proximity and their management, such as the corporate coordination mechanisms as a management strategy explored in paper 5, would benefit from further research. This is also an important issue to explore in connection to policy development. What are the corresponding coordination mechanisms necessary in order to ‘hook up’ the region to the wider, national and international, innovation network, and which dimensions of proximity would matter in this case?
References


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