Exploiting Science:
An In-depth Study of a Regional Collaborative Development Strategy

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Abstract

This paper explores how a new knowledge base centred on an emerging technology in a declining industrial city can spill over into the surrounding environment. Using a qualitative approach, it presents an in-depth case study of a Swedish urban region in order to explore who the actors are, how they have collaborated in the process, and what the outcomes have been. It discusses the impact of a regional collaborative strategy and bottom-up processes. It found a distinct difference between supportive and operative actors in relation to the creation of economic output, which has theoretical and policy implications. It concludes by categorising different bottom-up commercialisation processes.

Keywords: strategy, emerging technology, barrier, collaboration

1. Introduction

Policy makers after the Second World War tended to regard economic growth policy from a national-level perspective and considered large companies to be more efficient than small ones. This contributed to a decreased interest in regional development and firm formation (Krugman, 1992; Audretsch, 2009). They also perceived technological change as an exogenous variable that improved economic output but appeared in the economy as if it were manna from heaven (Solow, 1956; Audretsch, 2005).

The understanding of knowledge as an endogenous variable and regions as important constructs for understanding economic growth gradually replaced these paradigms (Romer, 1986; Krugman, 1992). Several studies also found that knowledge is an externality of the activities of research and development (R&D) organisations that refuels regional economies and knowledge-based regional development, primarily by the transferring mechanism of new firm formation (Cooke, 2002; Etzkowitz and Klofsten, 2005; Audretsch et al, 2006).

R&D organisations can be either large companies, research institutes, or universities. Audretsch et al (2005) and Etzkowitz and Klofsten (2005) have identified universities as increasingly the most important organisations for invigorating stalled economies. Only a few ways exist to exploit findings in science and technology emerging from research universities. These are commercialisation through licensing, generating start-ups, and knowledge transfer activities (Klofsten and Jones-Evans, 2000; Sharma et al, 2006; Svensson, 2007).

Converting scientific research into economic output, however, seems to be obstructed by such institutional and organisational problems as knowledge filters (Audretsch and Aldridge, 2009; Carlsson et al, 2009). Improving universities' institutional and organisational functions is therefore of increasing interest to regional and national policy makers (Sharma et al, 2006; Petrusson, 2007; Mowery et al, 2001).

A division exists, however, in how both scholars and policy makers perceive regional innovation systems (Ylilenpää, 2009). One perception is that the creation of a specific type of knowledge and its related innovation activities within a spatially restricted area takes place in the unplanned entrepreneurial activities of bottom-up actors and is therefore difficult for policy makers to affect (Johannisson, 1998; Johannisson and Lindholm-Dahlstrand, 2009). The other perception has a more systemic perspective and provides suggestions of how policy makers can create the ingredients for innovation systems (Porter, 1990; Edquist, 1997). Both these schools of thought apparently guide management behaviour, especially public policy, but the different streams of research stemming from them, although studying the same phenomena, do not cross-fertilise (Ylilenpää, 2009). This paper examines how regional top-down initiatives can be transferred to local bottom-up economic activities in knowledge-based regional development in order to shed light on both its institutional and entrepreneurial aspects.

2. Theoretical Framework

2.1. Knowledge-Based Regional Development

Many consider knowledge to be an externality that is an important factor in economic growth, as ideas are non-rival and therefore spread over borders and throughout economies (Romer, 1990; Audretsch et al, 2006). Factors apparently exist, however, that hinder the conversion of science into economic output. The existence of such knowledge filters between organisations involved in science and commercial users of innovation is at least partly due to such characteristics of knowledge as uncertainty, asymmetric information, and transaction costs (Arrow, 1962; Audretsch and Aldridge, 2009; Carlsson et al, 2009).

These organisational and institutional challenges are of interest in regard to understanding knowledge-based regional development because of the local nature of commercialisation, especially since the academic system freely reveals and rapidly diffuses local science production, which means that useful scientific research can be commercialised elsewhere, making regional gains minimal (Audretsch et al, 2005). Regional policy has therefore gradually undergone a transition from one of regions poaching or capturing each other's resources to the creation of new resources, typically based upon some knowledge advantage (Svensson et al, forthcoming).

Out of the three types of R&D organisations that contribute to new knowledge, research universities play an increasingly important role as institutions for facilitating the discovery of entrepreneurial opportunities and reinvigorating their regions' knowledge bases. They play an increasingly important role in science-based innovations because of their open science system, which increases the flow of new ideas. (Carlsson et al 2009; Etzkowitz and Ranga, 2009).

Shah and Tripsas (2007) found that the university environment attracts some sectors' end-user entrepreneurs who are more inclined to test radical or disruptive ideas. For instance, in Silicon Valley the research universities have been crucial factors for sectoral succession, the example being the silicon knowledge of the semiconductor industry transferring into the digital knowledge of the software industry and then into the current design and general information-technology knowledge of social networks. This succession compensates for decreases in the development of the regional economic base due to employment losses in such older sectors as the semiconductor industry resulting from waning competitiveness or relocation. Lucky regions or those that manage these transitions successfully experience positive outcomes in regard to population, income, and growth.

These sectoral-succession phenomena, moreover, occur in more sectors than those reliant on science-based innovations, and may also be found in regional forms of specialisation involving the reinvigoration of such varied older sectors as semiconductor engineering, financial services, and fashion design. (Agarwal et al, 2007; Storper and Scott, 2008). This regional-knowledge path dependency is at times called creative construction, a shift from Schumpeter's (1911) creative destruction. This perspective views creative destruction as valid on an aggregate level in economies, but also sees connections as tending to exist between knowledge bases regionally.

Innovation spaces emerge in knowledge-based regional development processes in order to exploit knowledge creation's opportunities (Etzkowitz and Klofsten, 2005). One of the reasons for innovation spaces is that the actors who are socially close to such knowledge creators as researchers often exploit knowledge spatially close to its creation. Information has a high degree of stickiness to the location where it is created (von Hippel, 2005; Sorenson et al, 2006).

Start-up firms in particular tend to locate themselves near a knowledge base. This tendency is therefore important to local economic development, since by locating geographically close to universities they contribute positively to university districts' business environments (Di Gregorio and Shane, 2003). The Association of University Technology Managers (1999) reported that 79% of the US's 364 Technology License Office start-up firms in 1998 were located in the same state as the licensing institution. Start-up firms are therefore valuable entities for local economic development and agglomeration economies (Zucker et al, 1998). Audretsch et al (2005) found that how recently a firm has started up affects its decision whether to locate close to a university, as when such firms first start up they depend on external knowledge, but when they become established they tend to have their own ways of creating new knowledge, such as R&D departments.

Porter (1990) attributed the benefits of a regional agglomeration process to the benefits of spatial proximity between suppliers and manufacturers, the resulting relationships and social closeness then become important for helping the knowledge to spill over. This implies that a region's chief asset is its sets of relationships, which take a long time to develop and are difficult to imitate. These relational assets are the key input for new firm formation, the economic process therefore centring on innovation through conversations and co-ordination rather than by improving efficiency. Such intangible assets represent a significant resource, albeit one that requires further investment and the construction of a viable strategy, ideally by engaging with the full range of relevant actors to realise its potential (Storper, 1997).

Ylinenpää (2009) found two different research streams in regard to regional innovation systems, the institutional and the entrepreneurial. Most studies are institutional, addressing how top-level actors in different organisations interact in order to create regional development, which is the research focus of the innovation-system, cluster, and triple-helix approaches. Entrepreneurial regional innovation-system studies focus on the creation of innovations and on how entrepreneurs develop new ideas into economic activities. This approach tends to centre on such terms as action-oriented, experimental learning, emergent, and effectuation, while the institutional approach tends to centre on such terms as planning-oriented, mechanistic, and causation.

Etzkowitz and Klofsten (2005) and Svensson et al (forthcoming) have, however, identified and attributed different characteristics to the top, middle, and bottom-level actors in triple-helix formation. National actors primarily supply the financial means and support development by stimulating knowledge for development processes. Regional actors, local actors, or both tend to set the agenda, set the scene for the enrolment of actors, acquire resources, and develop know-how. Furthermore, the bottom-level actors attract external human and financial capital, develop and commercialise new technologies, and facilitate the sharing of knowledge and information. Van de Ven (1993) and Storper (1997) have found that the significance of cooperation between different types of actors within a regional context is crucial to regeneration efforts.

2.2. Exploitation of Science

The bottom-up perspective of knowledge-based regional development focuses on the creation of new innovations from a knowledge base (Ylinenpää, 2009). The exogenous shock of new knowledge creates business opportunities, but the quantity of new opportunities depends on the nature of the new knowledge and which actors are close to the knowledge's creation. If the new knowledge is generic, such as multi-purpose technologies, it is more likely to result in many different applications than a single-purpose technology. A new knowledge's tacitness or codifiability also affects the number of opportunities it creates. Furthermore, whether the knowledge is isolated or part of a complex system also tends to shape the type and volume of opportunities it makes available for discovery and exploitation (Eckhardt and Shane, 2003).

This inside-out perspective of the transformation of knowledge creation into business opportunities also sees university researchers as entering academic loops with little effort, such as by moving from basic research to applied research and patents. When researchers enter a commercial loop, however, they need to acquire skills in marketing, and the interpersonal relationship skills required also change. The incentive to commercialise is of course usually monetary. Only some researchers are equipped to manage such changes, however, and therefore many new opportunities stay within academic organisations (Svensson and Öhrwall, forthcoming).

Klofsten and Dylan-Jones (2000) made distinctions between such activities involved in

transferring academic knowledge to the commercial market as large-scale science projects, contracted research, consulting, patenting and licensing, spin-off firms, external teaching, sales, and testing. The effects of the different knowledge-spillover activities are diverse, and it therefore seems reasonable to divide them into the categories of commercialisation through licensing, generating start-up firms, and knowledge-transfer activities (Audretsch et al, 2005; Sharma et al, 2006; Svensson and Öhrwall, forthcoming). This conforms with the understanding that incumbent companies in general often search for process innovations and that start-up firms base themselves on new service or product offerings, which in turn has implications for sectoral succession and employment growth (Utterback, 1994).

Knowledge-transfer activities benefit Swedish university researchers by producing increased research funding that results in high-technology equipment, skilled teaching, and high-level training that they can use to solve industrial problems (Jones-Evans and Klofsten, 1999). In commercialisation activities, however, the innovation-transfer processes involve know-how, the actual technology, and in some cases market knowledge, all of which move between organisations. In addition, an innovation's level of complexity is positively correlated to its transaction costs. Another factor affecting an innovation transfer's size and success is the receiving party's absorptive capacity. (Teece, 1977; Cohen and Levinthal, 1990; Afuah, 1998). Social proximity is therefore a crucial factor in the transfer of complex knowledge. This means that actors socially close to new knowledge or an invention tend to commercialise it or otherwise benefit from it during its knowledge-transfer processes (Sorenson et al., 2006).

Successful entrepreneurs have superior knowledge or information in regard to market or technology factors within the scope of the operations of their business, which means that the business opportunities involved are based on asymmetric information (Shane, 2000). Innovations, furthermore, consist of problem information and solution capability, and it is often superior knowledge of the latter that triggers university researchers to commercialise their discoveries.

Certain university departments, however, seem to accumulate more end-user entrepreneurs than others. These are nascent entrepreneurs with full problem information and a high level of solution capability. For example, when Sergey Brin and Larry Page, who were graduate students in the Stanford PhD computer science programme, wanted to find solutions for improving internet searches they had solution capability and also full information about a major problem area. They chose to act and created the search-engine company Google. When such lead-users, or those leading a trend, of existing products and services turn into innovators and end-user entrepreneurs, as in the cases of Yahoo! and Google, rapid growth tends to occur (von Hippel, 2005; Shah and Tripsas, 2007).

Audretsch and Aldrige (2009) found that those scientists who have a prolific publication record and who receive the most citations tend to have a higher propensity to patent. They also observed that institutional location mattered, finding that scientists in California and New England had a greater propensity for patenting even after controlling for other factors. This implies that a geographic location's institutions and culture affect the propensity to patent.

Powers (2005) had previously found that the presence and utilisation of such professional service providers for the exploitation of research findings as university technology-transfer offices increase the chances of successful commercialisation. A university's level of intellectual eminence, together with its having policies of making equity investments and maintaining a low inventor's share, are positive factors for its generating start-up firms. Di Gregorio and Shane (2003), however, found no correlation between the availability of industrially sponsored and venture capital and the number of start-up firms launched. Anand and Khanna (2000), furthermore, found that such prior relationships as personnel histories,

common board memberships, and alliance activities positively affected whether companies license their technology to others.

3. Scope and Research Questions

This paper focuses on the measures that local actors in a particular case undertook after the establishment of a knowledge space and the subsequent emergence of an innovation space resulting from the municipality involved changing its regional development strategy to a knowledge-oriented one (Etzkowitz, 2002; 2009, Svensson et al, forthcoming). As the organisational and institutional environment affected the subsequent knowledge spillover, this study examines local strategy formation and the bottom-up processes of academic entrepreneurship. It addresses the research questions of (a) who the main organisational actors in the formation of a viable local strategy for exploiting an emerging technology were, (b) what the results of the implemented strategy have been, and (c) in what activities to reduce the barriers to the exploitation of the emerging technology those involved have engaged.

It should be noted in regard to this paper that in Sweden any intellectual property resulting from university research belongs to the researchers themselves and not to the university in the absence of a contract stipulating otherwise. This means that Swedish researchers have the exclusive right to exploit their research results, unlike in most other countries, where universities hold the intellectual property rights (IPR). Another Swedish institutional factor is that it has a managed economy, which has resulted in a low entrepreneurial rate (Audretsch, 2009).

4. Methodology

This study employed qualitative research based on a detailed case study of a deindustrialising Swedish urban region named Norrköping and its redevelopment actors, including its university, regional industry, research institute, entrepreneurs, and governmental agencies. In 2008 and 2009 I conducted more than 20 in-depth, semi-structured, face-to-face interviews that lasted from 45 minutes to two hours and which I complemented with telephone interviews. The interviews were tape-recorded and transcribed and the interviewees checked the text for factual mistakes. I supported the interview data with an extensive secondary data collection of research applications, applications for funds, and thorough meeting notes in order to increase its validity (Yin, 1989).

I began by holding an introductory meeting with the participants, who were from Norrköping municipality and the Norrköping Science Park (NOSP). I then interviewed the head of a cluster initiative at length and participated in cluster meetings involving a particular technology field the regional university and research institute had established at their new campus. The next step was to interview the political leadership, specifically the municipality's current chairman and former director, followed by people from the industry involved, academia, and research institutes.

I then presented the collected data to the key actors and used their feedback to improve the subsequent in-depth interviews with those who had been part of the establishment of the new campus from the outset. Extensive studies of secondary material and archival records were included. I then presented the written material to three key informants who checked it for factual mistakes, ambiguous meanings, and the need for additional facts. The empirical data's construct validity may therefore be considered extremely high (Yin, 2003). Parts of the final document were printed as an empirical working paper and have been distributed to key informants (Svensson, 2009). In addition, the municipality of Norrköping has signed a contract with Linköping University (LiU) that states that the municipality shall be open for

research. This means that it is highly accessible and has an interest in the production of high-quality research.

I conducted process tracing as a within-case analysis and searched for congruence in the empirical material based on existing studies and theory. In this process I discovered patterns in the material and mapped these patterns in order to describe casual mechanisms (George and Bennett, 2005).

From 2004 to 2006 I had conducted a study of three research groups within one research programme in Sweden, focusing on the knowledge and technology transfer activities of the research groups (Svensson, 2007). One of the research groups was part of a department of LiU called the Institute of Technology and Natural Sciences (ITN) and was active in the emerging field of printed electronics (PE). This study led me to a pre-understanding of both Norrköping's contextual environment and PE's commercialisation processes. I then conducted a large, in-depth, empirical case study of Norrköping's urban renewal in 2009. Svensson et al (forthcoming) uses part of this study to analyse how the municipality's leadership joined with the regional LiU to establish the basis for an influx of new knowledge into its urban-renewal process. This pre-understanding increases this study's construct validity (Yin, 2003).

5. The Case of Printed Electronics Arena (PEA)

PE is an emerging technology based on the discovery of organic electronics in the 1970s, the originators of which received the Nobel Prize for Chemistry in 2000. Organic electronics and related scientific fields have been important parts of research at LiU, and this research has served as a base for the idea that electronics could also be printed on paper. The Printed Electronics Arena's (PEA) (2010, n.p.) website explains that:

> "Printed Electronics is a new technology that can lead to the production of simple, fast, and cheap electronic products by making use of conventional printing methods. This automatically involves a radical rejuvenation of production methods by incorporating new materials and methods, which in turn leads to producing electronics in a completely new way, thereby opening the door to the development of entirely new products." [Translated from Swedish by the author]

PE technology emerged in the late 1990s from the microelectronics research institute Acreo, also located in Linköping, which is near Norrköping, in an environment characterised by short feedback loops from industry. This research was application-oriented from the outset. At that time Acreo was searching for larger facilities, which it found in Norrköping. LiU had established a campus in Norrköping in 1997 (Svensson et al, 2010). Due to an industrial heritage within the electronics industry from Ericsson and Phillips, it located its ITN, which included electronic design, in Norrköping when the new campus was established.

The need to increase activity at the new campus and the synergistic effects of combining the ITN's and Acreo's human resources and special equipment were the main reasons for the move. The university's vice chancellor joined with the municipality's board to arrange for Acreo to move to the new campus. The transfer and upgrade of facilities received grants from the municipality and from the Swedish Agency for Innovation Systems (VINNOVA), which recognises the advantage of collaboration among different regional actors, not only by making it a requirement for funding but also by establishing helpful prices to help regions establish collaboration as part of their redevelopment processes. Acreo moved into the same building as the ITN and shared its microelectronic laboratory. The two organisations then started to work together with the new technology.

At the same time the municipality of Norrköping implemented a knowledge-based economic renewal strategy. The newly founded municipality fund, the Norrköping Regional Foundation (NRDF), was therefore able to sponsor projects for the PE researchers in regard to establishing market relationships. The overall objective of all this activity has been to help clusters of research and business involving technological knowledge to develop, making the municipality's industrial structure more differentiated and the region consequently less vulnerable to recessions.

In 2004 the newly appointed managing director of the local science park, later to be called the NOSP, realised that no formal relationship existed between it and Acreo. Later that year he met with representatives from the ITN and Acreo. At the time both organisations were well underway with their research and exploitation of the emerging PE technology and were actively in pursuit of industry feedback. Organic electronics researchers wanted to shorten the feedback loop between market input and research development in order to take years off development time and to hasten the discovery of successful market applications based on organic electronics.

Acreo recognised that many obstacles need to be lowered for new technologies to reach the market. The ITN, Acreo, and NOSP therefore created a prototype factory in order to help overcome the obstacles to exploiting PE for both start-up firms and established ones. They founded an organisation for commencing production of PE based on industry's needs, renaming it PEA Manufacturing (PEA-M) in 2008, which would also enable firms to test products based on PE without interfering with their own production. Material and equipment suppliers for the production of PE would also be able to test new materials and new equipment there.

They planned for what they called this greenhouse for production to be a focal point and meeting place where the ITN, Acreo, NOSP, and the industry could produce prototypes, develop new production processes, and produce PE applications. This strategy further included plans for PEA-M's assets and capabilities to be crucial for the retention of any international companies that PE managed to attract to the region, and to lower the costs and increase the speed of start-up companies in producing small series. PEA-M is organisationally a part of Acreo due to the two organisations' interrelated activities

PEA-M had to overcome several obstacles to establishing its production facilities. One involved the production of small series of prototypes with the advanced reel-to-reel printing equipment, as the equipment moves too fast, thereby creating too much waste material when experimenting with small series. PEA-M has corrected this with a simpler printing machine to complement the reel-to-reel one.

5.1. The National Programme

While this co-operation and the establishment of PEA-M was in progress, VINNOVA put out a call for applications it called the VINNVÄXT 2005 – Innovation Systems in Early Phases programme, a scheme that aimed to develop regional innovation systems. VINNOVA based this on the triple helix model for managing regional growth, which stresses the importance of collaboration among academia, industry, and the public sector. It set up the programme as a competition among different regional initiatives. The winners of the first stage received SEK100,000 for the further development of their growth strategies.

Acreo took the lead, and together with NOSP and the ITN sent in the application. The aim was to exploit the research conducted in Norrköping by Acreo and the ITN, to stimulate companies that could gain new business opportunities based on the new technology, and to develop the infrastructure for commercialisation and production. To reach these goals the

Norrköping conglomerate applied for marketing and network resources for PEA, which is basically an umbrella organisation. At the end of 2005 the PEA initiative received the first grant. Ten of 86 applications succeeded and received their first development contributions. The rationale for PEA's award was that VINNOVA (2009, n.p.) judged its:

> "initiative to have great growth potential and a good opportunity to become an internationally competitive innovation system. Furthermore, it has a high potential for renewal, especially because the technology creates added value to traditional products. LiU and Acreo have strong R&D capabilities. Some dedicated companies are in the region and they have many potential customers and application companies in Sweden." [Translated from Swedish by the author]

Acreo, NOSP, and municipality representatives had to attend workshops at VINNOVA after the first stage of the application procedure. These workshops provided information about how the triple helix model works. NOSP benefited from these workshops because its people learnt new management tools for regional development. The concept of the triple helix model's management tools confirmed the validity of Norrköping's collaborative path and helped NOSP's regional representatives to focus on three cluster initiatives, one of which was PE. After the workshops Acreo and NOSP put together an application for VINNVÄXT's next stage. The management tools provided a foundation for this second application by providing them with a more specific vocabulary and showing them how to deliver an application conforming to VINNOVA's ideas.

The municipality was also involved in the application, but took a less active role in it. In 2006 PEA received a SEK2 million award over two years. The project had to be financed equally by other sources, but this could be delivered in kind. The NRDF, Acreo, and LiU co-financed PEA. Representatives of Acreo, NOSP, the municipalities of Norrköping and Katrineholm, and regional industries became members of PEA's board. VINNOVA announced the final stage of VINNVÄXT at end of May 2008, and four regional initiatives won the prestigious prize, with PEA receiving SEK4 million annually for the next eight years. PEA applied for SEK1 million over three years from the NRDF in July 2008 in order to assure continuity for the region's market development and concurrent research. It intended for this application to be a base for further financing and to provide regional industries with support and information for increased product development based on PE.

5.2. PEA's Strategy and Organisation

PEA's vision is to create sustainable, long-term economic growth in the Norrköping region through the commercialisation and exploitation of the new-technology area of PE. Its goals are to create more jobs in the region with either start-up companies or established ones. Its long-term objectives, for 2016, are for the Norrköping region to become a world-leading cluster for electronics printed on paper, to achieve a world-leading position in PE research, and for PEA itself to have contributed to the creation of successful spin-off firms, the business development of established companies, and the attraction of foreign direct investment to the region. Other objectives include PEA-M being used, PEA becoming the region's centre point for industrial networks, and the Swedish paper and packaging industry's competitiveness strengthening due to PE. The PEA Strategy Document (2008, n.p.) stated that:

> "PEA shall: a) effectively support the exploitation of the new technology, b) gather and diffuse information about new printed electronics technology to companies in the Norrköping region, and c) engage established industry and entrepreneurs in the technology's use in competitive new offerings." [Translated from Swedish by the author]

The activities planned for the three-year period of 2008 to 2011, as presented in the application, are for PEA to assist regional companies in the development of PE technology and its applications, for PEA to serve as NOSP's branch for maintaining and developing the services for technology transfer and knowledge within PE, for NOSP to assist regional companies through PEA in capturing the benefits realised from PE's global development, and for PEA to continue to develop relationships with such national actors as the Invest in Sweden Agency, the Packaging Arena, the Swedish Agency for Economic and Regional Growth, VINNOVA, and VINNOVA's triple helix research, and with international networks as well.

The steering group consists of 10 representatives from the local municipalities of Norrköping, and Katrineholm, LiU, Acreo, and the regional companies Cloetta Fazer and Billerud. This is based on the strategy of using the triple helix model as a key driver of regional development. The PEA steering group meets four to six times annually and is responsible for strategic, operational, and financial matters. The execution of the steering group's strategies is the responsibility of a working committee and a person with the title of process leader.

Working committees consisting of people from the different stakeholder organisations assist the process leader. The processes being addressed are (a) leadership and marketing (NOSP), (b) research and development (LiU's head), (c) products (Acreo), and (d) support for commercialisation (NOSP). Product managers are to take part in product panels with the task of creating product ideas and prototypes for specific markets. The PEA restructured its working committee into a production committee in the autumn of 2008 in order to adapt to changing situations by overseeing the development of PEA-M. It had identified a bottleneck in the production of customised PE components and systems that required PEA's organisation to reemphasise its production facilities and in order to increase its production capabilities. The strategies reflect the ideas of the steering committee and the cluster coach, who said, "I believe in working with the existing companies and making them more competitive rather than setting up new industries." [Translated from Swedish by the author.]

Acreo was instrumental in establishing relationships with the packaging industry. A dialogue arose in the meeting between representatives of established industry and researchers. The researchers received industry input about how the existing packaging technology worked, and the new possibilities PE creates inspired the industry's representatives.

PEA's strategy also evolved from 2006 to 2008. It includes the same general goals, but started to specify its activities in more detail. It created a communication platform in order to bridge commercialisation gaps by increasing regional awareness of PE.

The main financier, VINNOVA, demands that those receiving VINNVÄXT take on co-financiers, a demand that has generated collaboration among PEA's participating organisations. PEA receives co-financing from the NRDF, the regional development council Östsam, Acreo, and LiU, both in cash and in kind. Another of VINNOVA's conditions is that regional growth be generated within what it calls a functional region, which is a geographically coherent area with the country. This means that it does not consider several PE hubs scattered about the country to constitute a functional region.

Acreo considers this condition to be an obstacle to PE's commercialisation process in Sweden because its potential customers and users are everywhere in the world and considering Sweden as a functional region would provide it with a stronger and more complete research base to market. Furthermore, the ITN's and Acreo's PE research is better known abroad than in Sweden, with Acreo having found more interest and commercial possibilities in continental Europe, Japan, and the US than at home. Acreo wanted PEA to be a core for all Swedish PE hubs, but VINNVÄXT could only award money to organisations with a regional scope.

VINNOVA does allow PEA to use the national network of PE knowledge, but it may only promote growth in the Norrköping region.

/see table 1 in appendix/

5.3. PEA's Activities and Results, 2006-2008

As an umbrella organisation, PEA works through a strategy it calls House of Brands, in which its stakeholders conduct the operational activities. It is a meeting place for coordinating those activities and for sharing information. The stakeholders described in Table 1 have different tasks connected with both their own internal aims and the goals related to PEA's strategy.

One result of this cooperation has been that in 2006 Acreo and LiU started Centerprise, a PE research centre financed by VINNOVA, Acreo, and LiU and supported by PEA. From 2006 through 2008 it created a road map for the development of PE technology, opened up such new research areas as bioelectronics, published in academic journals, created an IPR strategy, produced patentable technology, applied for patents, increased the number of PhD students in the PE field, took on visiting researchers, and participated in and arranged international conferences.

PEA has established three networks related to the assets of Norrköping's industries. The Erfapack network is based on companies involved in the regional packaging industry. The Erfadisplay network involves the regional printing industry, and the Erfabygg network is based on the building-materials industry. The goal of the first two is to integrate PE into new products to enable regional companies to increase their competitiveness. Erfabygg, with a slightly different perspective, aims to find specific PE applications in such areas as logistics services within the building-materials industry. These industry networks meet regularly to receive information about PE's development and to discuss how it may fit into their industries. By offering separate PE prizes at a yearly business-plan competition, PEA has encouraged entrepreneurs, students, and PhD candidates to write business plans centred on PE technology.

A cluster coach organises these PEA activities, in which many external stakeholders participate. The activities between 2006 and 2008 emphasised marketing PE and the formation of meeting places. One marketing instrument is PEA's monthly newsletter, which informs readers about international PE events and PEA's regional activities. It pays for PEA's stakeholders to receive the newsletter. When, for example, the cluster coach visited a conference in the UK, the newsletter was partly based on what he learnt at there.

PEA builds relationships with other hubs in Sweden. For example, the Packaging Arena cluster in Karlstad is in discussion with it about print production. Norrköping has many packaging manufacturers, but none of their customers. PEA's firm networks include one end-user of packages, Cloetta, which is a candy and chocolate manufacturer. The Faraday Packaging Network in the UK is one of PEA's partners, and it has many end-users. Faraday, however, focuses on all future packaging trends and not just PE.

Cluster meetings over lunch take place once or twice a month so such people responsible for PE production as researchers from LiU, Acreo representatives from both production and marketing, and people from NOSP and PEA can share information. PEA held seminars preceded by an international keynote speaker for 85 participating researchers, users, and stakeholders from industry and society in November 2007, then held another seminar in May 2008 for researchers and representatives of local companies. It also sends such representatives as researchers and marketing people from Acreo and the ITN to numerous conferences around the world annually. All these activities promote the region's PE knowledge hub.

PEA also participates in research conferences and bilateral research meetings. On a global level, it is involved in an EU project and the Organic Electronics Association's international conference took place in Norrköping in 2008. PEA is developing further international relationships and conducts intelligence surveillance through different types of international networks.

Table 2 presents PEA's first economic results of the House of Brands strategy and of having university research in Norrköping. Its PE R&D has attracted external interest that has resulted in the development of some cooperative research efforts. Some start-up firms based on PE have also emerged. This paper's appendix presents some illustrative cases of its economic outcomes or potential ones. The established local company Billerud appreciates being informed about PE developments and sees the benefits of being part of the local network, but has not yet seen any advantages in engaging in R&D activities based on PE. The start-up firm Neoplex, however, established itself in order to exploit PE.

Table 2 PEA's industry relationships 2006-2008 (PEA, 2008)

Events	**Industry (n)**	**SME (n)**
Paying customers at Acreo and LiU	9	5
Companies engaged in Acreo technology assessment	35	
Companies contributing in kind with Acreo and LiU	10	6
Start-up firms		5
Regional companies involved in the Erfa networks	50	
Regional companies acting as subcontractors for R&D projects and spin-offs	10	

6. Analysis

PEA's case shows how informal relationships can be formalised on a regional level into a collaborative strategy. Relationships on a regional leadership level created bottom-level spaces within which actors with a common interest in the emerging PE technology could network. This conforms with existing findings in regard to knowledge, innovation, and consensus spaces (Etzkowitz and Klofsten, 2005; Etzkowitz and Ranga, 2009). Furthermore, the Norrköping urban region has historical roots in both paper manufacturing and the electronics industry, and this along with many other factors contributed to PE becoming the source of potential sectoral succession or creative construction (Agarwal et al, 2007; Storper and Scott, 2008).

In regard to the research question of who the main organisational actors in the formation of this viable local strategy for the exploitation of an emerging technology have been, prior to PEA's founding Acreo and ITN had started to find ways to facilitate the exploitation of the emerging PE technology, but the establishment of closer relationships with NOSP and the municipalities created new local networks that increased its marketing and commercialisation resources immensely.

As Table 3 illustrates, the PEA case's main activities for exploiting PE have been knowledge creation, barrier reduction, resource mobilisation, and innovation (Romer, 1986; Braunerhjelm, 2010; Svensson et al, forthcoming; Audretsch, 2009). Knowledge creation has been based on research conducted by both Acreo and ITN. Acreo performed the barrier

reduction activities in the form of applied science, the PEA-M prototype factory, and PEA as the creator of relationships to bridge the gap between market needs and PE's available solution capacity. Resource mobilisation for knowledge creation and barrier reduction benefited from the collaboration among actors within academia, the public sector, and industry. PEA-M and Acreo have been involved in innovation activities, becoming expert PE organisations as well as partners with external organisations interested in PE.

Table 3 Impact of organisational actors

Main impact	**Organisational actors**
Knowledge creation	ITN, Acreo
Barrier reduction	Collaborative projects (PEA-M, and PEA), and all the participating organisations
Resource mobilisation	Municipality, NOSP, Acreo, and ITN
Innovation	Start-up firms

In regard to the research question about what the results of the strategy implementation and the activities to reduce the barriers to exploiting PE have been, the municipality leadership's strategy of establishing a research university and the vice chancellor's and the national government's assistance in doing so led to PE research being based in Norrköping. Help from the top and middle level of the public sector and additional assistance from private local pockets of wealth also reinforced PE's local development.

The application of the emerging organic electronics technology took a strategic turn towards paper in Norrköping due to the field's possibilities, the researchers' creativeness, and the interest of local donors. This is one factor involved in Schumpeter's (1911) theory of creative destruction being different on a regional level, where it becomes creative construction due to path-dependent regional factors (Agarwal et al, 2007). The strategy, furthermore, has primarily mobilised regional actors and regional networks, which has resulted in a regional understanding of what PE is, of what it is capable, and global scientific progress in it.

These top-level strategies led to the localisation of a knowledge space, and bottom-level actors do need to be spatially and socially close to an emerging technology for start-up firms to commercialise new ideas. The conversion from science and knowledge to technology and economic activities involves bottom-level processes by actors either involved in knowledge creation or in business development (von Hippel, 2005). The case of the start-up firm Neoplex, detailed in this paper's Appendix, illustrates the importance of PEA's barrier-reduction activities, especially PEA-M, as the close cooperation between Neoplex's founder and PEA-M's engineers was fundamental for its progress.

Furthermore, Neoplex's founder testified that he had had to invest a large amount of time in understanding PE's possibilities and limitations. Socially close actors often exploit knowledge spatially close to where knowledge creation takes place. This implies a high degree of stickiness of information to where it is created (Di Gregorio and Shane, 2003; von Hippel, 2005; Sorenson et al, 2006). The case's findings support the conclusion that how recently firms have started up affects their decisions whether to be close to a university because new firms are more likely to depend on knowledge created in university cities (Audretsch et al,

2005). Furthermore, general-purpose emerging technologies are more likely than narrower ones to have many different applications (Eckhardt and Shane, 2003).

Many knowledge-transfer activities took place, creating close networks among local industry actors and researchers. This has yet to lead to any R&D investment, but industry representatives have spent much time learning about PE. Furthermore, the international business intelligence in regard to PE that PEA and the researchers have provided has apparently been of value for such participants as Billerud, and Acreo has pursued its licensing activities professionally with an experienced licensing team who are present in global arenas. This has led to several research-related cooperative relationships between multinational companies and research groups.

The generation of start-up firms based on PE has so far had three sources. Two companies are spin-offs from Acreo. Another source was an entrepreneurial PhD student who found new applications in the course of his research. The third source was an entrepreneur who discovered a market opportunity and found PE to be a solution for satisfying it. This last phenomenon is also of interest due to PE's absorptive capacity. It is a pull effect that attracted the entrepreneur who launched a knowledge-intensive start-up firm. He resided two hours away from Norrköping but commuted there to build up a network with the actors in the knowledge and innovation spaces.

Table 4 Preliminary indications of innovation

Technology transfer modes	**Important conditions**	**Companies**
Externally generated entrepreneurs	Problem needs are identified	Neoplex
Internally generated entrepreneur	Converting solution capability to a search for applications	Inorel, Soleve
Licensing agreements	Acreo having technology-transfer capability	PEAB, Japanese company, StoraEnso
Spin-off from Acreo	Being close to the Acreo's activities	Webshape, Paperdisplay

7. Concluding Discussion

Both knowledge-based and regional factors have had special importance in the search for economic development (Romer, 1986; Krugman, 1992). Knowledge-based regional development centres on knowledge spillover in close geographical proximity to the knowledge's source. The sources of knowledge creation are R&D organisations as universities, research institutes, and large companies. Academic research organisations in particular are increasingly important knowledge creators, and such studies as Braunerhjelm et al (2010) have pointed out that such institutional and organisational obstacles as knowledge filters make a major difference in knowledge's economic output.

This study has shown that local actors can understand the importance of reducing knowledge-filter barriers and can mobilise resources to do so. They have dedicated these resources to

facilitating the commercialisation of an emerging technology and have used them to create local as well as international networks, a prototype factory, and a consensus space for the regional actors involved.

This study therefore concludes that although many actors have been involved, only a few specific actors and processes have been essential for turning the new knowledge into potential economic output in the four categories of internally and externally generated start-up firms, license agreements, and research-institute-initiated spin-offs (See Figure 3). These activities are all bottom-up processes that people initiate based on the technology's potential uses, the distribution of information about its potential among nascent innovators, and how low the barriers are for actors who want to exploit solution capability and problem information jointly. These findings suggest that knowledge-based regional economic development is based on the bottom-up processes of problem information, solution capability, and entrepreneurship.

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Table 1 PEA's actors and their activities (PEA, 2008)

Activities	**Actors**						
Coordin-ation:	PEA: Vision, Strategy, Networking, Marketing, Meeting-places, Services						
	Public actors		Academy			Industry	
	Municipalities, Östsam, NOSP, LEAD	Innova-tionsbron	LiU	Acreo	PEA-M	Established and start-up firms	VC
Research:			Material, components	Systems, production methods		Material, equipment, products, and market demands	
Creation:	Business idea contest, idea seminars, entrepreneurial activities		Ideas, entre-preneurs	Ideas, entrepreneurs, technology dissemination	Ideas, entre-preneurs	Ideas, entrepreneurs, products, and market demands	
Starting:	Start-up firms, incubator, ENP, soft landing, Venture Cup	Seed capital		Technology transfer, start-up firms	Prototype resources	Technology implementation	
Develop-ment:	Testing, management, human capital development		Basic techno-logical problems	Development projects	Test, pilot production	Applications	Com-pany
Growth:	Coordinating capital				Production resources	Sales, marketing	Capital

Appendix

Illustrative Cases of Commercialisation of an Emerging Technology

Initiative within established firms: Some examples.

Large companies interested in PE have approached Acreo with different proposals. PEA finds it easier to work with established companies because such companies know what they are doing, have financial clout, and have indicated a willingness to develop the product or service involved. PEA assists its members with market appraisals and information about state-of-the-art technology, what components are available, and structural information.

StoraEnso, a multinational pulp and paper company, is launching a controlled delaminating material product, which is glue that can be electronically delaminated that Acreo helped to create. It may be used to glue together primary packaging units for transport, which can then be detached at the click of a button to form individual packages for store shelves.

A large multinational security company with a regional presence has joined with Acreo and LiU in developing a tag to certify the authenticity of one of its products. It plans to integrate the tag into a mass-produced product and launch it on the market within two years, with the production line to be located in the region.

A Japanese company has joined with Acreo in developing commercial posters to be used in the retail and transport sectors. Their displays are matrix addressed, which means that their messages can therefore be changed within seconds. The company has one part-time employee at PEA-M.

A research project in Katrineholm called Brains and Bricks, financed by the construction company PEAB, has created a sensor based on organic materials and PE. It is possible to integrate these sensors into new houses to discover quickly if they are suffering from damp and to read them using wireless technology.

Start-up initiatives: Some examples.

Entrepreneurs with business ideas with a technological core based on PE need to gain access to the technology through Acreo, which manages all the IPR in this field. The businesses described in the following paragraphs are those that have been mentioned in applications to PEA's and Acreo's financiers.

Reeltronics-WebShape bases its activities on an environmentally friendly process that uses board foil to produce parts of antennas, heaters, and printed circuit boards, products that would otherwise be produced by an environmentally damaging slow-etching process. Acreo developed the technology, which involves a reel-to-reel process that can run at speeds up to 150 metres per minute. The company's business idea is to achieve a positive cash flow first and then to create its own products further up the value chain, where better margins exist.

PaperDisplay is a newly formed business area within Acreo aimed at commercialising paper displays. Acreo created it after receiving several requests to provide technology to customers who need low-cost displays called smart tags for their products. Discussions are currently underway with 28 regional, national, and international companies that want to license the production technology or buy the finished displays. Local production will be at the printers in PEA's networks and at PEA-M.

Inorel is a company being created to develop intelligent labels that monitor such transport conditions as temperature in transit and that indicate if any are incorrect. This business idea won the Venture Cup East 07-08, a business-plan competition.

Soleve is a company being created to develop and commercialise low-cost solar cells for large areas using organic materials.

Billerud: A large business case.

Billerud is a large packaging-paper company based in Norrköping that has 2,300 employees in 10 countries and a turnover of SEK8 billion. It outsources all its research to different university research groups, but mostly to KTH, the Royal Institute of Technology in Stockholm. Although it conducts no in-house research, it does undertake many development processes, which always involve a customer with a special need. This means that its R&D is always market-pull driven.

It joined the PEA network to obtain access to other packaging-paper companies. Doing so cost it little and such networks are inadequately established within the Norrköping region despite the number of companies in the industry. Although it might be interested in PE in the future, this is not why it joined. The international Organic Electronics Association, which briefs the network's members on the development of organic electronics around the world, offers a great means for Billerud to increase its business intelligence cheaply. Whether PE will be of interest to Billerud depends on what applications result from its research and technological development. Billerud is of course likely to be interested in any applications it sees as useful to its business.

According to the Billerud (2008) website's homepage, "The company's business concept is to offer demanding customers packaging material and solutions that promote and protect their products – packaging that is attractive, strong and made of renewable material." It focuses on the three market trends of "increased environment awareness, improved cost conditions in the conversion process and agreement that paper packaging provides a more luxurious feeling compared to many other materials."

Neoplex: A small business case.

The founder of a start-up firm based on PE called Neoplex, said that his idea started out as a need he had heard identified by a major incumbent firm in the Swedish gambling industry that, with its retail partners, had seen an increasing share of gambling revenues migrating from the physical world to online. The retail stores' representatives were concerned about the decreasing market for a product from which they not only made considerable profits but which also attracted customers into their stores.

The gambling-industry firm currently sells approximately 180 million of these lottery tickets in Sweden annually. The founder had worked as a business-development consultant with it and started to search for a new technology that might bring customers back into the stores. His research led him to PE, and he learnt that Acreo in Norrköping is one of the leaders in the field. He therefore initiated some meetings with Acreo in order to discuss the possibility of using their technology for new gambling and lottery products.

Acreo was excited about the idea, and they created a small pilot project together, the August 2005 evaluation of which was particularly positive. A two-day pilot study in Norrköping indicated that the displays worked. The founder then started to search for pre-seed financing. The local office of the national governmental development foundation, Technology Bridge Linköping, suggested Iteksa Ventures, an early-stage investment firm owned by Technology Bridge, SAAB, and Industrifonden. Its representative mentioned that Rendera, a small early-stage fund governed by the Technology Bridge Linköping, might be interested. Rendera decided to back the idea and the entrepreneur with SEK700,000, with further financing

coming from Almi and the Technology Bridge, which provided SEK150,000 each. By Christmas 2005 these financiers had invested SEK1 million in Neoplex.

The founder then went on paternity leave for three months while Acreo worked on the prototype, encountering many different problems. Just before summer 2006 the prototype was working and Neoplex demonstrated it to the gambling-industry firm and an almost functional prototype to Iteksa. Neoplex had a deal with the gambling-industry firm that stated that the firm would provide it with expert advice and information about the market in exchange for the exclusive rights to sell the lottery tickets in Sweden.

The Östergötland County Administrative Board called Neoplex and asked if it wanted to borrow SEK400,000, having received advice to do this from the Innovation Bridge and Almi. Neoplex then issued new shares, with Iteksa investing SEK700,000 and Rendera SEK300,000. This enabled Neoplex to further its technological development. The founder noted that, "I think Acreo and PE are very dependent on external entrepreneurs, companies, and other actors putting demands on them. Otherwise they would be conducting research without any particular commercial direction or goal" [Translated from Swedish by the author.]

The founder had told Acreo how he wanted the technology to perform. In order to do so he had had to develop a thorough understanding of the inner workings of PE technology. He also acquired a deeper understanding of the gap between businesses' commercial culture and universities' research culture. He perceived Acreo to be a highly professional organisation, although some misunderstandings did occur during technology development discussions due to differing expectations. Attempting to describe these differences, he said that he thought the problem lay in how different cultures set priorities during a development process. He said further that the business community defines its customers and that for it the end product is what counts, but that in the research community it is discoveries, articles, and how to satisfy research financiers that matters.

Neoplex received SEK1.4 million for technological verification in 2007. The technology was then due for production in a small series for an estimated cost of SEK8 million. After Iteksa dissolved later that year, Rendera took over its position as lead investor and wanted to invest a further SEK3 million. In February 2008 Neoplex received an order from the gambling-industry firm to buy the first batches of prototypes. StoraEnso Venturing indicated its interest in investing, but an organisation within it needed a sponsor, which created some inner tensions, and it therefore pulled out. This put Neoplex in a catch-22 situation, as it had its first order but insufficient development resource.

A US patent is pending that aims to protect the application of PE to lottery tickets. Neoplex may need to use all of Acreo's IPR abilities in the gambling market, with it acquiring 5% of the company due to the SEK8 million worth of injections. It had a potential stake in the company and it would be of great marketing interest for PE in general if Neoplex were to succeed. Despite this, however, no extra money has been available for prototyping due to the global financial crisis.