The Local Innovation System of the Oil and Gas Industry in the North Sea:

The Application of Patent Data in the Study of Innovation Systems

By

Wei Gao

B.S., Engineering Physics (1999)
Tsinghua University

M.S., Nuclear Engineering (2005)
Massachusetts Institute of Technology

SUBMITTED TO THE DEPARTMENT OF NUCLEAR SCIENCE AND ENGINEERING IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN NUCLEAR SCEIENCE AND ENGINEERING AT THE MASSACHUSSETTS INSTITUTE OF TECHNOLOGY

August 2008

[September]

Signature of Author: ______________________

Wei Gao
Department of Nuclear Science and Engineering
April 8, 2008

Certified by: ______________________

Richard K. Lester
Professor of Nuclear Science and Engineering
Thesis Supervisor

____

Jeffrey L. Furman
Assistant Professor, Boston University
Thesis Reader

Accepted by: ______________________

Jacquelyn C. Yanch
Professor of Nuclear Science and Engineering
Chair, Department Committee on Graduate Students

The Local Innovation System of the Oil and Gas Industry in the North Sea: The Application of Patent Data in the Study of Innovation Systems

by

Wei Gao

Submitted to the Department of Nuclear Science and Engineering
in partial fulfillment of the requirements for the degree of
Doctor of Philosophy in Nuclear Science and Engineering

ABSTRACT

The North Sea oil province, one of the world's major centers of petroleum and natural gas production, has been in play for four decades. Production rates have approached their peaks in recent years and are expected to decline continuously in the future. The economies of certain cities and regions bordering on the North Sea have become heavily dependent on the oil and gas industry. How these local economies will sustain themselves in the future as resource depletion continues is a critical question.

To gain insight into this question, we selected a matched pair of city-regions, each of which is an important center of the oil and gas industry in the North Sea province: Aberdeen in Scotland and Stavanger in Norway. By studying the similarities and differences between the local innovation systems in the two regions, we can gain a general understanding of how local economies respond to changes in their environment.

U.S. patenting data are used as a tool to describe the behavior and performance of the two local innovation systems. The patent data provide a means of systematically and consistently estimating knowledge flows. The use of U.S. patent and patent citation data provides evidence, references, and guidelines to the project from a quantitative perspective. Several indicators

were developed to describe these knowledge flows, along with a model providing further insight into how knowledge was acquired and introduced into the two local innovation systems, how and to what extent local innovation capabilities were developed, and how knowledge created locally has spread elsewhere.

Both Stavanger and Aberdeen have worked hard to strengthen their local innovation capabilities by learning from the world's most advanced firms, especially those from the U.S., and by building capabilities of their own. At the same time, attracted by the extensive reserves of oil and gas, multinational firms, many from the U.S., moved into the North Sea region. The involvement of multinational firms helped reinforce local innovation capabilities.

However, because of the different policy approaches pursued in the two regions, U.S. firms, the international leaders in oil and gas technology, have played more important roles in Aberdeen than in Stavanger. In the Stavanger area, local innovation activities have been led by national oil companies rather than by foreign firms.

Acknowledgements

I would like to begin with a special thanks to my thesis advisor Professor Richard K. Lester, who provided me the good opportunity to work on this wonderful project in the Industry Performance Center at MIT. Professor Lester has been continuously giving me extensive support, encouragement, and helpful guidance to explore my own ideas.

Secondly, I wish to thank my teammates on the North Sea Oil and Gas Project, Sachi Hatakenata, Peter Westnes, and Martin Gjelsvik, who have made tremendous contribution to the project. I obtained fruitful knowledge and research experience by learning from you. Without my colleagues, I cannot imagine that I can finish this job successfully.

A very special thanks also goes to Professor Jeffrey Furman for sharing with me of his broad knowledge in innovation and patent study. Professor Furman's instruction made me feel confident on my research. I would also like to thank Professor Michael Golay, who gave me his kindly suggestions and helps whenever I was in a difficult situation during my time in MIT.

I want to express my gratitude to my friends Bing Han, and Sisi Zhang, who are also experts on statistics and economics. Both of you helped me get started with STATA, and taught me many critical statistical analysis skills.

Many thanks to my officemates: Carlos A. Martinez-Vela, Ruthann Huising, Douglas B. Fuller, and especially our lovely IPC administrator Anita Kafka. You made my life in MIT much easier and smoother.

Finally, I dedicate this work to my parents Anshe Gao and Jifeng Lu. Throughout my life, they never hesitate to give me their love, support, and encouragement so that I can pursue my higher goals.

This research was partly sponsored by the Research Council of Norway.

Table of Contents

Chapter 1 Introduction

The research involved in this thesis is part of a study of the North Sea oil and gas industry research that is being conducted at the Industry Performance Center at Massachusetts Institute of Technology (MIT). The focus of this project is a matched pair comparative case study of the development of the offshore oil and gas industry in two important regional centers of activity in the North Sea oil province: Stavanger in Norway and Aberdeen in Scotland.

Stavanger and Aberdeen each began their rise as oil centers following the discovery of major oil resources in the North Sea in the 1960s. For more than three decades they have both served as important nodes of oil exploration, development, production, transportation, processing, and distribution operations in the local area. But the production of oil and gas is peaking in the North Sea province and will continue declining in the future. An important question for Stavanger and Aberdeen is how they will be able to maintain their prosperity and growth once oil and gas production in the North Sea begins to shrink. To achieve sustainable growth, the local innovation systems in Aberdeen and Stavanger can play critical roles.

In my research I will focus on using U.S. patent and patent citation data to evaluate and compare the local innovation capacity and capability of Stavanger and Aberdeen. I will use historical data to explore how knowledge from elsewhere was acquired and introduced into the local innovation systems, how and to what extent the internal innovation capabilities were developed, and how knowledge created locally diffused elsewhere.

1.1 The Local Innovation Systems Project

The North Sea oil and gas industry research project presented in my thesis is part of the Local Innovation Systems (LIS) project which is conducted by an international research team based at MIT Industrial Performance Center (IPC).

The LIS project is designed to address a critical question facing all industrial practitioners and economic policymakers throughout the world: How can local economic communities survive and prosper in the rapidly changing global economy? The project particularly focuses on the role of innovation – in products, services and processes – in innovation-driven or innovation-assisted industrial transformations at the local and regional level. The LIS project is studying the roles of universities and public research institutions, national and local governments, firms and other actors in the regional economy. It seeks to develop a comprehensive picture of the roles of all participants in the local innovation system.

The LIS project is investigating cases of actual and attempted industrial transformation in more than 20 locales in the United States, Europe and Asia. The current portfolio of case studies in the LIS project is shown in the Table 1-1. At each location, teams of researchers from the participating institutions are particularly interested in the local capacity and capability to absorb and/or to develop new technologies and knowledge. The researchers study innovation trajectories in these locales and seek to understand the factors that account for the particular outcomes.

Country	Location	Industry/technology
USA	Rochester , NY	Opto-electronics
USA	Akron , OH ,	Advanced polymers
USA	Allentown , PA	Opto-electronics/steel
USA	Boston , MA	Bioinformatics
USA	New Haven , CT	Biotechnology
USA	Charlotte , NC	Motor sports (NASCAR)
USA	Greenville-Spartanburg , SC	Autos
USA	Alfred-Corning	Ceramics
USA	Youngstown , OH	Steel/autos
Finland	Tampere	Industrial machinery
Finland	Turku	Biotechnology
Finland	Seinajoki	Industrial automation
Finland	Pori	Industrial automation
Finland	Helsinki	Wireless
Finland	Oulu	Medical Instruments
UK	Central Scotland	Opto-electronics
UK	Aberdeen	Oil and gas
UK	Cambridge	Bioinformatics
Taiwan	Taipei-Hsinchu	Electronics
Taiwan	Taipei-Hsinchu	Software
Japan	Hamamatsu	Opto-electronics
Japan	Kyoto	Electronics
Norway	Stavanger	Oil and gas

Table 1-1 Current LIS Research Portfolio

The LIS project has focused on a specific field or sub-field of industry, and in most instances a set of comparative case studies in multiple locations has been designed and developed. The primary data used in each case study are obtained from in-depth interviews with professionals from firms, university and public institution researchers, national and local government officials and policymakers, and/or other insiders. The case studies are augmented by qualitative and quantitative analysis using local and regional business and economic data sources, patent and publication databases as well as large-sample surveys.

1.2 The North Sea Oil and Gas Industry Research Project

The North Sea oil and gas industry research project is one of the case studies in the LIS project. In this project, we conducted a comparative case study of the development of the North Sea offshore oil and gas industry in two regional economic centers: Stavanger in Norway and Aberdeen in Scotland. The transition occurring in Stavanger and Aberdeen, from a resource-based to a knowledge-based economy, is one of several types of industrial transformation of interest in the LIS project.

The oil resources in the North Sea were first discovered in the 1960s. More than three decades after the first discoveries, both Stavanger and Aberdeen serve as important regional nodes of oil and gas exploration, development, production, transportation, processing and distribution operations in the North Sea. The oil and gas industry is among the most capital and technology-intensive of all industries. As the global demand for oil and gas continues to rise, the role of technological innovation in helping exploration, enhancing production and improving general efficiency becomes more and more critical. Throughout this period, Stavanger and Aberdeen have both benefited from the global stock of industry knowledge and technology, and both have contributed to it. But Stavanger and Aberdeen will not be able to serve as centers of exploration and production indefinitely. The oil and gas resources in the North Sea province will be depleted well before the world as a whole runs out of these fuels. Recent data show that oil and gas production from British zones of the North Sea province peaked around 2000. With greater proven and probable reserves, the production of oil from Norway peaked a few years later than it did in the U.K., and the production of gas is expected to peak shortly. A critical question facing both communities concerns whether they will be able to maintain their prosperity and sustainable growth even as oil and gas production begins to decline. The North Sea oil and gas industry research project is motivated by this question. Our focus is particularly on the capacities and capabilities for innovation that have developed in both locations since the discoveries of the natural resources and the role that these innovation capacities and capabilities have already played and will continue to play in the development of the local economy. Ultimately we seek practical recommendations for the local communities that can help strengthen their local innovation capabilities and transform their economies smoothly and successfully.

In the North Sea oil and gas industry research project, we used a comparative case study methodology to carry out the study. In theory, the matched pair methodology allows us to reach more general conclusions about the phenomena we are interested in, than would be possible if we only studied a single case. Two cases in the structured comparison are required to share similarity in all aspects except for the target phenomenon. It will be hardly possible to reach this rigorous condition in reality. In practice, we may only be able to control for a few of factors. But the matched pair methodology still can help us have much deeper understanding of each of cases by drawing contrasts between them. The data we used in this research was primarily obtained from in-depth interviews with key persons from firms, national and local governments, universities and research institutions, and other related organizations. We carried out 31 interviews in Stavanger and 40 in Aberdeen. The 31 Stavanger interviews were conducted with 29 key informants; with 14 people representing industry, 1 from government, 7 from research institutions, 4 from universities, and 3 people representing industry related organizations. In Aberdeen the 40 interviews were conducted with 40 key informants; with 17 people representing industry, 8 from governments, 9 from three universities, and 6 from other industry related organizations. We also used secondary materials and other quantitative data sources such as local business and economic statistics, and patent and publication databases to augment the interview data.

In my research, I used U.S. patent data to trace the innovation trajectories which occurred in the Stavanger and Aberdeen oil and gas industries following the initial North Sea discoveries of oil. I collected 819 oil and gas-related U.S. patents granted to Aberdeen inventors, 324 oil and gas-related U.S. patents granted to Stavanger inventors, and all of the forward and backward patent citations associated with each of these patents. The collected U.S. patent and patent citation data were used to measure the past and current innovation status in Stavanger and Aberdeen oil and gas industry. Being one of the few continuous records of innovation, the collected patent and patent citation data were also used to describe the evolution of the local innovation systems in the Stavanger and Aberdeen oil and gas industry. The patent study is thus able to provide evidence, and inferences for the whole project from a quantitative view.

1.3 Literature Review 1: The Study of Local Innovation Systems

The local economic system which contains firms, national and local governments, regional universities and public institutions, and other industry related organizations has been an interesting research topic for a while. In particular, as a critical part of the local system, the local innovation system catches many research scholars' attention. Consequently, a lot of theoretical approaches and concepts of different aspects of local innovation systems have been developed, including regional clusters or territorial agglomeration (e.g. Porter 1990, Kolehmainen 2003), regional learning capacity and capability (e.g. Cooke and Morgan 1998, Kosonen 2005), and knowledge network (e.g. Safford 2004). In our research, we put a lot of emphasis on knowledge spillover, and on university-industry interaction, the role that universities play in local innovation systems or.

The causes, effects, and implications of knowledge spillover have been in the range of academic research interests for a long time. Its theoretical foundations are based on the productivity research. This discussion started as early as in Griliches (1979). After that many scholars brought in their theoretical ideas. Spence (1984) and Cohen and Levinthal (1989) introduced "partial equilibrium" theoretical treatments of the effects of R&D spillovers. But the most important theoretical contributions were given by Grossman and Helpman (1990, 1991, 1995). Grossman and Helpman introduced a general equilibrium framework of two trading economies in which the rate of world economic growth is determined by the rate of innovation. In their framework, R&D activity requires both investment of resources such as capital, labor, and a stock of general knowledge which is assumed to be accessible to all innovators for free. In turn, the innovations as the outcomes of R&D activities generate both new products which the innovators can benefit from, and some new general knowledge. Therefore, the knowledge foundation can grow and more innovations are created without extra investment of resources. Thus, "knowledge spillovers serve as engines of endogenous growth, allowing economic growth to proceed indefinitely without diminishing returns setting in". The work done by Grossman and Helpman provided solid foundation to the empirical research. The most general empirical models of knowledge spillovers designed to measure knowledge spillovers are some kind of production functions or a combination of production function and cost function such as the ones presented in Griliches (1992) and Griliches and Mairesse (1995). Caballero and Jaffe (1993) tried a different approach and started the work of using patent and patent citation data to quantitatively access knowledge spillover. Later, a great amount of empirical research was carried out based on these models (e.g. Coe and Helpman 1995, Jaffe and Trajtenberg 1996, Hu and Jaffe 2003). Our empirical research is an application of Jaffe's framework.

University-industry interaction has been a hot topic in the innovation research field for a while, and is attracting more and more attention of many scholars. Bower (1992, 1993) showed that university-industry relationships have a long history. The firms benefit from this relationship by accessing well trained students, high-end facilities, advanced information, and knowledge (Fombrun 1996). Universities collaborate with industry for additional funds (NSB 1996), access to applied technological areas (NSB 2000) and many other purposes. Many researchers who work for the Local Innovation Systems Project carried out at MIT Industrial Performance Center have also put their emphasis on the role of universities in the local innovation system and worked on many case studies. Chakrabarti and Lester (2002) compared the roles of four technological universities in the U.S. and four technological universities in Finland in knowledge generation, diffusion, and implementation for the purpose of helping develop their regions. Srinivas and Viljamaa (2005) found that in Turku, Finland where biotechnology is concentrated, the way in which the local universities collaborate with industry and engage with regional development is driven by resource constraints rather than a consistent strategy. Lester (2005) gave a summary of the results from the first phase of the Local Innovation Systems Project. The evidence shows that universities contribute to local innovation processes in a variety of ways. The most important contribution of universities is education. They also serve as public spaces for ongoing local conversations about the future direction of technology and market. Their current major focus is on technology transfer through patenting, licensing, and many other ways.

1.4 Overview of the Dissertation

The rest of this thesis will be organized as follow:

In Chapter 2 we describe what the reasons behind our research are. Stavanger and Aberdeen as two important cities within the North Sea province experienced a significant transition from non-energy related economies to economies focused on energy development since the initial discoveries of oil and gas in the 1960s. After decades of exploration and production, these two cities are now facing a new challenge because the production of the precious natural resource in the North Sea is nonreversibly decreasing. My research is designed to address the challenges faced by the local innovation systems of Stavanger and Aberdeen when the regional economies experienced these two transitions. We carry out the study by using a comparative case study methodology to analyze the U.S. patent and patent citation data. After a brief introduction of the U.S. patent and patent citation, we review the previous literature in the field of patent analysis.

In Chapter 3 we give an overview of the North Sea province. We compare the general information, the status of natural resources, and the situation of the local oil and gas industry between the great Stavanger area and the great Aberdeen area.

In Chapter 4 we first describe several different sources of patent data more in detail. And then we present the method that how we collect and process the U.S. patent data. To be unabridged research documentation, we give some detail description of the design of patent database. At the end of this chapter, we show the general results of the numbers of the U.S. patent granted to the Aberdeen and Stavanger local inventors and assignees.

In Chapter 5 we describe the methodology of data analysis used in our research. First we introduce a few general indicators that use patent data to measure the basicness and appropriability of innovation. Second we describe the mechanism of knowledge spillover and a regression model applied to patent data.

In Chapter 6 we present the results of the study of the U.S. patent, patent citation and scientific reference. At the end of this chapter we discuss and summarize the primary findings from the results.

In Chapter 7 we review the contributions of the thesis, and list several possible directions of future research.

Chapter 2 Research Approach

2.1 Research Purpose

It has been nearly forty years since the initial discoveries of oil and gas in the North Sea. During this period, Stavanger in Norway and Aberdeen in Scotland experienced a significant transition from non-energy related economies to economies focused on oil and gas development. Prior to the discoveries of the natural fuels, both of these cities had served as important local economic centers for years, but neither was energy-focused. The main industries in Stavanger were shipbuilding, agriculture, and the canning industry. The primary economic activities in Aberdeen were fishing, granite quarrying, and others. After forty years of development, both Stavanger and Aberdeen and their surrounding areas have become regional centers of the offshore oil and gas industry in the North Sea province and are relying heavily on it. After decades of exploration and production, these two cities are facing a new challenge because the precious natural resource in the North Sea is expected to be depleted at some point. Recent data shows that oil and gas production from the U.K. peaked around 2000. With greater proven and probable reserves, the production of oil from Norway peaked a few years later than it did in the U.K., and the production of gas is expected to peak shortly. Given these developments, a second transition will have to be made so that the cities can survive during the decline of oil and gas production and achieve sustainable growth.

The progress of the first transition was affected by the way in which the local innovation system responded to the new situation, and the success of the second transition will be similarly influenced by the reaction of the local innovation system. When the first transition started in the 1960s, Stavanger and Aberdeen both took their approaches to restructure the local systems of technological know-how so that they could adapt to the natural resources dependent economy. Both approaches helped Stavanger and Aberdeen realize the first transition successfully and come to lead the local oil and gas industry to be the centers of the region and even the world. While the natural fuel is close to depletion, the local innovation systems will also be likely to play a critical role in helping the second transition so that the local economies can survive and even achieve sustainable growth. What have happened in Stavanger and Aberdeen gives strong evidence that today a local innovation system contributes significantly to the reform of a regional economy so that it can adapt to the environment of globalization. This phenomenon brings tremendous interest to the study of how the local innovation systems of Stavanger and Aberdeen respond to the changes in their surrounding conditions, and what the effect of these actions is. The results of our study can not only benefit the future development of the North Sea region, but can also provide examples to other emerging economies that rely heavily on natural resource exploration and production, or to any other systems facing significant changes because of globalization.

My research is designed to address the challenges faced by the local innovation systems of Stavanger and Aberdeen when the regional economies experienced the past transition because of the discoveries of natural fuel as well as when they will face the future changes regarding the depletion of oil and gas. The local innovation system to which we refer is a spatial concentration of firms, institutions, local government agencies, associated organizations and others that combine to create new products and/or services in the oil and gas industry. The challenges faced by the two local systems are generally the same during each transition. But the challenges can also be slightly different because Stavanger and Aberdeen do not share exactly all the same characteristics and figures. For example, the reserves of oil and gas in Norway are greater than the reserve in the U.K. The local systems can take active approaches to change themselves when they meet the challenges. But not all the changes of the systems are the results of deliberate selection. Some changes can happen in a passive way to adapt to the figures of the system, such as the national policy that the local system has to follow. My research will study both deliberate approaches and passive selections, but with emphasis on the first. Even though the second transition is still pending, some changes of the systems have happened already. This makes it possible for us to use historical data to observe the changes of the systems and study the deliberate approaches and passive selections taken by both regions in response over time. I will make a comparison study to find out the similarity and difference between Stavanger and Aberdeen.

2.1.1 The first transition – discovery of the "black gold"

Before the initial discoveries of oil and gas, Stavanger and Aberdeen had been hubs of their respective regional economies for centuries, but both of them had at most a very limited relationship to the oil and gas industry. Given that the two cities were starting essentially from scratch and with very limited know-how, if they were to emerge as centers of industrial capability in the oil and gas sector, it would be very helpful if they can build up associated technological capabilities and set up some local innovation systems quickly. It will be much easier and more efficient for the local economies to take advantage of the opportunities created by the oil and gas discoveries if they can master sufficient and sustainable related knowledge.

2.1.1.1 Learning versus creating

In order to accumulate necessary knowledge, there are at least two different choices. First, advanced information can be acquired from experienced individuals or organizations outside the region. This is an efficient way for a region starting with nothing. By learning from outsiders, a large amount of essential knowledge can be brought in within a short period. With modest investment, the local innovation system will in principle be able to catch up with the advanced developed oil and gas sectors in the other places of the world quickly, assuming there is strong local absorptive capability. Alternatively, innovative ideas can be created locally by building up internal innovation capability organically. Being the regional economic centers for centuries, both Stavanger and Aberdeen are more likely than the other regional places to have the desires to lead the development of the industry in stead of acting as a follower. Apparently this can not simply succeed by learning from the others. Incubating and developing local innovation capacity will make it easier to achieve the goal.

It is very unlikely that a given community would adopt just one of these approaches exclusively. Both approaches could be implemented given different weights at different times according to the situation. For most of the local innovation systems that begin from scratch, it is very likely for them to start building up the local innovation capacity by importing knowledge from outside first. This process may never stop even after the local innovation system becomes strong. Later on, the internal innovation capability can be possibly set up if the surrounding system meets certain requirement. When the internal innovation capability starts being build up depends on the characteristics of every individual system. The internal innovation capability may grow continuously. It can exceed the external innovation capability eventually or it can go flat and never beat. Therefore it is more reasonable for us to think that the growth of local innovation system is a result of the combination of learning and creating. My research will observe which approaches at what time Stavanger and Aberdeen local communities focused on, and how the approaches affected the transition from non-energy locales to the regional centers of oil and gas industry.

When a local economy tries to bring in the external knowledge so that it benefits internal development, there are several possible sources that it can ask for help from. The most likely choice is that local developers directly go to the most advanced player in the world. This action will help the laggard society quickly catch up with the most recent discoveries in the world and minimize the difference within a short time. But this requires that local developers have good enough capability and big enough capacity to accept and digest substantive inflowing advanced knowledge. However it is not enough to have inclination from the local developers only. It is more decisive that if the local economy can generate sufficient benefit to the advanced players from elsewhere so that they have motive to bring in their technology.

Beyond the primary choice, there are several other options. The local developers can approach the geographically nearest neighborhood, close collaborators in other non-oil-and-gas-related activities or any other potential sources that they have certain relationship with. These types of approaches have the advantages of sharing the same language, faster and easier mutual communication, familiarity or other conveniences that make the knowledge cognitive process less difficult. Any of these sources may not necessarily hold the most advanced or relevant knowledge. Therefore the benefit may not be maximized.

Every individual player in the local innovation system will try to learn from one or multiple information sources listed above based on his own condition and preference. Some sources may attract more users, and some others may have less audience. Therefore it is not necessary for the local innovation system to obtain knowledge from one single source. It is more likely to have a combination. Our research interest is to characterize the distributions of sources of different local systems.

In addition to learn from the same industry, the local developers can also obtain relevant knowledge from other functionally related or technologically connected industries. Learning from the same industry is likely to be the most efficient way to achieve serviceable knowledge and technology. But it does not rule out any other relevant industries. Getting information from related industries can possibly increase the innovative capability of the regional system by bringing fresh and different ideas. The ability to retrieve knowledge widely also has the potential to reveal an aspect of the innovation capability of the local players. Therefore it might be hard for us to tell whether learning from a broad range of other industries or other sources is a cause of the enhancement of innovation capability or a manifestation of it.

My study will observe all of these preferences that Stavanger and Aberdeen oil and gas industry players had while they imported the knowledge from outside of the local region. I will explore the questions of how heavily they relied on the knowledge from national, continental or international sources, whether they learnt anything from industries besides oil and gas field, how these preferences changed by time, and how quickly the local system responded to the external innovation.

As we mentioned above, another solution to build up the local knowledge capacity is through the internal development. In order to become a strong local center and lead the development of industry in the region, it is barely enough to simply rely on the knowledge and technology learnt from the others. It is more important to stimulate and exercise internal creativeness after digesting external knowledge. This provides more flexibility and self-determination power to the local system and makes it more active and self-sustainable. Again, the internal innovation capability development will always exist along with external knowledge ingestion during all the time periods with different weights on each.

A well set up local innovation system is a must-have to support this interior progress. To set up this system, both local academic and industrial communities are required to have active participations independently or mutually. The same as the industry, the academia acts as an input of the local innovation system. The products of the academia and the industry then serve and benefit the industry itself as the output of the system. The joining of local institutions lifts up the level of knowledge foundation and provides solid scientific support. The local industry focuses on the practical application and realizes the commercialization in response to rapid changes in market. The emerging institution-industry interaction is likely to make the innovation more efficient. Therefore more and more cooperation and mutual penetration between academia and industry are found.

My study will explore how Stavanger and Aberdeen oil and gas industries took advantage of the local innovative capability, how the local innovation systems were contributed by the local academia and the local industry, how important the roles of institutions and industries were in the system, and to what extent the academia and industry cooperated with each other.

2.1.1.2 The role of multinational firms

Another very interesting topic concerns the contribution of multinational firms to the accumulation of innovative capabilities in these regions. Multinational firms act as more than local learners or knowledge creators. They help transport the knowledge from one place to the other, educate local communities, and reinforce the local innovation capability. I would expect that the presence of multinational companies will accelerate the knowledge transfer process that happens between different geographical locations. With the assistance of multinational firms, the local innovation capacity is likely to be built up faster and easier. But these firms may also enforce some limitations on the local innovation development to protect their own benefit. Sometimes they will not transmit the most recent and advanced technology that they have to the local innovation system or may even block it, so that the local developers will not be able to compete with them or harm their benefits. In my study, I will compare the role of multinational firms in the local innovation systems of Stavanger and Aberdeen oil and gas industry, including their contribution to knowledge diffusion.

2.1.2 The second transition – natural resource depletion

After more than three decades of development, recent data shows that the oil and gas production from the U.K. peaked around 2000. With greater proven and probable reserves, the production from Norway is expected to peak several years later than it did in the U.K. Though the oil and gas industry will continue playing a vital role in both regions for many years, how the economy can sustain itself as the production of oil and gas continues to decline will become an important question for local governments.

Today, a large number of local innovation capabilities are used to enhance the performance of exploration, development and production activities. But eventually the local innovation system will be required to provide a foundation for a more sustainable economy that depends less on oil and gas. The local economy can export knowledge under the format of products or services to the other oil and gas producing regions. It can also diversify its strength into different industries that are more likely to be energy-related or technology-related. We can not know today which scenario will dominate in the future of Stavanger or Aberdeen. But even in prior years, both cities not only benefited from the knowledge and technology developed globally; they also made significant contributions to it. Their local innovation systems created a large amount of advanced knowledge and technology. Some of this knowledge diffused to the other locations and to other industries. Therefore even a study of the historical data can provide some insight into the likelihood that Stavanger and Aberdeen will be able to negotiate the forthcoming transition.

2.1.2.1 Exporting knowledge and technology

One possible path that can lead to a sustainable economy even after the depletion of oil and gas resources within the region is by exporting products and services to locations where reserves of fossil fuel remain extensive. In order to be competent to provide competitive products and services globally, the local industry must not only master the necessary advanced technology, but must also maintain an active and productive innovation system that helps support continued development.

It is not necessary to wait until abundant knowledge has been accumulated or a complete system has been set up. The process of exporting products and services can occur at each stage by distributing knowledge to other places where technology is less developed and/or cost of production is higher. It is not necessary for the knowledge itself to be the most advanced as long as it is compatible with and useful to the users in the other area. Therefore it is possible for us to develop insights into the region's potential as a future source of exports by studying the historical data. It will be enlightening for us to know how the local Stavanger and Aberdeen innovations affected development outside the region during different time periods, as well as who was most likely to be influenced.

Everyone, including local firms, regional institutions, multinational companies, and whoever is involved in the local innovation system, can contribute to the knowledge exporting process. But it is especially important for local players establish a strong position and play a critical role within the system. Most multinational firms have no particular motivation or obligation to promote local innovation capacities. These firms have much greater flexibility to choose to leave or stay. They will decide to stay only if they can benefit from the local system, whether by exploiting the natural resource itself or by exploiting an advantageous local cost structure or local knowledge. If none of these benefits can be obtained, the multinational companies have no reason to stay. Even if they choose to stay and grow along with the local system, a large part of the reward could be shared with other locations or transmitted out of the local area. The best scenario for the local system is that, by learning from others and accumulating through development, the local players quickly build up their independent innovation capability, becomes strong enough to provide competitive products or services to extensive areas. In my study I will show to what extent in Stavanger and Aberdeen, the local innovation capabilities were developed by the local and external players, and how these different players contributed to the knowledge export.

2.1.2.2 Industrial diversification

Rather than finding new markets elsewhere for its products and services, the local economy can also achieve sustainable growth by diversifying into related industries. These may be functionally related fields such as refining or alternative energy supply, or technically related fields which include the options of machine design and manufacturing, information technology, bioengineering and many others. This approach could be harder to achieve than the previous one. It requires either a stronger internal innovation capability or a reconstruction of the local innovation system so that the system can again adapt to external knowledge inflow from the new industry. But this approach is important because it provides the local society a much larger space of options. I will test if either Stavanger or Aberdeen tried to make this approach. If the cities did try, I will further explore when they started it, how far they have been on this path, and what the domain of diversification might be.

2.2 Research Methods

I have used a comparative case study methodology to carry out the research. The emphasis is on the analysis of U.S. patent and patent citation data. By comparing the historical patent and patent citation data, we are able to examine the similarities and differences between the local innovation systems of Stavanger and Aberdeen. This comparative methodology allows us to move from an isolated case to a more general situation. This methodology gives us chance to make more universal conclusions, and to have much deeper understanding of the characteristics of each local system. The use of patent and patent citation data in the North Sea oil and gas industry research provides evidences, references and guidelines to the whole project from a quantitative view. The results of the U.S. patent study make the findings from the North Sea oil and gas industry research project more solid and believable.

2.2.1 Understanding U.S. Patents

A patent is one of the few documents that systematically and consistently record the occurrence of knowledge and of knowledge flows. It provides us with an effective way to review our innovation trajectories. The patent data also makes it possible for us to implement quantitative analysis of knowledge creation and knowledge diffusion. There are several advantages of using patent and especially U.S. patent data.

First, the number of patents is very large. Close to 8 million U.S. patents have been granted since 1870, and all are on file at the U.S. Patent and Trademark Office. The number is continuously increasing, at a rate of more than 190,000 patents per year (as of 2006-2007). This huge amount of rich data makes it possible for us to implement quantitative analysis on knowledge related research.

Second, patents have been granted in U.S. continuously since 1870s. This provides an uninterrupted historical record of more than 100 years with consistent reported data. Moreover, during the past three decades, U.S. patents have been reflecting more and more international inventive activities rather than just activities within U.S. itself. The percentage of U.S. patents granted to foreign inventors has risen from about 20% in the early 1960s, to about 45% in the late 1990s. This wide coverage of time and geographical space provides us with immensely useful information and research opportunities.

Third, each patent contains highly detailed information including the invention itself, the patent's inventors and assignees and their geographical locations, the time of filing and other important chronological information, the technological field to which the patent belongs, and the citation information. This last is especially important because it connects the patent to its ancestors and descendants. This integrated information database allows us to do more complicated analysis rather than simple statistics.

The final advantage of the use of patent data is that the information contained in each patent is provided entirely on a voluntary basis, and the incentives to do so are plain and clear. The information provider acquires the grant of temporary monopoly rights in exchange for the disclosure.

Besides the advantages, there are several nontrivial limitations to the use of patent data. The first and most important limitation is that not all inventions are patented. Every individual inventor will make his own strategic decision on patenting his invention versus simply relying on secrecy or other means of knowledge protection. Only some inventors choose to protect their inventions by patenting. Even if they decide to patent their inventions, not all of the inventions will meet the patentability criteria set by the national patent office. Unfortunately, until now we have very limited knowledge about the extent to which patents represent the overall universe of inventions. Furthermore, not every innovation is necessarily exploited as an invention. It is very unlikely for us to find out the exact relationship between the amount of inventions and the amount of innovations. This relationship can be changed through time. And it is not necessary for the relationship to be the same for different countries or regions.

Another limitation to the use of patent data is that, as has long been known, patenting behaviors vary enormously in their related innovations' technological fields, geographical areas, and economic "importance" or "value". It is hard to make direct comparisons of patenting behaviors across different industries. Fortunately this limitation has little impact on our research because our project concentrates on oil and gas industry alone, and focuses on two important cities in the North Sea province which share similar background.

2.2.2 Understanding U.S. Patent Citations

An important feature of the U.S. patent database is that it includes citation information which connects every individual patent to its ancestors and descendants. There are basically two types of citations according to the time sequence of the citations and the original patent --- backward citations and forward citations. Those references which are cited by the original patent are called backward citations. Those patents which cite the underlining patent are called forward citations. In the U.S. Patent and Trademark Office database, two different types of backward citations are recorded. One is to prior patents. The other is to the pre-existing scientific literature or other non-patent sources.

The existence and physical record of citations make it possible to trace multiple or cross linkages between inventions, inventors, assignees, geographical locations of innovations, technological fields, time sequences and other factors. This rich information can be used to study the evolution of innovation, knowledge spillover or geographical diffusion, knowledge transformation between different industries, university-industry interaction and many other interesting topics. The patent citations can also be used to construct a series of indicators of innovation, such as "importance", "originality", "generality"; thus it is possible to measure the "value" of patents. Because of the large amount of patent and patent citation data, without computer assistance, it is barely possible to implement citation analysis. However, thanks to rapid progress in computer technology, one can now easily and quickly process a large amount of patent and patent citation data with the aid of computer software. Therefore a lot of quantitative methodologies have been developed during the past ten years to assist the citation analysis. Many of them have been contributed by Jaffe and Trajtenberg.

Though patent citation data provides us with a lot of useful information, it also has its own limitations. The fundamental purpose of citing prior art in patent files is to inform the patent owner and the public in general that such patents are in existence and should be considered when evaluating the validity of the patent claims. Thus if patent A is cited by patent B, it means that patent A represents a piece of previously existing knowledge on which patent B builds, and over which patent B cannot have a claim. Therefore, patent citations serve an important legal function rather than as an academic record. According to the Manual of Patent Examining Procedure (MPEP) posted on the U.S. Patent and Trademark Office website, "Any person at any time may cite to the Office in writing prior art consisting of patents or printed publications which that person believes to have a bearing on the patentability of any claim of a particular patent." It is widely know that the inventors or applicants of the patent have the duty to disclose any knowledge of the prior art. But we are able to tell from this statement that not all the citations of prior art from each patent are necessarily known by the inventors or the owners of the patent. The decision regarding which patents to cite ultimately is made by the patent examiner, who is supposed to be an expert in the area. Therefore the citations do not represent a connection between the inventor and the prior knowledge unless the citations are filed by the inventor himself. Some citations do occur in absence of any knowledge flow.

2.3 Literature Review 2: the Study of Patents

As early as 1966, Schmookler started the idea of using patent data in a large scale for economic research. In Schmookler's work, he assigned patent counts to industries. Schmookler only used the timing information of the patent, such that the patent data he applied to his research consisted of patent counts by industries, by year. A few years later, Griliches (1984) linked patent counts with firms.

At the early stage of applying patent data to economic research, scholars relied exclusively on simple patent counts as indicators of innovative output without taking advantage of other information contained in patents, because of the limitations on data availability at the time. However it is well known that innovation activities and patenting behaviors vary enormously in between technological fields and industries, geographical areas, and economic "importance" or "value". Schankerman and Pakes (1986) showed the skew in the distribution of patent values in their research. Therefore simple patent counts were inherently limited and exclusive use of simple patent counts could not faithfully capture the truth.

Aware of these limitations, scholars put efforts to construct systematic patent database and design new indicators and methodology using as much information in patents as possible. Hall, Jaffe and Trajtenberg (2001) spent approximately a decade with their colleagues from Notational Bureau of Economic Research (NBER) developing a database on U.S. patents with the goal of making it widely accessible for research. Trajtenberg, Henderson and Jaffe(1992) explored the use of patent and patent citations to measure the "basicness" and appropriability of inventions. They proposed that the previous patents cited by an invention or called backward citations could be used to measure the basicness of research underlying the invention; the patents that cite an invention, called forward citations, could be used to measure the basicness of outcomes of the invention; and the appropriability could be measured by the fraction of citing patents that are assigned to the same assignee as the original invention. In their research, Trajtenberg et al constructed a series of measures of innovations, such as "importance", "originality", "generality" and others. Caballero and Jaffe (1993) started the work of using patent citations to quantitatively access knowledge spillover. In Caballero and Jaffe's work, they built a nonlinear regression model to simulate the mechanism of knowledge spillover. The model parameters are used to estimate the knowledge diffusion speed and knowledge obsolescence rate.

After the methodology was well established, a lot of practical applications have been carried out by many scholars. For example, Hu and Jaffe (2003) examined patterns of international knowledge diffusion from the U.S. and Japan to Korea and Taiwan using patent citations. They found that it is much more likely for Korean patents to cite Japanese patents than U.S. patents, whereas Taiwanese inventors tend to cite equally from both. Kim, Lee and Marshke (2005) studied the influence of university research on industrial innovation. They used U.S. patent records to examine the role of research personnel as a pathway for the diffusion of ideas from university to industry. They found a steady increase in industry's use of inventors with university research experience over the period 1985-1997 economy wide.

In my research work, rather than use the NBER patent database, I built up our own U.S. patent database by extracting information from U.S. Patent and Trademark Office patent database directly. This provides the benefit of more up to date information and better flexibility of data processing. I studied and refined the previous methodologies so that they fit with our particular research case. I apply these methodologies especially on offshore oil and gas industry which I believe has never been studied using patent and patent citation data and assessing method. We are particularly interested in U.S. patents granted to inventors residing in Stavanger and Aberdeen.

Chapter 3 Overview of the North Sea Province

The North Sea province had never been considered as a district with rich oil and gas deposits until the discovery of gas at Groningen in the Netherlands in 1959. A few years later, after Norway and the UK reached an agreement on dividing the North Sea in March 1965, the first exploration activity started. Shortly afterwards the Forties field in the UK and Ekofisk field in Norway were discovered and the North Sea oil and gas industry started to emerge.

Before the discoveries of oil and gas in the North Sea, Stavanger in Norway and Aberdeen in Scotland had both served as regional economic centers for centuries. Since the eighteenth century Stavanger's leading industries had been fishing, canning, shipbuilding and agriculture. Aberdeen was home to fishing, textiles, granite quarrying, shipbuilding and paper making. In recent decades, electronics design and agriculture have also developed in Aberdeen. Beginning in the late 1960s, exploratory oil-drilling in the North Sea changed the situation for Stavanger and Aberdeen. Petroleum exploration and production became the most important business sector in both cities. After more than three decades of development, Stavanger and Aberdeen are now regarded as the oil capitals of the North Sea and even of Europe.

As figure 3-1 shows, Stavanger and Aberdeen are located on opposite sides of the North Sea. The former is adjacent to the Norwegian Continental Shelf (NCS) and the latter to the United Kingdom Continental Shelf (UKCS), which are neighboring areas divided only by a median line. These two areas share similar geology and a harsh physical environment.

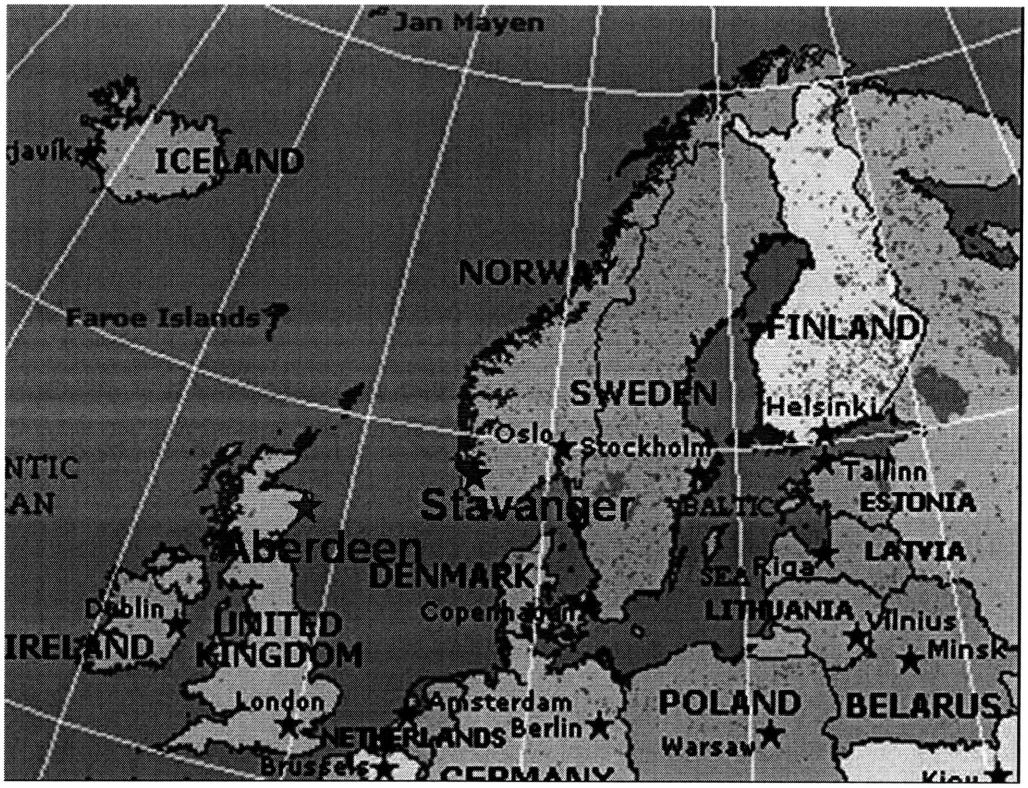

Figure 3-1 The North Sea Province

Stavanger sits on the southwest coast of Norway in the county of Rogaland. Aberdeen is located on the northeast coast of Scotland and is the main city in the county of the Aberdeenshire. For reasons of available data and convenience of comparison, in part of this chapter, we will compare Rogaland county and Aberdeenshire rather than Stavanger and Aberdeen. We will examine the similarities and differences of these regions with respect to general characteristics, resources and circumstances of the oil and gas industry.

3.1 General Comparison

Stavanger is the 4th largest city in Norway with a population of 117,315 (2007). The Stavanger city covers an area of 71 square kilometers. Stavanger is the administrative centre of the county of Rogaland which is one of Norway's leading industrial areas and the center of the Norwegian petroleum industry. Rogaland has a total of 26 municipalities with a population of 410,760 (2007), comprising 8.49% of Norway's total population. Rogaland County occupies 9,378 square kilometers which accounts for 2.82% of Norway's land area. More than 70% of the Rogaland population lives in the so-called greater Stavanger region. This region consists of

14 municipalities: Stavanger, Sandnes, Randaberg, Sola, Finnøy, Rennesøy, Kvitsøy, Klepp, Time, Hå, Forsand, Strand, Hjelmeland and Gjesdal. The total population of greater Stavanger is approximately 298,615 (2007).

Aberdeen City is the administrative centre of Aberdeenshire. The city covers an area of 188.46 square kilometers and is home to a population of 202,370 (2005). Aberdeenshire is a predominantly rural county in the northeast of Scotland. It consists of six administrative areas: Banff and Buchan, Buchan, Formartine, Garioch, Marr, and Kincardine and Mearns. The population of Aberdeenshire excluding the city of Aberdeen is 236,260 (2006), accounting for 4.6% of Scotland's total. Aberdeenshire excluding Aberdeen city occupies an area of 6,313 square kilometers, representing 8% of Scotland's overall territory. A significant proportion of Aberdeenshire's working residents commute to the city of Aberdeen each day, ranging from 11.5% of working population in Fraserburgh to 65% in Westhill. We define the areas within 30 miles (50 kilometers) away from the center of Aberdeen city as the greater Aberdeen region. It covers the region of Buckie to the North, Inverbervie to the South and Aboyne to the West. The total population in this region is over 350,000. Two simple district maps of Rogaland and Aberdeenshire are given below.

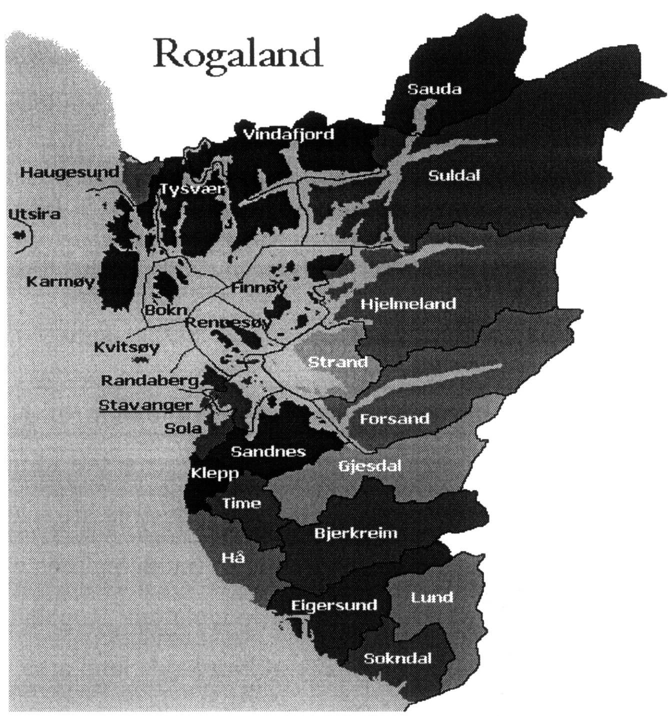

Figure 3-2 Rogaland

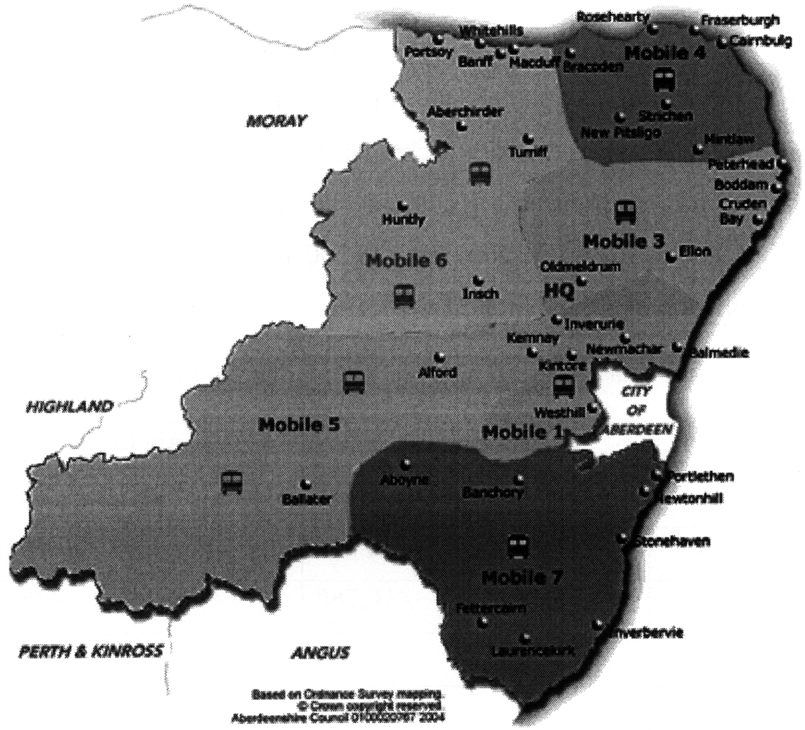

Figure 3-3 Aberdeenshire

The Gross Product (GDP) for Rogaland County was about NOK 145,000M in 2006, or around 6.8% of the Norwegian national GDP. Rogaland employed 211,699 people in 2006, of whom 57,193 were employed in Stavanger. In 2006 the unemployment rate was 1.4%, far below the Norwegian national unemployment rate of 3.4%. Out of all employed people in Rogaland, 13,845 (6.5%) worked on extraction of crude petroleum and natural gas. Since a total of 33,444 people were employed in the Norwegian oil and gas sector as a whole in 2006, Rogaland accounted for 41.4% of the national oil and gas employment. Employment in the oil and gas sector in Rogaland increased steadily during the 1990s and reached a peak in 1999. It fell dramatically in 2000, and increased slightly thereafter.

The Gross Product of Aberdeen city is £6,649M (2006) and £2,924M (2006) for the rest of Aberdeenshire. The Gross Product of £9,573M for Aberdeenshire County accounted for 11.5% of the Scottish total in 2006. About 142,000 people were employed in the city of Aberdeen in 2006, and another 80,000 were employed in the rest of the county. The unemployment rates were 1.4% for the city and 0.9% for the county in 2006, well below the overall Scottish rate of 2.6%. 33,400 of the people employed in the city of Aberdeen (23.5% of total Aberdeen City employment) worked in the energy sector in 2006. For the county as a whole (including the city), about 37,000 people worked in the energy sector in 2006 (16.7% of total employment). In 2001, Aberdeen city accounted for 23% of the UK's total oil and gas employment. The city has experienced a gradual decline in oil and gas employment from a peak in the early 1990s to 36,800 in 2001 and 35,200 in 2003. This trend is expected to continue with an estimation of 22,500 in 2021.

Some of the statistical data discussed here are summarized in the table below.

	Stavanger	Aberdeen
Population within city	117,315	202,370
Population within region	298,615	350,000
Population within county	410,760	438,630
Area of city (sq km)	71	189
Area of county (sq km)	9,378	6,501
GDP of city	£6,649M	-
GDP of county	£9,573M	NOK 145,000M
Employment of city	142,000	57,193
Employment of county	211,699	222,000
Oil and gas sector employment of county	37,000 (23% of the nation)	13,845 (41% of the nation)

Table 3-1 Stavanger and Aberdeen General Statistics

3.2 Resource Comparison

Because of its political stability and proximity to major European markets, the North Sea region emerged as a key non-OPEC oil and gas producing area beginning in the 1980s, when most major fields had been discovered and had begun production. Now five countries operate crude oil and natural gas production facilities in the North Sea: Norway, the United Kingdom, Germany, Denmark and the Netherlands. All of Norway's oil and gas reserves are located offshore on the Norwegian Continental Shelf (NCS), which is divided into three sections: the North Sea, the Norwegian Sea and the Barents Sea. The UK Continental Shelf (UKCS) is located in the North Sea off the eastern coast of Scotland. The UKCS contains the bulk of the UK's oil reserves.

Norway's proven oil and gas reserves are respectively almost twice and more than four times as large as the UK's reserves. The North Sea province had 13.4 billion barrels of proven oil reserves in January 2006. Norway contained 57% (about 7.7 billion barrels) of all North Sea proven reserves, followed by the UK at 30% or 4 billion barrels. The proven natural gas reserves in the North Sea region were 176.9 trillion cubic feet in 2006. 84.3 trillion cubic feet of proven natural gas reserves were in Norwegian territory, while the UK accounted for another 18.8 trillion cubic feet.

Compared to the UK, Norway is producing oil at a higher rate and gas at a lower rate. During 2006 oil production in the North Sea reached 4.4 million barrels per day (b/d), down from 4.7 million b/d in 2005. The 2006 oil production rate was about 25% lower than the peak in 1999. In 2006, Norway accounted for the largest share of North Sea oil output with 57% or 2.5 million b/d. The UK represented the second largest share, with 34% or 1.5 million b/d. In 2004, natural gas production in the North Sea reached 10.4 trillion cubic feet. Though the UK only controls 11% of North Sea natural gas reserves, it is currently the largest natural gas producer in the North Sea and the fourth largest in the world. The UK produced 3.6 trillion cubic feet of natural gas in 2003. In 2004, Norway's natural gas production was 2.95 trillion cubic feet, making it the eighth largest producer in the world. Selected regional reserves and production data are presented in the table below.

	The North Sea	Norway	UK
2006 Oil Reserves(billion barrels)	13.4	7.7	4
2006 Gas Reserves (trillion cubic feet)	176.9	84.3	18.8
2006 Oil Production (million b/d)	4.4	2.5	1.5
2004 Gas Production (trillion cubic feet)	10.4	2.95	3.6 (2003)

Table 3-2 Oil and Gas Resources in the North Sea

Although the North Sea region will continue to be an important supplier of oil and natural gas, output from this region has already peaked and entered a period of long term decline. Norwegian oil production rose dramatically from 1980 until the mid 1990s. After that the output remained flat for a few years and began to decline after 2001. UK oil production peaked in 1999, two years earlier than Norway. Since then UK oil output declined significantly and had fallen to 1.87 b/d in 2005, 37% below the peak. Regarding natural gas, the North Sea is also regarded as a mature region. Regional natural gas production increased dramatically after the early 1980s. However the output of natural gas began to flatten in recent years, with only Norway adding new capacity. Unless significant new reserve volumes are discovered, the current downward trends of oil and gas production from the North Sea will continue and will not reverse.

3.3 The Oil and Gas Industry Comparison

Because of the inhospitable climate and great depths in the North Sea region, generally the firms operating in this region have high costs. Our previous study shows that Norwegian companies have even a higher cost structure than their U.K. counterparts (Hatakenaka et al 2006). This is because of the higher labor costs in Norway, which in turn arise from more stringent personnel practices and labor market regulation.

Besides the difference of operating cost, the oil and gas industrial structures of Stavanger and Aberdeen are also slightly different. Generally we categorize the firms working in the oil and gas industry into three groups: operators and licensees, integrated service providers, and contractors and service suppliers. Aberdeen has a greater diversity of operators and contractors and service providers than Stavanger. There are 116 operators in the UKCS, compared with only 39 operators in the NCS. The number of contractors and service suppliers in Aberdeen is also much greater than in Stavanger. There are 800-900 contractors and service providers in Aberdeen, and only 450-500 in Stavanger. However, all of the big four integrated service providers operate both in Stavanger and Aberdeen. Many attempts have been made to identify all the oil and gas related firms in Norway and Scotland, with a wide range of results. The total number of oil and gas related firms in Aberdeen has recently been estimated at 900-1000, compared with 500-600 in Stavanger (Hatakenaka, Westnes, Gjelsvik, Lester 2006).

3.3.1 Operators and Licensees

Oil and gas operators are firms which obtain licenses from national or local governments which allow them to extract and produce petroleum or natural gas within a specific area. Operators are the key players in the oil and gas industry because they have direct control over the fields.

Operators and licensees have different presences in Stavanger and Aberdeen. First, all the major international oil and gas operators such as Total, BP, ExxonMobil, Shell and Statoil participate in both the UK and Norway. But the number of medium sized integrated and independent oil and gas operators differs significantly. In early 2006, a total of 116 operators were registered on the UKCS, compared with only 39 companies on the NCS.

Second, for most operators on the NCS, Stavanger is their Norwegian headquarters. In contrast, most operators on the UKCS treat Aberdeen as an operational center, setting their headquarters in London where the licensing offices of the Department of Energy (DOE) or Department of Trade and Industry (DTI) are.

Third, the major operators in Norway control a significantly greater portion of the reserves on the NCS than their counterparts in the UK. In Norway, non-major operators hold only 4% of the NCS reserves, with the rest under the control of the major operators. The big three players, Statoil, Norsk Hydro and Petoro together own 66% of total reserves on the NCS. In the UK, non-major operators control 40% of the reserves on the UKCS, while 60% belongs to the majors. BP, ExxonMobil and Shell, the three leading players on the UKCS, own only 44% of the reserves.

Differences in licensing strategies and regulations in the two countries are one of the major contributors to the differences in the operators' presences in the two localities. The UK usually has flexible licensing terms that are attractive to new and small entrants. However, Norway traditionally has focused on projects that are large in size but few in number. In 2003 its licensing strategies changed somewhat and many smaller firms have entered the market. By January 2005, 25 new operators had been pre-qualified for licensees on the NCS and another 10 firms were in process.

3.3.2 Integrated Services Providers

The integrated services companies are a small group of global firms that develop and produce technology and services based on the particular needs of oil companies. After numerous mergers and acquisitions, three American firms, Schlumberger, Baker Hughes and Halliburton, and a firm originating in the UK, Weatherford, are now the dominant firms in this segment. These four big service providers have substantial worldwide R&D investments and constitute the core of the industry's innovation system.

All three US firms, Schlumberger, Baker Hughes and Halliburton, play an important role in both Norway and the UK. However, Weatherford is considered a super-major in the UK but not in Norway. Weatherford and Baker Hughes have located their North Sea headquarters in Aberdeen. Schlumberger's regional headquarter is in Stavanger. Halliburton decided not to establish a regional head office but is present equally in both locations

All of the big four integrated services firms have set up some innovation facilities within the local areas. Schlumberger's research and technology center in Norway is distributed between Oslo and Stavanger and focuses on seismic and reservoir monitoring studies. Weatherford has a test and research capacity in Aberdeen covering areas such as downhole technology, well intervention, well screen, offshore well services, expandable sand screen and many others. Baker Hughes and Halliburton have also contributed to local technology development by establishing their local R&D units or through the process of interacting with regional professionals in both Stavanger and Aberdeen.

3.3.3 Contractors and Service Suppliers

Contractors and service suppliers are companies that operate in the maintenance, modification and operation (MMO) market and the engineering, procurement, construction and installation (EPCI) market. They also offer project management, process systems, equipment, and subsea systems to the oil and gas industry.

Integrated contracting has been introduced since the 1990s on both sides of the North Sea as a cost reduction measure. After numerous mergers and acquisitions, the shift to larger contracts has resulted in major consolidation in this segment. A large share of the market in both Stavanger and Aberdeen is now controlled by a handful of major contractors who are capable of carrying out total enterprise contracts by themselves. In Norway, this market is dominated by major players such as Aker Kvaerner and Vetco Aibel. In the UK, the four major actors are Aker Kvaerner, the Wood Group, AMEC and Vetco Aibel.

Besides the major contractors, many mid-sized or niche service suppliers also participate actively in both locations. In order to compete with the majors, some of these small firms tend to team up in alliances so that they are capable of taking large contracts. Some other firms rely on their innovative capability and provide creative and customized products and services to operators and integrated service companies. The number of such companies in Aberdeen is much greater than the number in Stavanger. The total number of companies in oil and gas service and supply industry in Aberdeen is estimated to be about 800-900 compared with 450-500 in Stavanger (Hatakenaka et al 2006).

Chapter 4 Data Collection

Our aim is to use the patent and patent citation statistics to compare the nature and extent of innovative activities in Stavanger and Aberdeen. The limitations of patents as measures of innovative activity are well known. But patenting data can be useful nonetheless.

There are several accessible patent databases that we can potentially use. First, the World Intellectual Property Organization (WIPO) maintains a worldwide patent application process and database under the international Patent Cooperation Treaty (PCT). The WIPO is one of the 16 specialized agencies of the United Nations. It currently has 184 member states. The WIPO provides patenting services to each of its contracting states under the PCT to protect intellectual property throughout the world. A patent application filed under the PCT is called an international application. Every international application is made with a national or regional patent office first. It then goes through the procedure of search performed by the International Searching Authority (ISA) and an optional preliminary examination performed by the International Preliminary Examining Authority (IPEA). Finally if the application passes the examination, it will be granted by the relevant national or regional authorities. The granted application will be published in one of eight languages: Arabic, Chinese, English, French, German, Japanese, Russian and Spanish. Applicants from the United States of America are the largest filers of PCT international applications. In 2005, there were slightly more than 45,000 PCT international applications filed through the U.S. patent office, accounting for slightly more than 10% of the total number of patent filings in the U.S. in that year. The number of PCT international applications filed by applicants from the U.K. and Norway combined was less than 7,000 in 2005. However, these accounted for about 30% of the total patent applications from these two countries. In our study, the majority of inventors are from the United States, the United Kingdom, Norway and a few of other countries such as France, Germany and Sweden. A large part of the related firms are international companies with their headquarters in the United States. Therefore they are very likely to file patent applications either through the U.S. or through their home country. The WIPO patent database only covers 10% of US patent applications and 30% of the U.K. and Norway applications. This will not be good enough to meet our research interest.

Another regional patent database of possible interest is the database maintained by the European Patent Office (EPO). The EPO is an organ of the European Patent Organization. The EPO grants patents on behalf of the member States of the European Patent Convention (EPC). The membership of EPC is larger than that of the European Union. Every individual applicant can either apply for a patent through his national patent office or he may apply for a European patent via the European Patent Office. Granted patents are included in the EPO patent database in either case. Patent applications may be filed in any language but must be translated into one of the EPO official languages (English, French and German) within two months. The main disadvantage of using the EPO database for our purposes is that it does not cover any US patents, which are important to our research. The EPO database also has the drawback that it provides very limited patent search tools. In particular, it does not allow us to identify inventors within the regions of interest through their registered address.

The patent database provided by the US Patent and Trademark Office is the most appealing source. Currently there are two attractive methods for searching and retrieving US patent data. One is from the US patent database directly. The other is by using the National Bureau of Economic Research (NBER) patent database.

Beginning in the early 1990s, several NBER researchers, led by Adam Jaffe and Manuel Trajtenberg, spent approximately a decade developing a database of U.S. patents to stimulate and facilitate the use of patent data in economic research. The database currently covers almost 3 million U.S. patents granted between January 1963 and December 1999, and over 16 million related citations made to these patents between 1975 and 1999. All the collected patent data have been pre-organized into a database structure designed by the NBER for convenience of use. However, in the process some original information is neglected, such as the assignee address. The NBER researchers also implemented some further processing of the data. Each patent has been categorized into one of 6 major applied groups and 36 subcategories. The 6 major groups are Computers and Communications, Drugs and Medical, Electrical and Electronics, Chemical, Mechanical and Others. The inventor names have also been codified to solve the problems caused by input typographical errors as much as possible. The entire NBER patent data has been uploaded to the NBER website and is available to all users at no charge. A new release of the data updated through December 2004 will not be available until 2009.

In our research project, we are interested in US patents granted to inventors and assignees in the greater Aberdeen and greater Stavanger areas from the 1950s to the present. We are particularly interested in US patents relevant to the oil and gas industry, which is not highlighted in the NBER database. In order to have the option to access all original data, as well as the flexibility to process the data, we decided to retrieve the patent data directly from the US Patent and Trademark office database. To do this, however, additional efforts on data collection and database structure development were required.

4.1 Introduction of U.S. Patent

A U.S. patent is a grant of intellectual property right by the U.S. Patent and Trademark Office (USPTO) to the inventor. This right allows the inventor to exclude others from making, using or selling the invention for a limited period of time. The USPTO is the government agency responsible for examining patent applications and issuing patents. According to current patent law, the USPTO can grant three different types of patents: utility patents, design patents and plant patents. Most of the patents involved in our study are utility patents. Utility patents apply to new and useful processes, machines, manufactures, compositions of matter, or any new and useful improvement of one of these. A much smaller number of design patents are also covered by our study. Design patents are granted to anyone who invents a new, original, and ornamental design for an article of manufacture. The third type of patent, plant patents, which do not appear in our collected data, apply to inventions or discoveries and asexual reproduction of any distinct and new variety of plant.

The first US patent was a utility patent granted in 1836. Since then, the USPTO has issued close to 8 million patents in total, most of which are utility patents. In 2007, the USPTO granted 157,283 utility, 24,063 design and 1047 plant patents. The annual grants of all US patents increased sharply in the years prior to 2000, almost doubling between 1990 (when 96,725 were issued) and 2000 (182,218 issued). After 2000 the trend flattened for several reasons, one of which was an increase in the stringency of the standards for patentability.

The percentage of U.S. patents granted to foreign inventors has risen significantly since the 1960s. According to the data we have, in 1973 36% of all U.S. patents in that year were granted to residents of foreign countries. In 2007, foreign resident inventors claimed a 48.8% share of all U.S. patents. Of these, 19.6% were granted to Japanese, 5.5% to German, 4.1% to Taiwanese and 4% to South Korean inventors.

Every U.S. patent contains not only the protected intellectual property. It also records a lot of useful background information about the invention, its inventors and assignees. This adds to the usefulness of U.S. patents as markers of innovation. In our study, we are particularly interested in several items contained in a typical U.S. patent:

a) The abstract, which contains a brief summary of the patented invention.

b) The text of the patent claims; we identify a patent as oil and gas-related by searching the keywords within the claims and abstract.

c) Filing date or application date, which is the date of receipt by the USPTO of a patent application. This is the closest date to the time of original invention that we can find within a patent. We use it to approximate the date of the original innovation activity.

d) Issue date: the date when a patent application becomes a U.S. patent.

e) Inventors' names and addresses, including country, state, and city of residence at the time of patent issue. By assuming that inventors always locate within reasonable commuting distance of their place of work, we use this information to approximate the geographical location of the underlying innovation activity.

f) Assignees' names and their countries, states and cities. This provides us with the name and address of the individual or entity to whom ownership of the patent is assigned at the time of patent issue.

g) Current U.S. classification, which tells the original and cross-reference classes in which the patent is classified. This classifies each patent into a particular technical group, though as already noted the oil and gas sector is not one of them.

h) Backward citations, which include both U.S. and foreign patents that are cited as references.

i) Other references, which identify all other references cited as prior art by the underlying patent, including books, journals, conference proceedings and other non-patent references.

j) Forward citations, which include a list of other patents that cite the subject patent as prior art.

4.2 Methodology and Process of Data Collection

In our study, we are particularly interested in U.S. patents with relevance to the oil and gas industry that have been granted to inventors working in the greater Aberdeen or greater Stavanger areas over the years,. This means that we have three basic criteria when we search the U.S. patent database. First, the innovation activity connected to the subject patent has to happen within the target area. Second, we are interested in any U.S. patents issued up to the most recent available year. For the purpose of convenience and consistency, we set up a time boundary of December 31st 2005. Any U.S. patent granted before this time will be considered. Third, we only study patents that apply to the oil and gas industry. These three constraints are applied only in the search for original patents, but not to their backward or forward citations. Any patent or reference that cites or is cited by the original patent, no matter when it was granted or written, where it took place, or what industry it served, is of interest.

Within a patent, there are two types of geographical location information which can be used to identify where the inventive activity related to the patent actually took place: the registered address of the inventor and the address of the assignee. A limitation of the inventor address information is that it may refer either to the residence or to the place of work of the inventor, and there is no way to tell which. However, since in most cases the two locations are in reasonable proximity, the inventor address information is not a bad proxy for the location of the actual work. For inventions by corporate employees, the assignee is typically the employer. The assignee addresses reported in the database in such cases are generally the headquarters location of the firms. For large, multi-divisional and/or multinational firms, the addresses reported sometimes refer to the headquarters of the parent, and sometimes to the headquarters of the local affiliate. In either case, this is a less reliable indicator of the location of the inventive activity than the inventor's address.

In order to collect as many valid patents as possible, we defined the greater Aberdeen area and greater Stavanger areas by reasonable commuting time. This area is defined by a radius of approximately 30 miles (50 kilometers) from the center of the city. For the greater Aberdeen area, this region takes in Buckie to the North, Inverbervie to the South and Aboyne to the West. The greater Stavanger area is roughly bounded by Hjelmeland to the North, Haa to the South and Forsand to the East.

We generated two lists of cities, towns and communes, one each for the greater Aberdeen area and the greater Stavanger area. We found these communities from the maps first. Then we searched the U.S. patent database for all patents with at least one inventor or one assignee located in one of these communities. We then checked the addresses of the other inventors and assignees in each of the patents we found to see if any of them is located within the greater Aberdeen area or the greater Stavanger area but not on our list of communities by checking the maps again. We added the newly identified communities to our lists, and then iterated the search process until no further new community was found. The final two lists can be considered as representative of the greater Aberdeen area and the greater Stavanger area we defined. The flow chart in figure 4-1 describes the detailed procedure.

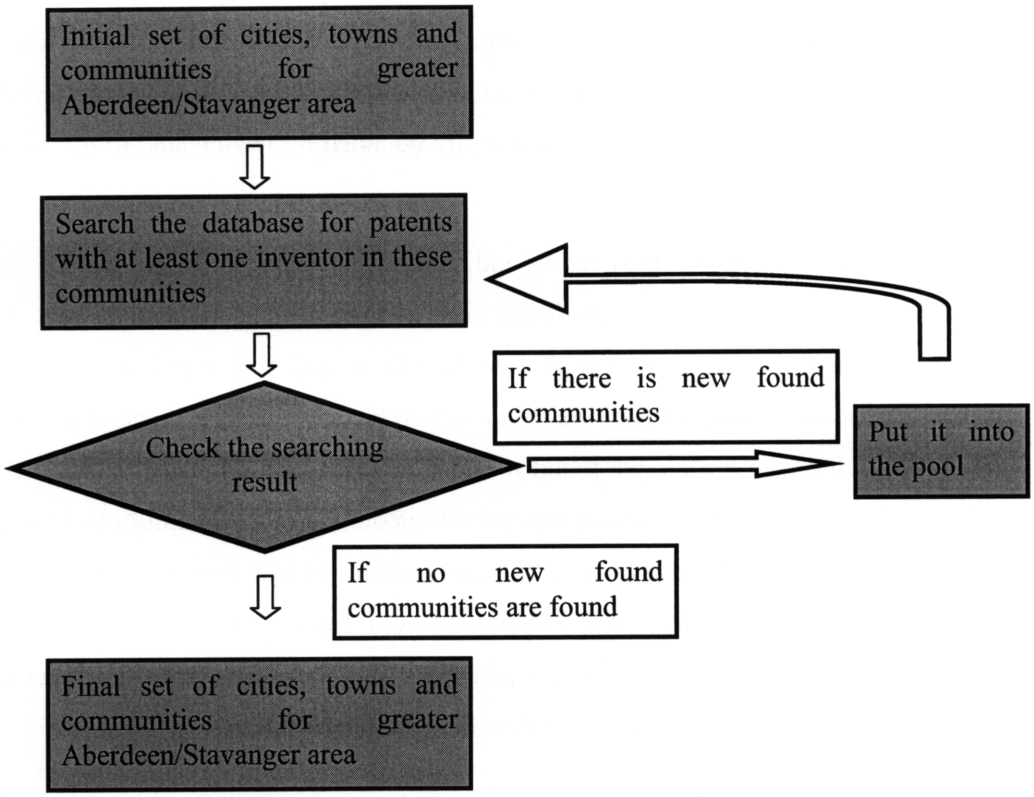

Figure 4-1 Procedure for defining the greater Aberdeen area and greater Stavanger area

Using this method we found 92 communities located in the greater Aberdeen area, and 61 communities in the greater Stavanger area from the records of U.S. patent database. Some of these are actually the same town but with different names or careless typos. In table 4-1, we give a complete list of these cities and communities that we used to define the greater Aberdeen area and greater Stavanger area.

Greater Aberdeen Area					
aberdeen	aboyne	alford	Arberdeen	auchenblae	balmedie
banchory	banff	belhelvie	blackburn	blairs	blairydryne
brathens	brechin	bridge of canny	bridge of don	britannic house	bucksburn
cammachmore	catterline	cove bay	crathes	cullen	cults
drumlithie	drumoak	dunecht	dyce	echt	ellon
findon	footdee	fordoun	fraserburgh	fyvie	glenberve
hatton	huntly	inchmarlo	insch	inverbervie	inverurie
johnshaven	keith	kemnay	kincardine	kincardine O neil	Kincardineshire
kinellar	kingswells	kintore	kirkton of maryculter	kirkton of skene	kirktown of fetteresso
laurencekirk	lumphanan	macduff	marywell	methlick	milltimber
monymusk	muchalls	multimber	new deer	new pitsligo	newachar
newburgh	newmachar	newtonhill	oldmeldrum	oyne	peterculter
peterhead	pitmedden	port elphinstone	portlethen	portsoy	potterton
roadside of kinneff	skene	st. cyrus	stonehaven	strachan	tarves
torphins	turriff	udny green	upper lochton	west hill	westhill
whitecairns	whiterashes				
Greater Stavanger Area					
.ANGig.ang.rd	.ANGlg.ang.rd	alg.ang.rd	algard	austrevig.ang	brusand
bryne	byrkjedal	dirdal	eikjeskog	espedal	figgio
finnoy	forsand	forus	fossmork	gjesdal	gronvik
ha	hafrsfjord	Hafrsfyord	Harsfjord	hinna	hjelmeland
hommersak	hovda	hundv.ang.g	hundvag	J.o slashed.rpeland	Joerpeland
jorpeland	kartavoll	kartavollvikesa	klepp	kleppe	kvernaland
kvitsoy	lauvvik	malmein	naerbo	nedrebo	oltedal
paradis	r.cedilla.yneberg	r.o slashed.yneberg	randaberg	rennesoy	sandnes
sirevag	sola	stavanger	strand	tananger	tau
time	tveit	varhaug	vatne	verdalen	vigrestad
vikevag					

Table 4-1 Greater Aberdeen Area and Greater Stavanger Area

We searched the U.S. patent database for all patents issuing prior to December 31st 2005 which met the criterion that at least one of the inventors was located in the greater Aberdeen area. We further identified all patents issuing prior to December 31st 2005 for which at least one of the assignees was located in the greater Aberdeen area. We refer collectively to the set of patents meeting one or both of these criteria as "Aberdeen-related patents". In our study, we pay more attention to the patents with at least one inventor local to Aberdeen.

Similarly, we searched the U.S. patent database for all patents issuing prior to December 31st 2005 for which at least one of the inventors was located in the greater Stavanger area. We further searched for all patents for which at least one of the assignees was located in the greater Stavanger area. We refer to the set of patents meeting one or both of these criteria as "Stavanger-related patents". Mostly we focus on the patents with at least one local Stavanger inventor.

The next task is to identify if any of the selected patents apply to the oil and gas industry. We first examined a patent by looking for the key words such as "petroleum", "drilling rig", "well logging" and many others in the body of the patent. If none of the key words were found, we would further read through the patent abstract and claims and make a judgment as to whether it was directly applicable to the oil and gas industry. After eliminating all none-oil-and-gas related patents, we achieved the desired sets of patents, one for the greater Aberdeen oil and gas industry, and one for the greater Stavanger petroleum industry. Before 2006, 1651 U.S. patents had been granted to at least one Aberdeen inventor, and 610 U.S. patents had been issued to Stavanger inventor. Within these patents, we identified that 819 patents are relevant to oil and gas industry in Aberdeen, and 324 patents have connection to oil and gas industry in Stavanger.

For each of the patents in the two collected original patent sets, we gathered all necessary patent information from the U.S. patent database, such as the application date, inventors' information, assignees' information, technical classification, backward and forward citation list, and correlative citation information. All this information was reorganized and stored in a database as described below.

4.3 Design of the Database

A comprehensive database structure was developed to store the gathered patent information. The design of the database has to meet several requirements. First the database is asked to accommodate all patent related information. Second the database structure has to be well organized so that different information items are connected to each other logically. Third the database must be easy to use for the purpose of developing statistics.

Our database consists of 16 tables. These tables can be generally divided into three groups. The first group contains 3 tables which present the basic information in the original patents. The names of these three tables are "Patents", "Aberdeen Original Patents" and "Stavanger Original Patents". The second group has 8 tables which generate linkage between the original patents and their backward citations, forward citations, inventors, assignees and patent classifications. The names of these eight tables are "Inventors", "Assignees", "Aberdeen Backward Citations", "Aberdeen Forward Citations", "Stavanger Backward Citations", "Stavanger Forward Citations", "Other References" and "Patent Classes". There are 5 tables in the last group. These are: "Aberdeen Commune", "Stavanger Commune", "Countries", "Company List" and "Scientific Reference List". These five tables provide general information that we need when we process the patent data. In what follows I will emphasize a few of these tables and fields within them. A complete description of the database can be found in Appendix I to Chapter 4.

The "Patents" table contains all the basic information of every original patent, forward patent citation and backward patent citation. Each observation is identified by a non-duplicated patent ID. We will be able to find the patent's name, patent application date, patent issued date, number of inventors, number of assignees, number of patent classifications from this table. The table also contains several flags to identify if this patent is an Aberdeen-related patent or Stavanger-related patent, an original patent, a forward citation or a backward citation.

The tables of "Aberdeen Original Patents" and "Stavanger Original Patents" give the lists of all original patents. Each observation is identified by the patent ID also. The tables each have two flags which indicate whether the patent has local inventors and/or local assignees.

Most of the original patents may have a number of backward citations and forward citations. The linkage between the original patents and their citing and cited patent citations are recorded within the tables of "Aberdeen Backward Citations", "Aberdeen Forward Citations", "Stavanger Backward Citations" and "Stavanger Forward Citations". The non-duplicated index of these four tables is the combination of original patent ID and corresponding citation patent ID. Within these four tables we can also recognize the 'geographical distance', 'technical distance' and time difference between the original patent and the patent citation. These terms are defined in the following paragraphs.

The registered addresses of the inventors of both the original patent and the patent citation is used to determine the geographical distance as we believe this address gives the closest available approximation of the location of innovation activity. To those patents with at least one local inventor, we assume that part of the related innovation activity, if not all, happened locally. "Local" here means within the greater Aberdeen area or the greater Stavanger area. Therefore all original patents which have at least one Aberdeen inventor or one Stavanger inventor are considered to be local patents. The geographical distance between the original patent and the patent citation is determined by how far away the address of inventors of the patent citation is from the local area. We define 5 major categories of geographic distance regarding the distance between the original patent and the patent citation: within the same local area; within the same state, province or county; within the same country; within the same continent; and international. For the convenience of modeling and calculation, we further specify the geographical distance as 1 for the original patent and patent citation within the same local area, 2 within the same county, 3 within the same country, 4 within the same continent and 5 for international spread. As we mentioned in Chapter 3, the greater Stavanger area locates within Rogaland County. Rogaland County has a total of 26 municipalities with a population of 410,760 (2007). The greater Stavanger area refers to 14 of the 26 municipalities in the county. The total population within this area is about 298,615 in 2007. The greater Aberdeen area sits in the middle east of the county of Aberdeenshire. Aberdeenshire consists of 6 administrative areas with a population of 438,630 (2006). The greater Aberdeen area covers the region of Buckie to the North, Inverbervie to the South and Aboyne to the West. The total population in this region is over 350,000. Since it is very difficult for us to identify all the communities within the county of Aberdeenshire and within

Rogaland County, we actually were unable to identify the second category of geographical distance -- that is, the patent and citation being located within the same county. Any observation which in fact belongs to the second level is assigned to level 3, within the same country.

In many cases, a patent may have more than one inventor. All these inventors may or may not be located within the same geographic area. If one patent has more than one inventor and the inventors are located in different geographic area, we assume that the related innovation activities took place simultaneously in all these different locations instead of just one of them. When we face this multi-inventor situation, we present both the closest and the furthest geographical distance between the patent and patent citation. The closest distance represents the shortest channel through which the knowledge has flowed. The furthest distance describes how far the knowledge receiver has reached out for information.

The 'technical distance' describes the technical proximity of the original patent and its patent citation. For every granted U.S. patent, a patent classification number is assigned. The patent classification number is a code which provides a method for categorizing the invention. It identifies the original and cross-reference classes into which the patent is classified. A typical patent classification number consists of two parts. The first part is a three digit number which represents the class of invention. The second part is another number with at most three digits which refers to the subclass of invention within the major class. There are about 450 major classes of invention and about 150,000 subclasses of invention.

In our study, we only consider the major class of invention, which is represented by a three digit number. We assign the technical distance between the original patent and its patent citation to one of four groups by comparing the two patent classification numbers.

If the original patent and its patent citation share the same class of invention, that is, if all the three digits of the patent classification number are the same, the original patent and its patent citation have the closest technical distance. This is described by the identifier 3.

If only the first two digits of the patent classification number are the same, the technical distance between the original patent and its patent citation is set as 4.

If only the first digit of the patent classification number is the same for the original and its patent citation, the corresponding technical distance is set as 5.

If none of the three digits of the patent classification number are the same, the original patent and its patent citation have the longest technical distance which is set as 6.

If the original patent or its patent citation have been assigned to more than one class of invention, we make cross comparisons. This means comparing each pair of patent classification numbers. The technical distance between the original patent and its patent citation is then set as the shortest distance between the pairs.

The time difference between the original patent and the patent citation is determined by the difference between the two patent application dates. These are the closest dates to the actual time of invention that can be found within the patent information. The time difference is specified to the nearest month.

In the four patent-citation relationship tables, there is another important field, which contains a flag of self-citation. This refers to whether the citation is a self-citation or not. 'Self-citation' occurs when the citing or cited patents are assigned to the same assignee as the original patent.

When we estimate knowledge spillovers between physical locations, between different industries, or from university to industry, we usually do not include patent citations which are self-citations. This is because we assume that no knowledge spillover is involved when the original patent is cited by its own assignees. There is, however, one exception. For multi-national companies which have many branches in different locations, these firms themselves act as media for knowledge transmission. These multi-national firms help transfer knowledge from place to place through their internal networks. Therefore, for self-citations which are assigned to multi-national firms, it is not necessarily correct to assert that no knowledge spillover is involved. In order to judge if there is any geographical knowledge spillover in such cases, we need to check if the parent patent and child patent have any inventors from different branches of the firm. To examine if the inventors are from the same branch location, we look at the registered addresses of the inventors. If they are within the same local area, we conclude that they are from the same branch. We affirm that there is no knowledge spillover involved only if all inventors of both the original patent and its patent citation are from the same branch. Otherwise the self-citation will be taken into consideration.

The other tables in our database describe the relationship between the patents and their inventors, assignees, other references and some other general information. The detailed description of all tables and fields in the tables can be found in Appendix I to Chapter 4.

4.4 Results

Some general statistical results are shown in table 4-2. There are 854 Aberdeen-related oil and gas industry patents, of which 819 involved at least one Aberdeen-based inventor. 178 Aberdeen-related patents were granted to Aberdeen-based assignees. There are 431 Stavanger-related patents, of which 324 involved at least one Stavanger-based inventor. 259 Stavanger-related patents were granted to Stavanger-based assignees.

	No. of Patents	Ratio
With at least one Aberdeen inventor	819	95.9%
With at least one Aberdeen assignee	178	20.8%
With both Aberdeen assignee and Aberdeen inventor	143	16.7%
Total Aberdeen Related Patents	**854**	
With at least one Stavanger inventor	324	75.2%
With at least one Stavanger assignee	259	60.1%
With both Stavanger assignee and Stavanger inventor	152	35.3%
Total Stavanger Related Patents	**431**	

Table 4-2 Distribution of Patents by Assignee and Inventor

According to Table 4-2, Aberdeen inventors have received more than twice as many U.S. oil and gas industry patents as Stavanger inventors. What accounts for this difference? There are several possible explanations:

1. *A difference between Stavanger and Aberdeen in the level of R&D activity in the oil and gas sector in the two locations.* In general we might expect that the rate of patenting within a region in any given sector would vary with the level of R&D activity in that sector.

2. *A difference in the general level of 'inventiveness' of the firms and/or individuals operating in the two locations.*

3. *A difference in the propensity to patent.* If individual inventors and/or firms in one location are more likely to seek patent protection, or, more specifically, are more likely to seek U.S. patents, then this would contribute to overall differences in the rate of patenting.

In order to interpret the data more precisely, a simple model was developed to summarize the relationship between the number of patents and R&D expenditures, inventiveness and propensity to patent. This is based on earlier work by Ashish Arora, Marco Ceccagnoli, Wesley Cohen (2003). We write that

$$N = R \cdot I \cdot P$$

The number of granted patents N is determined by the product of an index of R&D expenditure, R, an index of inventiveness, I, and an index of propensity to patent, P.

It is easy to understand that the number of granted patents should be proportional to the total R&D expenditure or investment. The R here is not the actual R&D expenditure, but an index of it. The greater the R&D expenditure, the greater the value of the index is. By using an index of R&D instead of the actual R&D investment, the formula is simplified since we do not have to consider the detailed relation between the R&D expenditure and the number of granted patents. In our study, we have four different R&D expenditures, R_{UK}, $R_{US\text{-}A}$, R_{NO} and $R_{US\text{-}S}$ representing the amount of R&D expenditure by UK firms in Aberdeen, US firms in Aberdeen, Norwegian firms in Stavanger and US firms in Stavanger, respectively.

Holding R&D expenditure constant, the stronger the inventive ability, the more inventions will be created. The inventive ability or inventiveness is a function of several factors, including the literacy level of the inventors, the maturity of the innovation environment both inside and outside the firm, and other factors. It is not our purpose to study the precise expression of the inventive ability here, so I use the index of inventiveness I to describe the overall inventive ability. The index of inventiveness may be different between different countries and between different types of firms. In order to further simplify the calculation, we ignore the difference of inventiveness between different types of firms within the same business environment. Thus we only have I_{UK} and I_{NO}.

Finally, holding the number of inventions constant, a higher propensity to patent, P, will lead to more granted patents. We can understand this propensity as the probability of successful patenting given an innovation. It should be a number between 0 and 1. This probability is also affected by several factors including the cost of patenting, the value added to the invention by patenting, the grant ratio, the inventiveness of competitors, the way the invention is further developed, the level of intellectual property protection, and so on. We are interested in many of these factors. But we cannot obtain enough information to describe these factors precisely from the US patent database alone. Therefore, we use an overall index of propensity P to describe the total patenting propensity effect. The index of propensity can be be expected to differ between different firms and between different countries. In this study, we use the same index of propensity for all firms from the same country. We have P_{UK}, P_{NO} and P_{US} representing the propensity of firms from U.K., Norway and U.S. respectively. Now our formulas are modified to

$$R_{UK} I_{UK} P_{UK} + R_{US-A} I_{UK} P_{US} = N_A$$
$$R_{NO} I_{NO} P_{NO} + R_{US-S} I_{NO} P_{US} = N_S$$

In 2001, the most recent year for which data are available, 3965 U.S. patents were granted to inventors located in the U.K., and 265 patents were granted to Norwegian inventors.[1] Adjusting these figures to account for the size difference between the two economies, we find that in 2001 UK inventors received about 170 US patents per billion dollars (US) of R&D expenditures in the UK, while Norwegian inventors received about 95 US patents per billion dollars (US) of R&D expenditures in Norway.[2] We assume that the oil and gas industries in Aberdeen and Stavanger have the same productivity of U.S. patent per unit R&D expenditure as the whole countries.

Table 4-3 shows the distribution of patents by country of assignee. We use a fractional allocation scheme to account for patents with multiple assignees in different locations. For example, patent 6510898 has two different assignees. One is Weatherford, located in Houston, Texas. The other is Target Well Control Limited, located in Aberdeen, UK. In such cases, we consider that ownership of the patent is equally divided among the assignees. In the case above, for example, we treat Weatherford as owning half of the patent, and Target Well Control Limited as owning the other half. We call this phenomenon the multi-assignee effect. The Table shows that about 60% of Aberdeen inventions and slightly over 35% of Stavanger inventions were assigned to foreign firms. And in both cases the overwhelming majority of foreign assignees are US companies. Table 4-3 tells us that, for all 726 U.S. patents with at least one Aberdeen inventor, 291.5 of them are granted to U.K. assignees, and 415.5 of them are issued to U.S. assignees. For all 290.5 Stavanger-related U.S. patents, 185 of them are granted to Norwegian firms, and 92 of them are issued to U.S companies.

---

[1] National Science Foundation, *Science and Engineering Indicators – 2004.*

[2] National R&D statistics for the two countries were obtained from the OECD R&D database.

Patents with one or more Aberdeen inventors and at least one non-individual assignee			Patents with one or more Stavanger inventors and at least one non-individual assignee		
Country	No. of Patents	Ratio	Country	No. of Patents	Ratio
Venezuela	0.5	0.1%			
Belgium	1	0.1%	Japan	0.5	0.2%
Canada	1	0.1%	Netherlands	0.5	0.2%
Norway	1	0.1%	Bahamas	1	0.3%
Singapore	1	0.1%	Hong Kong	1	0.3%
Japan	1.5	0.2%	UK	1.5	0.5%
Sweden	2	0.3%	Germany	2.5	0.9%
Germany	2.5	0.3%	France	2.5	0.9%
France	8.5	1.2%	Sweden	4	1.4%
Subtotal	**19**	**2.6%**	**Subtotal**	**13.5**	**4.6%**
UK	291.5	40.2%	Norway	185	63.7%
USA	415.5	57.2%	USA	92	31.7%
Total	**726**		**Total**	**290.5**	

Table 4-3 Distribution of Patents by Country of Assignee

Applying these data to our model we obtain the 6 basic equations shown below,

$$\frac{R_{UK}I_{UK}P_{UK}+R_{US-A}I_{UK}P_{US}}{R_{UK}+R_{US-A}}=170$$

$$\frac{R_{NO}I_{NO}P_{NO}+R_{US-S}I_{NO}P_{US}}{R_{NO}+R_{US-S}}=95$$

$$R_{UK}I_{UK}P_{UK}=291.5$$

$$R_{US-A}I_{UK}P_{US}=415.5$$

$$R_{NO}I_{NO}P_{NO}=185$$

$$R_{US-S}I_{NO}P_{US}=92$$

Here we ignore the patents granted to non-UK, non-Norwegian and non-US assignees, which is a relatively small number.

Since we have 9 variables, but only 6 equations, it is not possible to find a single solution. But we are more interested in the ratio of the indexes between different countries than the actual scale of the indexes. With some further deduction, we have

$$R_{UK} + R_{US-A} = 4.16$$

$$R_{NO} + R_{US-S} = 2.92$$

$$\frac{R_{UK} P_{UK}}{R_{US-A} P_{US}} = 0.71$$

$$\frac{R_{NO} P_{NO}}{R_{US-S} P_{US}} = 2.01$$

$$\frac{R_{UK-A} I_{UK}}{R_{US-S} I_{NO}} = 4.52$$

For our purposes, the ratios $\frac{P_{UK}}{P_{US}}, \frac{P_{NO}}{P_{US}}, \frac{I_{UK}}{I_{NO}}$ are of greatest interest. In order to calculate these numbers, we need to know $\frac{R_{UK}}{R_{US-A}}, \frac{R_{NO}}{R_{US-S}}, \frac{R_{US-A}}{R_{US-S}}$. The results depend on how well we know the R&D expenditure ratios. We collected data from the United Nations Conference on Trade and Development (UNCTAD) World Investment Report to obtain a rough estimate of these ratios. From 1994 to 2001, the gross Foreign Direct Investment (FDI) flow in Norway was about 249,505 million Norwegian kroner. Of this, 20,128 million Norwegian kroner were spent on mining, quarrying and petroleum. 8,381 million Norwegian kroner were provided by American companies[3]. During the same period, the gross FDI flow into the UK was about 274,378 million pounds sterling. 30,829 million pounds were spent on mining, quarrying and petroleum. 84,701 million pound was provided by American companies[4]. The data also show that the annual average (i.e. from 1991 to 1997) FDI flows as percentages of gross fixed capital formation were 5.2% for Norway, and 13.6% for UK[5]. Before using these data to estimate the R&D expenditure ratios, two assumptions must be made. First, the distribution of FDI flows from American companies in specific industries is the same as the distribution of total FDI flows, in both Norway and UK. Second, R&D expenditure as a share of gross investment is approximately the same in Norway and UK for any type of investment. With these assumptions, we have,

---

[3] FDI Profiles for Norway, UNCTAD

[4] FDI Profiles for United Kingdom, UNCTAD

[5] World Investment Report (1993-1999), UNCTAD

$$\frac{R_{US-A}}{R_{US-S}} = 162 \pm 20\% \qquad \frac{R_{US-A}}{R_{UK}} = 0.044 \pm 20\% \qquad \frac{R_{US-S}}{R_{NO}} = 0.0018 \pm 20\%$$

$$\frac{P_{UK}}{P_{NO}} = 8.6 \pm 3.2 \qquad \frac{I_{UK}}{I_{NO}} = 0.028 \pm 0.006$$

Because of the simplifications of the model and several fairly heroic assumptions, we cannot definitively say that the actual differences between Norway and the UK in terms of propensity and inventiveness correspond to these calculated figures. But given the size of the calculated differences, it is reasonable to suspect that UK companies are more likely to apply for US patents than their Norwegian counterparts, and that Norwegian inventors are more inventive than UK inventors. After 71 in-depth interviews with key person from firms, governments, universities, and other related organizations in Stavanger and Aberdeen, our Norwegian colleagues' reached similar findings that the Aberdeen industry is 'business-driven' and the Stavanger industry is 'technology-driven' (Hatakenaka et al 2006).

More detailed results of the patent analysis will be provided in chapter 6. But first, in Chapter 5 I describe the methods which have been used to analyze the patent data.

Appendix I Patent Database Structure

Table Name: Patents

This table contains the basic information of all original patents, forward patent citations, backward patent citations. This table shares by Aberdeen, Stavanger.

Fields:

ID – integer: Automatically generated index

Patent ID – text: The non-duplicated U.S. patent identification

Patent Name – text: The name of the patent

Inventors Number – float: The number of inventors of the patent

Assignees Number – float: The number of assignees of the patent

Application Date – date: The date when the assignee submitted the patent application.

Issued Date – date: The date when the patent was granted to the assignee.

Class Number – float: This gives how many U.S. Patent classes the patent belongs to.

Technical Group – float: This tells what the primary technical group the original patent belongs to. Not use.

Application Group – float: This tells what the primary application field the original patent belongs to. Not use.

Flag Aberdeen Original – float: This tells if the patent is an Aberdeen original patent or not. 1: yes, it is an Aberdeen original patent. 0: no, it is not.

Flag Aberdeen Inventor – float: This tells if the patent has at least one Aberdeen Inventor. 1: yes, it has at least one Aberdeen Inventor. 2: no, it does not.

Flag Aberdeen Stavanger – float: This tells if the patent has at least one Aberdeen Assignee. 1: yes, it has at least one Aberdeen Assignee. 2: no, it does not.

Flag Stavanger Original – float: This tells if the patent is a Stavanger original patent or not. 1: yes, it is a Stavanger original patent. 0: no, it is not.

Flag Stavanger Inventor – float: This tells if the patent has at least one Stavanger Inventor. 1: yes, it has at least one Stavanger Inventor. 2: no, it does not.

Flag Stavanger Stavanger – float: This tells if the patent has at least one Stavanger Assignee. 1: yes, it has at least one Stavanger Assignee. 2: no, it does not.

Flag Forward – float: This tells if the patent is a forward patent citation or not. 1: yes it is a forward patent citation. 0: no. it is not.

Flag Aberdeen Forward – float: This tells if the patent is a forward patent citation of an Aberdeen related patent or not. 1: yes it is a forward patent citation of an Aberdeen related patent. 0: no it is not.

Flag Stavanger Forward – float: This tells if the patent is a forward patent citation of a Stavanger related patent or not. 1: yes it is a forward patent citation of a Stavanger related patent. 0: no it is not.

Flag Backward – float: This tells if the patent is a backward patent citation or not. 1: yes, it is a backward patent citation. 0: no it is not.

Flag Aberdeen Backward – float: This tells if the patent is a backward patent citation of an Aberdeen related patent or not. 1: yes it is a backward patent citation of an Aberdeen related patent. 0: no it is not.

Flag Stavanger Backward – float: This tells if the patent is a backward patent citation of a Stavanger related patent or not. 1: yes it is a backward patent citation of a Stavanger related patent. 0: no it is not.

Flag Control – float: This tells if the patent is a control patent or not. 1: yes, 0: no. Not used

Flag Aberdeen – float: This tells if the patent is Aberdeen related or not. 1: yes, it is Aberdeen related. 0: no it is not.

Flag Stavanger – float: This tells if the patent is Stavanger related or not. 1: yes, it is Stavanger related. 0: no it is not.

Flag Huston – float: This tells if the patent is Huston related or not. 1: yes, it is Huston related. 0: no, it is not. Not used

Flag Foreign – float: This tells if the patent is a foreign (Non-US) patent or not. This is used for backward citation only. 1: yes, this is a foreign patent. 0: no, it is not.

Foreign Date – text: This tells when the foreign patent was granted. This is also used for other patents when it was originally filed in other country.

Foreign Country – text: This tells the country where the foreign patent was granted. This is also used for other patent when it was originally filed in other country.

Foreign Issue Date – date: this contains the same information as Foreign Date but in a format of date.

Table name: Aberdeen Original Patents

This is the list of all original Aberdeen patents

Fields:

ID – integer: Automatically generated index

Patent ID – text: The non-duplicated U.S. patent identification

Original Inventor – float: This tells if the patent has an Aberdeen inventor or not. 1: yes, it has at least one Aberdeen inventor. 0: no, it has not.

Original Assignee – float: This tells if the patent has an Aberdeen assignee or not. 1: yes, it has at least one Aberdeen assignee. 0: no, it has not.

Table name: Stavanger Original Patents

This is the list of all original Stavanger patents

Fields:

ID – integer: Automatically generated index

Patent ID – text: The non-duplicated U.S. patent identification

Original Inventor – float: This tells if the patent has a Stavanger inventor or not. 1: yes, it has at least one Stavanger inventor. 0: no, it has not.

Original Assignee – float: This tells if the patent has a Stavanger assignee or not. 1: yes, it has at least one Stavanger assignee. 0: no, it has not.

Table name: Inventors

This contains the information of the inventors for all original patents, forward patent citations and backward patent citations.

Fields:

ID – integer: Automatically generated index

Patent ID – text: The non-duplicated U.S. patent identification

Inventor SN – float: the series number of the inventor. For every patent, it starts from 1.

Inventor Name – text: the name of the inventor.

Inventor Address – text: the detail address of the inventor if there is any in the database.

Inventor City – text: the city where the inventor locates.

Inventor State – text: the state where the inventor locates.

Inventor Country – text: the country where the inventor locates.

Aberdeen Location Category – float: This tells the geographical area in which the inventor locates relatively to Aberdeen. 1: Local, 2: within the same county, 3: within the same country, 4: within the same continent, 5: international.

Stavanger Location Category – float: This tells the geographical area in which the inventor locates relatively to Stavanger. 1: Local, 2: within the same county, 3: within the same country, 4: within the same continent, 5: international.

Table name: Assignees

This contains the information of the Assignees for all original patents, forward patent citations and backward patent citations.

Fields:

ID – integer: Automatically generated index

Patent ID – text: The non-duplicated U.S. patent identification

Assignee SN – float: the series number of the assignee. For every patent, it starts from 1.

Assignee Name – text: the name of the assignee.

Assignee Name ID – text: the identical name of the assignee.

Assignee City – text: the city where the assignee locates.

Assignee State – text: the state where the assignee locates.

Assignee Country – text: the country where the assignee locates.

Assignees Type – float: this tells us what type the assignee of the original patent is. 1: Major Contractors, 2: All Other Contractors and Suppliers, 3: Operators, 4: Research Institutes, 5: Unknown, 6: Individual Not Used

Multinational Firm – integer: This tells if the assignee is a multinational firm or not. 1: yes, it is a multinational firm. 0: no, it is not.

Aberdeen Location Category – float: This tells the geographical area in which the assignee locates relatively to Aberdeen. 1: Local, 2: within the same county, 3: within the same country, 4: within the same continent, 5: international.

Stavanger Location Category – float: This tells the geographical area in which the assignee locates relatively to Stavanger. 1: Local, 2: within the same county, 3: within the same country, 4: within the same continent, 5: international.

Table name: Aberdeen Backward Citations

This contains the information of all backward patent citation of Aberdeen related patents.

Fields:

ID – integer: Automatically generated index

Original Patent ID – text: The non-duplicated U.S. patent identification of the original Aberdeen patent.

Backward Citation ID – text: The non-duplicated U.S. patent identification of the backward patent citation.

Closest Geographical Distance – float: The closest geographical distance between the original patent and the backward patent citation. 1: Local, 2: within the same county, 3: within the same country, 4: within the same continent, 5: international.

Furthest Geographical Distance – float: The furthest geographical distance between the original patent and the backward patent citation. 1: Local, 2: within the same county, 3: within the same country, 4: within the same continent, 5: international.

Foreign – integer: This tells if the backward patent citation is a foreign patent or not. 1: yes, it is a foreign patent. 0: no, it is not.

Self Citation – integer: This tells if the backward patent citation is a self citation or not. 1: yes, it is a self citation. 0: no, it is not.

Technical Distance – float: This tells the technical distance between the original patent and backward patent citation.

Time Distance – integer: This tells the time difference between the original patent and backward patent citation.

Table name: Aberdeen Forward Citations

This contains the information of all forward patent citation of Aberdeen related patents.

Fields:

ID – integer: Automatically generated index

Original Patent ID – text: The non-duplicated U.S. patent identification of the original Aberdeen patent.

Forward Citation ID – text: The non-duplicated U.S. patent identification of the forward patent citation.

Closest Geographical Distance – float: The closest geographical distance between the original patent and the forward patent citation. 1: Local, 2: within the same county, 3: within the same country, 4: within the same continent, 5: international.

Furthest Geographical Distance – float: The furthest geographical distance between the original patent and the forward patent citation. 1: Local, 2: within the same county, 3: within the same country, 4: within the same continent, 5: international.

Foreign – integer: This tells if the forward patent citation is a foreign patent or not. 1: yes, it is a foreign patent. 0: no, it is not.

Self Citation – integer: This tells if the forward patent citation is a self citation or not. 1: yes, it is a self citation. 0: no, it is not.

Technical Distance – float: This tells the technical distance between the original patent and forward patent citation.

Time Distance – integer: This tells the time difference between the original patent and forward patent citation.

Table name: Stavanger Backward Citations

This contains the information of all backward patent citation of Stavanger related patents.

Fields:

ID – integer: Automatically generated index

Original Patent ID – text: The non-duplicated U.S. patent identification of the original Stavanger patent.

Backward Citation ID – text: The non-duplicated U.S. patent identification of the backward patent citation.

Closest Geographical Distance – float: The closest geographical distance between the original patent and the backward patent citation. 1: Local, 2: within the same county, 3: within the same country, 4: within the same continent, 5: international.

Furthest Geographical Distance – float: The furthest geographical distance between the original patent and the backward patent citation. 1: Local, 2: within the same county, 3: within the same country, 4: within the same continent, 5: international.

Foreign – integer: This tells if the backward patent citation is a foreign patent or not. 1:

yes, it is a foreign patent. 0: no, it is not.

Self Citation – integer: This tells if the backward patent citation is a self citation or not. 1: yes, it is a self citation. 0: no, it is not.

Technical Distance – float: This tells the technical distance between the original patent and backward patent citation.

Time Distance – integer: This tells the time difference between the original patent and backward patent citation.

Table name: Stavanger Forward Citations

This contains the information of all forward patent citation of Stavanger related patents.

Fields:

ID – integer: Automatically generated index

Original Patent ID – text: The non-duplicated U.S. patent identification of the original Stavanger patent.

Forward Citation ID – text: The non-duplicated U.S. patent identification of the forward patent citation.

Closest Geographical Distance – float: The closest geographical distance between the original patent and the forward patent citation. 1: Local, 2: within the same county, 3: within the same country, 4: within the same continent, 5: international.

Furthest Geographical Distance – float: The furthest geographical distance between the original patent and the forward patent citation. 1: Local, 2: within the same county, 3: within the same country, 4: within the same continent, 5: international.

Foreign – integer: This tells if the forward patent citation is a foreign patent or not. 1: yes, it is a foreign patent. 0: no, it is not.

Self Citation – integer: This tells if the forward patent citation is a self citation or not. 1: yes, it is a self citation. 0: no, it is not.

Technical Distance – float: This tells the technical distance between the original patent and forward patent citation.

Time Distance – integer: This tells the time difference between the original patent and forward patent citation.

Table name: Patent Classes

This contains the information of all U.S. patent classification of the original patents, backward patent citations and forward patent citations.

Fields:

ID – integer: Automatically generated index

Patent ID – text: The non-duplicated U.S. patent identification

Class SN – float: the series number of the class. For every patent, it starts from 1.

Class Name – text: the 3 digit U.S. patent classification number of the patent.

Table name: Other References

This contains the information of all other references of the original patents, backward patent citations and forward patent citations.

Fields:

ID – integer: Automatically generated index

Patent ID – text: The non-duplicated U.S. patent identification

Other Reference SN – float: the series number of the other reference. For every patent, it starts from 1.

Other Reference – text: the name of the other reference

Reference Source – text: This tells the source of the other reference. It usually is the name of a journal or conference.

Reference Type – text: This tells the type of the other reference.

Reference Type ID – integer: This also tells the type of the other reference in a format of number. 1: Academic Journal or Organization, 2: Conference and Symposium, 3: University or Research Institution, 4: Magazine, 5: Book, 6: Website, 7: Company Document, 8: Patent Related, 9: Others.

Table name: Aberdeen Commune

This contains the names of commune in the great Aberdeen area.

Fields:

Aberdeen Commune – text: the name of the Aberdeen commune.

Table name: Stavanger Commune

This contains the names of commune in the great Stavanger area.

Fields:

Stavanger Commune – text: the name of the Stavanger commune.

Table name: Countries

This contains the list of countries which appear in the patent database.

Fields:

Country Code – text: this is the code of the country.

Country – text: this is the name of the country.

Continent – text: this tells the continent to which the country belongs.

Table name: Company List

This contains the list of firms which appear in the patent database.

Fields:

ID – integer: Automatically generated index

Company Name – text: It is the name of the company.

Company Type – text: This tells the type of the company.

Company Type ID – integer: This also tells the type of the company in a format or number. 1: Major Contractors, 2: All Other Contractors and Suppliers, 3: Operators, 4: Research Institutes, 5: Unknown, 6: Individual

Table name: Scientific Reference List

This contains the list of scientific references which appear in the patent database.

Fields:

ID – integer: Automatically generated index

Citation Name – text: The name of the scientific reference

Citation Source – text: This tells the source of the scientific reference. It usually is the name of a journal or conference.

Citation Type – text: This tells the type of the scientific reference.

Citation Type ID – integer: This also tells the type of the scientific reference in a format of number. 1: Academic Journal or Organization, 2: Conference and Symposium, 3: University or Research Institution, 4: Magazine, 5: Book, 6: Website, 7: Company Document, 8: Patent Related, 9: Others.

Chapter 5 Methodology of Data Analysis

In order to understand the general patenting situation in Stavanger and Aberdeen, we first compared the two locations with respect to the distribution of U.S. patents and patent citations by application year, countries of assignee, assignee types, names of assignee, countries of inventor, locations of inventor and others. Wherever there were sufficient observations, we further cross tabulated pairs of the variables mentioned above. The cross tabulation helps us break down the numbers, and explore more details of patenting behavior of Stavanger and Aberdeen.

In addition to the general comparison, a few measures and a regression model were developed and used to analyze the collected U.S. patent data.

5.1 General Measures

Within the past half century, several patent-based indicators have been devised to measure the basicness of innovation. In this study we made a few minor changes to some of these indicators so as to match our patent data. A brief introduction to these indicators follows.

One dimension of interest in describing scientific and technological activity is the extent to which it can be said to be fundamental or 'basic' in character. There are actually two different aspects of this property. First, in order to make technological advances, a certain amount of pre-existing knowledge is required as an important input. Thus how the research in question is related to the pre-existing body of knowledge is one aspect of 'basicness'. Second, the newly generated knowledge may also contribute to subsequent technological development. Thus, the second aspect of basicness is the relationship between the research outcome and subsequent knowledge creation. Patents and patent citations, as records of connections between inventions, prior art, and succeeding inventions, provide an effective way to trace and identify the relationships between innovations and their antecedents and descendents. Therefore, patents and patent citations can be used to study the basicness of innovation.

Five measures of basicness (Trajtenberg et al 1992) have been used in our analysis. We briefly introduce them next.

The first measure of basicness is what is called the "importance" of the patent. For each patent, there are backward importance and forward importance measures which are denoted as IMPORTB and IMPORTF respectively.

IMPORTB is defined as

$$IMPORTB(i) = N_{BP}(i)$$

And IMPORTF is defined as

$$IMPORTF(i) = N_{FP}(i)$$

N_{BP} is the number of backward patent citations of the original patent. N_{FP} is the number of forward patent citation of the original patent. The "i" represents the index of the original patent.

When we calculate the "importance" of a patent, we only consider the number of first-generation patent citations. But many researchers also take the number of second-generation patent citations into account because this provides a more accurate measure of "importance". In our study, we collected 819 U.S. patents granted to Aberdeen inventor, and 324 U.S. patents granted to Stavanger inventor. For all these original patents, we further observed 13,038 first-generation U.S. patent backward citations in Aberdeen, and 3,786 in Stavanger. The numbers of first-generation U.S. patent forward citations are 5,595 in Aberdeen and 1,482 in Stavanger. We can see that the number of observations is huge. It would have been very difficult for us to obtain the number of second-generation patent citations for all our original patents within the time available for this research, since the size of the database would have increased exponentially. Therefore we choose to use a simple form of the "importance" of patent as defined above.

If the original patent cites many previous patents, the backward importance of the patent, IMPORTB, will be large. Therefore IMPORTB reveals the extent to which the original patent stands on a broad base of prior inventions. A larger backward importance reflects a wider base of previous inventions on which the original patent stands. However, the backward importance of the patent is not a direct measure of its basicness. A larger backward importance does not mean that the patent is more important or more basic. We can say only that it stands on a broader base of prior knowledge.

If the original patent is cited by many descendants or subsequence patents, it will have a large forward importance, IMPORTF. A patent with a large forward importance is highly cited. Therefore the forward importance corresponds to intuitive understandings of what constitutes a basic advance.

The next two measures of basicness focus on the coverage of technological fields in the original patent. The first measure, ORIGINALITY, is defined as

$$ORIGINALITY(i) = 1 - \sum_{k=1}^{C_i} [N_{BP}(i,k) / N_{BP}(i)]^2$$

k is the index of patent classification. $N_{BP}(i,k)$ is the number of backward citations of the original patent i which fall into the patent classification k. $N_{BP}(i)$ is the total number of backward citations of the original patent i, regardless of patent classes. C_i is the total number of patent classes occupied by the backward citations of the original patent.

The ORIGINALITY is a number between 0 and 1. If all the backward citations of the original patent are in the same patent class, the ORIGINALITY of the original patent is equal to 0. If the original patent cites previous patents that belong to a broad range of technical fields, the ORIGINALITY of the original patent will be large and close to 1. Therefore a larger ORIGINALITY score implies broader technological roots of the underlying patent.

Along similar lines, the GENERALITY, a measure of 'forward basicness', is defined as

$$GENERALITY(i) = 1 - \sum_{k=1}^{C_i} [N_{FP}(i,k) / N_{FP}(i)]^2$$

$N_{FP}(i,k)$ is the number of forward citations of the original patent i, which fall into the patent classification k. $N_{FP}(i)$ is the total number of forward citations of the original patent I, regardless of patent class. C_i is the total number of patent classes occupied by the forward citations of the original patent i.

The GENERALITY reflects the extent to which the follow-on inventions from the original patent are spread across different technical fields. If the subsequent patents are concentrated in a few patent classes, the GENERALITY will be low and close to 0, whereas if the descendants belong to a wide range of technological fields, the GENERALITY will be high and close to 1. Therefore a high GENERALITY suggests that the underlying patent may have had a broad impact because it influences subsequent inventions in a variety of technical fields.

In general, where there are more citations, there is a built-in tendency for the citations to cover more patent classes. Patents citing more backward citations tend to have large ORIGINALITY, and likewise highly cited patents tend to exhibit large GENERALITY on average. Therefore when we compare the ORIGINALITY and GENERALITY of two groups of patents, we need to consider whether these two groups of patents contain roughly the same scale of citations.

The final measure of basicness, SCIENCE, measures the scientific basis of the patent. SCIENCE is defined as

$$SCIENCE(i) = N_{BS}(i)/[N_{BS}(i) + N_{BP}(i)]$$

$N_{BS}(i)$ is the total number of scientific references in the original patent i. SCIENCE actually measures the rate of scientific references as a fraction of all citations in the original patent. SCIENCE measures the predominance of scientific sources. We assume that if the inventive activity of a patent involves more basic research, the inventors will tend to draw more from scientific references than from technical patents. Therefore the subject patent should be associated with a higher value of SCIENCE.

All the measures of basicness using patents and patent citations are summarized in table 5-1 below.

	Forward	Backwards
Basicness	IMPORTF	IMPORTB
	GENERALITY	ORIGINALITY
		SCIENCE

Table 5-1 Measures of Basicness

5.2 Regression Model of Knowledge Spillover

In this research, we try to use patents and patent citations as tools to study knowledge spillovers. The major reason for us to use patents is that a patent is one of the few documents that systematically and consistently records the flow of knowledge.. Before developing the detailed mathematical formulation that can be implemented empirically to describe the dynamics of knowledge spillovers using patents, we should first understand the systematic mechanism of overall knowledge spillovers.

5.2.1 Mechanism of Knowledge Spillover

Throughout the knowledge spillover process, there are four types of actors or objects that we will be particularly interested in: the innovators who create the original knowledge that may diffuse to others; the absorbers who create secondary generations of knowledge based on what they learn from the original knowledge; the carriers which transmit the knowledge over time and from place to place; and the transmission media through which the carriers go.

The relationships between these four objects are shown in figure 5-1 below. First, the inventor from the initial location, time period and industry sector creates the original knowledge. According to the characteristics of the newly created knowledge, the innovator chooses carriers and uploads the knowledge onto them. Passing through different transmission media, the carriers deliver the knowledge to a different location and/or industry sector over time. With an interest in the knowledge from the original location, time period and industry sector, the absorber from the other location, time period and/or industry sector downloads the knowledge from his favorite carriers. After absorbing the original knowledge and combining it with his own creativity, the absorber generates new knowledge which cites the initial knowledge as prior art. Then the knowledge diffusion process starts again.

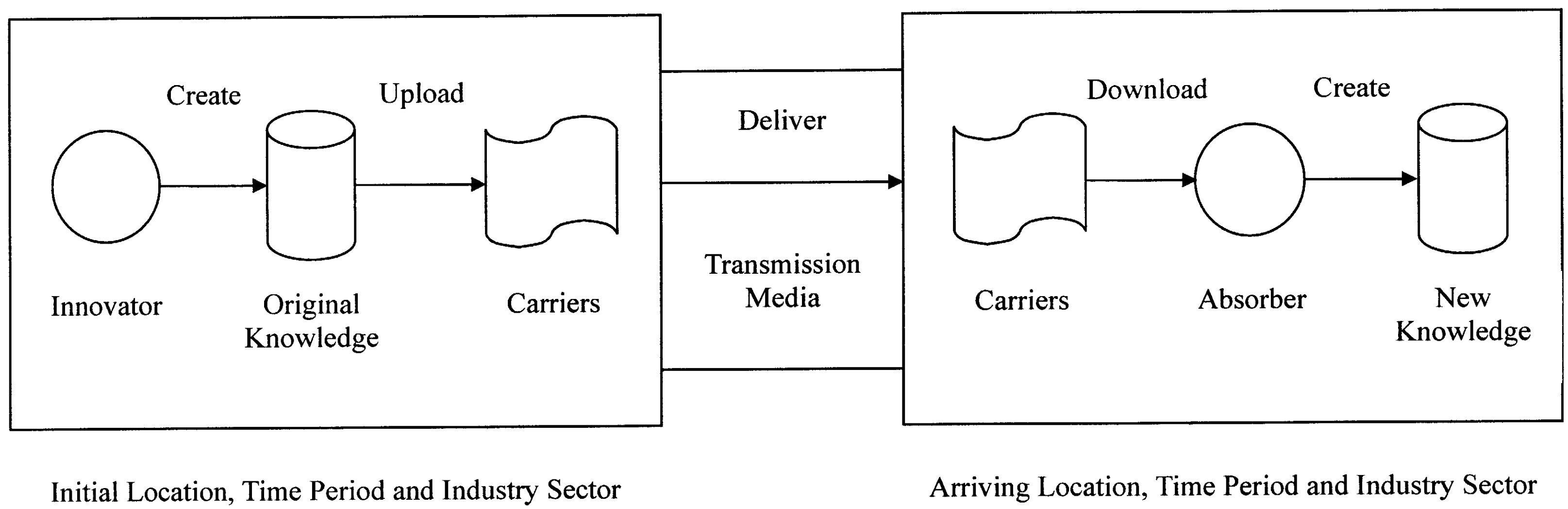

Figure 5-1 Mechanism of Knowledge Spillover

In this study, we focus mainly on innovators and absorbers. But inevitably, we will also touch on some properties of carriers and transmission media. We first explore the properties of each object in our model.

When we study innovators, two properties of the newly created knowledge are of primary interest, "importance" and "generality". The importance of newly created knowledge reflects its value or contribution to its descendants. An invention with greater importance is likely to have more descendents than the others. Unlike importance, generality describes the fundamental impact on the overall knowledge system. An invention with greater generality should be useful across a wider range of industries and over a longer time period.

Moving now to absorbers, the first property we want to explore is the propensity to cite knowledge from a particular innovation source. The propensity to cite reveals the likelihood that the absorber pursues knowledge from a specific group of innovators. After the absorber generates a connection with a source of information and starts absorbing knowledge from the source, two additional properties are of interest: the absorptive ability and the creativeness of the absorber. The absorptive ability tells us how efficiently the absorber can obtain and understand prior knowledge. Creativeness reflects the ability of the absorber to transform what he knows into new innovations. It is difficult to separately estimate the absorptiveness and creativeness of absorbers from the U.S. patent database. This is because patents do not reveal any information about how absorbers learn from the source of knowledge and how they transform this knowledge into newly developed innovations.

Carriers in our model can be any information bearers, such as books, other publications, and so on. Different carriers excel at bearing different types of information. But this is not the focus of our study. We only consider one type of carrier – U.S. patents. We are interested in exploring the propensity to 'upload' knowledge onto U.S. patents by innovators, and the propensity to 'download' information from U.S. patents by absorbers.

The final object in our model is the transmission medium. This is the diffusion environment through which the carriers pass when they deliver the knowledge. Transmission media can be paper subscriptions, internet, human networks or others. Sometimes medium and carrier can be separated from each other, and sometimes they cannot. For example, the website as a carrier is always bundled with the internet. We do not study any particular medium in detail. We only care about the diffusion speed of the knowledge which can be affected by the media and carrier in combination.

In our research we use U.S. patent data to study knowledge spillovers. The cited patents represent part of the original knowledge created by innovators. The citing patents reveal a portion of the new knowledge generated by absorbers. The citations documented within each patent link the two cohorts together and disclose information about knowledge diffusion.

It should be noted that the knowledge diffusion process in our model in principle includes all types of knowledge carried by every kind of carrier and delivered from the source to the end. Moreover the knowledge diffusion process exists as long as absorbers obtain information from the source. It does not matter if a second-generation knowledge are created or not. However, in practice we can only observe part of the diffusion process which has been physically recorded by the U.S. patent citations. This means that in our study, we only catch the diffusion of knowledge carried by U.S. patents. And the diffusion process is only observable if new knowledge in the form of patent has been generated by absorbers. We need to understand that these patent citations may reveal only part or even a very small part of the overall diffusion process.

On the other hand, some patent citations are processed and included in patent documents by patent examiners for legal reasons only. This means that not all patent citations reveal true knowledge diffusion from innovator to absorber. Some patent citations are not associated with any knowledge transmission whatsoever. The fraction of patent citations that are associated with true knowledge diffusion is unclear.

Our next job is to develop an empirical mathematical model and match it with the mechanism of knowledge spillovers we have described here.

5.2.2 Regression Model Development

Ricardo Caballero and Adam Jaffe have introduced a citation function to describe knowledge spillovers in their paper "How High Are the Giants' Shoulders: An Empirical Assessment of Knowledge Spillovers and Creative Destruction in a Model of Economic Growth" (Caballer and Jaffe 1993). The citation function is the product of the usefulness of old ideas and the probability of having seen them.

$$\alpha(o,s)=\delta e^{-\beta(N_o-N_s)}(1-e^{-\gamma(T_o-T_s)}) \qquad T_o \geq T_s \quad \gamma \geq 0 \quad \beta \geq 0 \quad 0 \leq \delta \leq 1$$

"O" represents the cohort of absorbers. "S" represents the cohort of innovators.

The citation function $\alpha(o,s)$, also called citation frequency, is an estimate of the probability that a randomly drawn idea from the citing group will cite a randomly drawn idea from the cited group. This probability cannot be observed by looking at each individual idea. However if there are enough observations of ideas from the citing and the cited group, and citations between these two groups, we can use the citation frequency as an approximation of the citing probability. The citation function is a function of the properties of innovators, absorbers, carriers and transmission media. The type of citation here is not limited to patent citations. It can be any form of knowledge reference, some of which may not be fully observable. The citation function is also not able to cover all knowledge spillovers. This is because in order to produce the citation, the original diffusing ideas must be transformed into new ideas with creative work involved. But not all diffused ideas can successfully trigger follow-on development and then generate citations.

The first parameter δ in the function captures the spillover intensity. It is an index with value between 0 and 1, with higher spillover intensity closer to 1. There are two distinct effects affecting the spillover intensity the most. One is the "potency" of old ideas. The other is the "absorption", measuring the intensity of use of old ideas by new ideas.

The second term $e^{-\beta(N_o-N_s)}$ captures the obsolescence effect. It is apparent that the power of old knowledge to generate new ideas will decline with time, as progress is made in related fields. The old knowledge is expected to obsolesce along the knowledge state rather than over time. There is no evidence that human societies advance knowledge at a constant speed. It is also evident that people in different locations make progress at difference speeds. For these reasons, it is more reasonable to describe knowledge as obsolescing along the knowledge state rather than over time. The knowledge state is represented as the accumulated inventions and/or ideas in a certain area at a particular time. The knowledge state is denoted as N in the formula. β represents the obsolescence speed. The greater β is, the faster the knowledge obsolesces. β is mostly affected by the properties of the original knowledge.

The last term $1-e^{-\gamma(T_o-T_s)}$ captures the diffusion effect. It takes time for the newly created knowledge to diffuse from one location to the other. The diffusion speed γ will vary depending on the nature of the carrier and the transmission medium. In reality, it is difficult to observe all possible transmission channels individually. We can only observe the overall effect caused by the whole system. Moreover, the γ we observe might also be affected by the absorptive and/or innovative abilities of the absorbers. This is because if the absorber has stronger absorptive and /or innovative abilities, the second generation of knowledge will be created sooner, as will the citations. Therefore we are likely to observe a higher value of γ. But this does not mean that the old knowledge diffuses faster.

The diffusion term does not incorporate any information about geographical distance, which means that it is not really a diffusion equation. We next develop a similar equation to describe the diffusion process in more detail based on our understanding of knowledge diffusion.

First we define Φ(x,t) as the probability of seeing an idea within a unit area at time t and location x. Φ is actually a probability density with units of length^{-2}. Assuming the idea is created at t=0 and x=0, at time zero Φ should be equal to 1 at x=0 and zero at all other locations (x≠0) where the information has not yet diffused. If there is a difference in Φ between two nearby locations, the information contained in the idea will diffuse from the high Φ area to the low Φ area. After the information flows to a given location, the probability of seeing the idea within that unit area increases, which means the Φ increases. The amount of information which diffuses from one place to another can then be calculated with the equation below,

$$J = -k\frac{\partial \phi}{\partial x}$$

This equation is analogous to Fick's first law of particle and thermal diffusion. J is defined as the amount of information which diffuses per unit time from x-. where Φ is higher, to x+ where Φ is lower. J can be called as probability flux with a unit of length^{-2}•time^{-1}. k is the diffusion coefficient representing the diffusion speed. It has the unit of length•time^{-1}. It tells how fast the information can diffuse between two places with a unit distance under a unit difference of probability density between these two locations.

Unlike particle diffusion or thermal diffusion, the probability of seeing the idea within a unit area Φ increases when the information enters the area. On the other hand the probability of seeing the idea within a unit area does not change when the information radiates out of the area. This means that only information inflow affects Φ. Therefore we have our second equation as below,

$$+J = \frac{\partial \phi}{\partial t}$$

Combining both equations we have the final first order linear partial differential equation,

$$\frac{\partial \phi}{\partial t} = -k\frac{\partial \phi}{\partial x} \qquad 0 \le \phi(x,t) \le 1$$

The initial condition for our problem is,

$$\begin{cases} \phi(x=0, t=0) = 1 \\ \phi(x \neq 0, t=0) = 0 \end{cases}$$

The boundary condition is,

$$\begin{cases} \phi(x,t) = 1 & for \quad x = 0 \\ \phi(x,t) = 0 & for \quad x > kt \end{cases}$$

For an arbitrary function F(z), Φ(x,t)=F(x-kt) can be the solution of our equation. This is because,

$$\frac{\partial \phi}{\partial t} = F'(z)(-k) = -kF'(z) = -k\frac{\partial \phi}{\partial x}$$

Considering the initial conditions and boundary conditions of our problem, we select a function that has a similar form to the one developed by Caballero and Jaffe.

$$\begin{cases} \phi(x,t) = 1 & for \quad x = 0 \\ \phi(x,t) = 1 - e^{-\lambda\kappa t + \lambda x} = 1 - e^{-\gamma t + \lambda x} & for \quad 0 < x \le k \qquad \lambda > 0 \quad \gamma \ge 0 \\ \phi(x,t) = 0 & for \quad x > kt \end{cases}$$

The diffusion speed κ is equal to γ/λ. We will explain the reason why we introduce an additional parameter λ and what it means later.

After introducing the new diffusion form, the citation function changes to,

$$\alpha(o,s) = \delta e^{-\beta(N_o-N_s)}(1-e^{-\gamma(T_o-T_s)+\lambda(X_o-X_s)}) \quad T_o \geq T_s \quad \gamma \geq 0 \quad \lambda > 0 \quad \beta \geq 0 \quad 0 \leq \delta \leq 1$$

The citation function above takes all kinds of knowledge spillover into account. It describes the overall situation of an absorber seeking information from an innovator and subsequently creating a new generation of ideas. Because we are working only with U.S. patent information we next need to transform the general citation function into the patent citation function.

Recall the definition of the citation function. α is an estimate of the probability that a knowledge citation (of any kind) is generated between the citing group comprised of absorbers and the cited group comprised of innovators. α is also called citation frequency. It can be calculated by dividing the total number of knowledge citations or "used ideas" ($R_{o,s}$) by the product of the total number of potential citing ideas created by absorbers (K_o) and the total number of potential cited ideas generated by innovators (K_s).

$$\alpha = \frac{[actual \cdot used \cdot ideas]}{[citing \cdot ideas] \times [cited \cdot ideas]} = \frac{R_{o,s}}{K_o K_s}$$

Similarly, we can define the patent citation frequency α^* as an estimate of the probability that a randomly drawn patent in the citing group will cite a randomly drawn patent in the cited group. It is equal to the total number of patent citations ($C_{o,s}$) divided by the product of the number of potential citing patents (P_o) and the number of potential cited patents (P_s).

$$\alpha^* = \frac{[actual \cdot patent \cdot citations]}{[potential \cdot \cdot citing \cdot patents] \times [potential \cdot \cdot cited \cdot patents]} = \frac{C_{o,s}}{P_o P_s}$$

In order to transform α into α^*, we need to set up the relationships between 1) the number of patents (P) and the stock of knowledge or ideas (K), and 2) the patent citations (C) and the knowledge references or 'used ideas' (R), based on some assumptions.

First, as we noted above, not all ideas created are patented. We assume that the number of patents is proportional to the total amount of knowledge or ideas. If the proportionality constant is Ψ, we have,

$$P_o = \Psi_o K_o \qquad 0 \leq \Psi_o \leq 1$$
$$P_s = \Psi_s K_s \qquad 0 \leq \Psi_s \leq 1$$

Next we develop the relationship between knowledge references and patent citations. According to the Manual of Patent Examining Procedures (MPEP) posted on the U.S. Patent Office website, "Any person at any time may cite to the Office in writing prior art consisting of patents or printed publications which that person believes to have a bearing on the patentability of any claim of a particular patent." This means not all the patent citations are provided by the inventors of the patent. The implication is that it is not true that every patent citation is associated with knowledge spillover. Therefore our second assumption is that the number of patent citations connected with real knowledge spillover is related to the number of all patent citations by a proportionality constant θ_o. We further assume that the number of patent citations representing real knowledge spillover is proportional to the total quantity of all kinds of knowledge references or "used ideas" with factor $\Psi_{o,s}$. Then we have,

$$\theta_o C_{o,s} = \Psi_{o,s} R_{o,s} \qquad 0 \le \theta_o \le 1, \quad 0 \le \Psi_{o,s} \le 1$$

Now the relationship between the patent citation function and the general citation function can be presented as,

$$\alpha^*(o,s) = \frac{C_{o,s}}{P_o P_s} = \frac{\Psi_{o,s} R_{o,s} / \theta_o}{\Psi_o K_o \Psi_r K_r} = \frac{\Psi_{o,s}}{\theta_o \Psi_o \Psi_s} \delta e^{-\beta(N_o - N_s)} (1 - e^{-\gamma(T_o - T_s) + \lambda(X_o - X_s)})$$
$$T_o \ge T_s \quad 0 \le \theta_o \le 1 \quad 0 \le \delta \le 1 \quad \beta \ge 0 \quad \gamma \ge 0 \quad \lambda > 0$$
$$0 \le \Psi_o \le 1 \quad 0 \le \Psi_s \le 1 \quad 0 \le \Psi_{o,s} \le 1$$

Finally, we need to relate the accumulated knowledge N to the number of patents P. As noted previously, the accumulated knowledge N should be equal to the total stock of ideas developed within the citing or the cited group over all time. Recalling the relationship between the stock of ideas, K, and the number of patents, P, introduced previously, we have,

$$N = \int_{-\infty}^{T} K_t dt = \sum_{-\infty}^{T} P_t / \Psi_t$$

Now the difference in accumulated knowledge between the citing group and the cited group is,

$$N_o - N_s = \sum_{-\infty}^{T_o} P_{t_o} / \Psi_{t_o} - \sum_{-\infty}^{T_s} P_{t_s} / \Psi_{t_s}$$

As a practical matter it is difficult to determine the total number of patents granted to the citing and cited groups over all time and the associated factors Ψ_t. Our next job is to bring together the patent citation function and the general systematic model of knowledge spillovers. Several practical problems including this one will also be addressed at this stage.

5.2.3 Parameters Interpretation

Previously we developed a general systematic model of knowledge spillovers which contains 4 objects, innovator, carrier, transmission media and absorber. Each object has interesting properties that affect the knowledge diffusion process in a particular way. Afterwards we made a small improvement to the citation function developed by Caballero and Jaffe. The citation function can be used as a regression model to study knowledge spillover quantitatively. The final regression model has five different estimators: θ, δ, β, γ and λ. Our next task is to put these two models together and interpret the five estimators as indicators of the properties of the four objects.

Before we start, several symbols that we use below need to be clarified. Most of patent citations represent instances of knowledge spillover from the cited group, to which the innovators belong, to the citing group to which the absorbers belong. Here we use "S" to denote the cited group. And "O" denotes the citing group. Both the citing group and the cited group will be divided into several sub-classes based on the inventor's location "L", the time period "T", the industrial sector "G" and the patent classes "Z" to which the patent belong. The capital letters "L", "T", "G" and "Z" are used for the citing group, and the lowercase "l", "t", "g" and "z" are used for the cited group.

We begin with the properties of innovators in the cited group. There are two important properties to consider. The first is the importance. If the knowledge created by the innovators is important, it is more likely that its descendants will be observed, and that more citations will be found. This means that original knowledge with greater importance can result in a higher δ score. We specify its contribution to δ and name it as $\delta_{importance}(l,t,g,z)$. $\delta_{importance}$ is a function of l, t, g and z, because innovators from different locations, time periods, industrial sectors and patent classes might be expected to create knowledge with different importance. We also postulate that knowledge with greater importance spreads more rapidly than knowledge with lower importance. As shown earlier, the diffusion speed κ is equal to γ/λ. Faster diffusion speed leads to greater γ. Therefore we associate the importance of the knowledge created by innovators with γ and separately specify this effect as $\gamma_{importance}(l,t,g,z)$.

The second property of innovators is generality. We consider that inventions with greater generality should be useful across a wider range of industries and over longer times. This means that the rate of obsolescence should be slower for ideas with greater generality. Thus we associate generality with obsolescence speed β and denote it as $\beta_{basicness}(l,t,g,z)$.

As discussed above, not all the knowledge created by innovators is represented in the form of a patent. Only a small fraction of this knowledge is 'uploaded' to U.S. patents (which is the only information carrier we consider in this work). We assume that the stock of knowledge that is uploaded to patents is directly proportional to the total stock of knowledge created by innovators, with the proportionality constant set as Ψ_s. We call this constant the innovators' propensity to patent in the U.S. It will be a function of the location, time period, industrial sector and patent class of the cited group. Thus we have $\Psi_s(l,t,g,z)$.

As mentioned previously, the transmission media and carriers together can affect the diffusion speed. The more efficient the diffusion channel, the faster the knowledge will diffuse. We associate the effect on diffusion speed caused by transmission media and carriers to the factor λ in the citation function. If λ is small, the diffusion speed κ is greater, meaning that the diffusion channel is more efficient. In principle there may be multiple transmission media linking the citing group and the cited group.. But it is impossible for us to identify every transmission medium. We will only consider the average diffusion effect between these two groups. Therefore the value of λ will be determined by both cohorts. Now we should have $\lambda_{transmission}(l,L,t,T,g,G,z,Z)$, which represents the overall diffusion efficiency resulting from the combined effects of the transmission media and carriers between citing and cited groups.

After the knowledge has been passed to the citing group, it will be absorbed. Some of the absorbers may apply their own creativity to this knowledge to produce a second generation of knowledge. We do not have enough information from the U.S. patent database to study the absorptiveness and creativeness of the absorbers separately since not all of the relevant factors are observable. We assume that if the absorbers have both better absorptive ability and better innovative ability, there will be more secondary generation of knowledge, and hence a larger number of backward citations. Therefore, better absorptiveness and creativeness of absorbers will result in a greater δ score. As we did with the innovator property of importance, we specify the combined contribution of absorbers' absorptiveness and creativeness to δ as $\delta_o(L,T,G,Z)$, a function of location, time period, industrial sector and patent class of the citing group.

Again, not all the new knowledge created by the absorbers is patented. We introduce another factor Ψ_o to represent the fraction of all secondary knowledge generated by in the cited group that takes the form of patents. We call this the absorbers' propensity to patent in the U.S. and denote it as $\Psi_o(L,T,G,Z)$.

The observable link between the citing group and the cited group is comprised of the patent citations listed in the patents granted to absorbers in the citing group. As we pointed out previously, not all of these patent citations reflect real knowledge spillovers. This is because the patent examiners may add citations due to legal concerns. We assume that those patent citations that reflect real knowledge spillovers are proportional to the total number of observed patent citations, with a constant of proportionality $\theta_o(T,G,Z)$. We also assume that the number of patent citations with real knowledge spillover is proportional to the total number of "used ideas" passing between cited group and citing group, with a constant of proportionality $\Psi_{o,s}(l,L,t,T,g,G,z,Z)$. We call this the absorbers' propensity to cite U.S. patents granted to the cited group.

The final practical problem we need to address here is that in the citation function the knowledge is represented as obsolescing along the knowledge state rather than over time. The knowledge state is represented as the accumulated stock of ideas N. In order to describe the accumulated ideas N, we would need to obtain the total number of patents over all time for each individual citing and cited group. This information is difficult to acquire. To solve this problem, we substitute the passage of time for the stock of accumulated knowledge N in the citation function. To reflect the fact that this is an approximation, we introduce another factor $\beta_{state}(l,L,t,T,g,G,z,Z)$.

$$N_o - N_s = \beta_{state}(l,L,t,T,g,G,z,Z)(T_o - T_s)$$

For the same time difference (T_o-T_s), a greater value of β_{state} means a larger difference in the knowledge states of the citing and cited groups.

In summary, we list all the estimators in the final patent citation function and their interpretations in the table below,

Parameter	Interpretation
$\delta_{importance}(l,t,g,z)$	The importance of knowledge created by innovators which controls the number of overall citations
$\delta_o(L,T,G,Z)$	The combined effect of absorbers' absorptiveness and creativeness
$\Psi_s(l,t,g,z)$	Innovators' propensity to patent in U.S.
$\Psi_o(L,T,G,Z)$	Absorbers' propensity to patent in U.S.
$\Psi_{o,s}(l,L,t,T,g,G,z,Z)$	Absorbers' propensity to cite U.S. patents
$\theta_o(T,G,Z)$	The citation add-on effect caused by patent examiners
$\beta_{basicness}(l,t,g,z)$	The basicness of knowledge created by innovators
$\beta_{state}(l,L,t,T,g,G,z,Z)$	The adjustment for the knowledge state difference between citing and cited groups
$\gamma_{importance}(l,t,g,z)$	The importance of knowledge created by innovators which affects the diffusion speed
$\lambda_{transmission}(l,L,t,T,g,G,z,Z)$	The diffusion efficiency caused by transmission media and carriers.

Table 5-2 Estimators in the Knowledge Spillover Regression Model

The final patent citation function is,

$$\alpha^*(o,s) = \frac{C_{o,s}}{P_o P_s} = \frac{\Psi_{o,s}}{\theta_o \Psi_o \Psi_s} \delta_{importance} \delta_o \delta e^{-\beta_{basiceness} \beta_{state} \beta (T_o - T_s)} (1 - e^{-\gamma_{importance} \gamma (T_o - T_s) + \lambda_{transmission} (X_o - X_s)})$$

$$T_o \geq T_s \quad 0 \leq \theta_o \leq 1 \quad 0 \leq \delta \leq 1 \quad \beta \geq 0 \quad \gamma \geq 0 \quad \lambda > 0$$

$$0 \leq \Psi_o \leq 1 \quad 0 \leq \Psi_s \leq 1 \quad 0 \leq \Psi_{o,s} \leq 1$$

In this final version of the patent citation function, we left the general parameters δ, β, and γ unchanged so as to capture all the other fundamental effects that we have not explicitly accounted for.

Chapter 6 Results and Discussion

In this chapter, I will present the results of the U.S. patent analysis, patent citations analysis, and patent scientific citations analysis. I will compare the results between Stavanger and Aberdeen to find out if they share any common features and/or if there are any significant differences between them.

6.1 Foreign Entrants

Oil and gas was first discovered in 1960s in the North Sea province. Before that Stavanger and Aberdeen had been hubs of their respective regional economies for centuries, but both of them had at most a very limited relationship to the oil and gas industry. Given that the two cities were starting essentially from scratch and with very limited know-how, neither of them had the ability to build up the local oil and gas sector on their own. Therefore, the local developers had to and were willing to seek help from the most advanced players in the world. On the other hand, the lack of knowledge and experience of exploring and producing the newfound natural resources in the local regions provided a good opportunity for the external developers to enter the local market. Because of the large proven reserves of oil and gas in the North Sea and the attractive benefits from further exploration and production, the advanced players from elsewhere also had strong motivations to bring in their technology and participate in local economic development.

6.1.1 Who are the Foreign Players

U.S.-origin technology has dominated the international petroleum engineering industry for decades. U.S. petroleum engineers became the international leaders beginning in the early decades of the last century. Moreover, U.S. oil firms began signing agreements to explore and produce oil in other countries before World War II. However, the tempo and range of these arrangements did not explode till the war ended (JPT 1999). The discoveries of oil and gas in the North Sea started in the early 1960s when U.S. oil companies were unquestionably the most advanced players in the world. It is thus no surprise to find U.S. firms as the most active foreign players in local patenting activities in Stavanger and Aberdeen.

In chapter 4, table 4-3 shows the distribution of U.S. patents by the country of assignee. In Aberdeen it is U.S. firms that are the biggest winners in U.S. patenting. About 57% of U.S. patents with at least one Aberdeen-based inventor and one non-individual assignee were granted to U.S. firms or other U.S. organizations. Though the ratio is much lower in Stavanger -- less than 32% of the Stavanger-related patents were granted to U.S. assignees, and about 64% to Norwegian assignees -- U.S. firms were still the biggest foreign players there.

Aberdeen Related Patents								
Type of Assignee	U.S. Assignee			U.K. Assignee			**Total**	
	No. of Patent	Row Ratio	Column Ratio	No. of Patent	Row Ratio	Column Ratio	**No. of Patent**	**Column Ratio**
Major Contractors	202.5	99.51%	48.74%	1	0.49%	0.34%	**203.5**	**28.03%**
All Other Contractors	189	42.28%	45.49%	240.5	53.80%	82.50%	**447**	**61.57%**
Operators	18	34.95%	4.33%	32	62.14%	10.98%	**51.5**	**7.09%**
Total	**415.5**	**57.23%**		**291.5**	**40.15%**		726	
Stavanger Related Patents								
Type of Assignee	U.S. Assignee			Norwegian Assignee			**Total**	
	No. of Patent	Row Ratio	Column Ratio	No. of Patent	Row Ratio	Column Ratio	**No. of Patent**	**Row Ratio**
Major Contractors	62.00	100.00%	67.39%	0.00	0.00%	0.00%	**62.00**	**21.34%**
All Other Contractors	10.00	9.69%	10.87%	83.67	81.10%	45.23%	**103.17**	**35.51%**
Operators	19.00	16.62%	20.65%	92.33	80.76%	49.91%	**114.33**	**39.36%**
Total	**92.00**	**31.67%**		**185.00**	**63.68%**		290. 50	

Table 6-1 Distribution of Patents by the Type of Assignee and the Country of Assignee

Table 6-1 gives the distribution of patents with at least one local inventor by type of assignee and country of assignee. In both locations, most of the patents granted to U.S. assignees have been granted to the four major contractors. It is noteworthy that in Stavanger, U.S. contractors other than the big four are not active in patenting, having received only 10 patents between them. In contrast, U.S. contractors other than the big four were granted 189 patents in Aberdeen.

One reason for the U.S. firms' weaker performance in Stavanger is the difference between UK and Norwegian national policies on domestic capacity building. The Norwegian government has focused on domestic capacity building from early on. The government helped establish a national oil firm, Statoil, and promoted technology transfer from foreign companies to domestic organizations. The policies of U.K. government were that it was up to industry to make its own R&D decision and there were many fewer limitations. This suggests that it may have been easier for U.S. firms to undertake activities in Aberdeen than in Stavanger.

The first emergence of petroleum engineering as a sophisticated technology occurred in Europe. Though the U.S. quickly moved into a leadership position in this field and has remained the leader, European countries have caught up over the past 20 years as the fast pace of globalization in the oil and gas industry has continued (JPT 1999). Though the numbers of patents granted to European assignees are small, it is still meaningful to notice the difference of proportion of U.S. patents issued to European firms out of all original patents between Stavanger and Aberdeen. This is because we assume that the European firms operate in Stavanger and Aberdeen have generally the same propensity to patent and the same inventiveness. Therefore, the difference of numbers of patents owned by European firms is primarily caused by the difference of local R&D investment in the places. Then the proportion of patents indicates the interest to carry out local R&D activities under the control of the size of overall local R&D investment. Table 4-3 shows that in Stavanger and Aberdeen, the proportion of U.S. patents that were granted to assignees from all other countries (most of which are European countries) was 4.6% and 2.6% respectively. The difference suggests that European assignees are more likely to participate in patenting activities in Stavanger than in Aberdeen.

What drove the European firms' stronger interests in Stavanger than in Aberdeen is not yet clear to us. One of our suspicions is that because many European firms are not as big as U.S. firms are, they have been more inclined to cooperate with local firms than their U.S. counterparts in order to compete with U.S. companies and win a portion of market share. For the purpose of knowledge import, the Norwegian government and local industry set up a much more cooperative environment in Stavanger than in Aberdeen, and we suspect that this brought in more European participants.

6.1.2 The Growth of U.S. Firms

Figure 6-1 shows the distribution of Aberdeen-related patents and Stavanger-related patents granted to U.S. assignees by year of application. For the purpose of comparison, the trend in overall U.S. patenting is also shown. The figure has been normalized to a base year of 1987. We chose 1987 as the base year because after that year the number of granted U.S. patents rose steadily.

In Figure 6-1 we can see a clear decline in the number of patents in both locations after 2002. This is caused by the truncation problem. What the figure shows is the distribution of patents by year of application. Usually there is a 2 to 5 year delay between the time when the patent application is submitted and the time when the patent is granted. Therefore, some of the patent applications which were submitted in the most recent years may still be in the process of review. They will not be observable in the U.S. patent database unless and until they are issued in the future.

Figure 6-1 shows that the total number of U.S. patents granted annually by USPTO increased steadily after 1987. The rate more than doubled within 15 years. The figure also shows that for both Aberdeen and Stavanger-related inventions the number of patents granted annually to U.S. assignees increased much faster than the overall rate of patenting. In 2002, the number of Aberdeen-related patents granted to U.S. assignees was 14 times higher than it was in 1987.

There are two likely explanations for the rapid growth of local patents granted to U.S. firms. First, the number of U.S. firms and other organizations that operated in both locations increased gradually over the years. Following the initial discoveries of oil, the prospect of further discoveries attracted additional multinational oil firms, most of which are U.S. companies. As the market grew bigger and more mature, more and more small oil firms followed in the footsteps of the giants and moved into the regions. Many international service providers, often with long-term relations with operators, also arrived over time.

Second, the local branches of U.S. firms grew bigger and bigger. If the local economy is able to generate economic benefits that are large enough, some foreign companies will be happy to strengthen their local capabilities to capture future rewards. The four integrated service providers gave strong evidence of expanding their local capabilities through acquisitions over this period. For example, Schlumberger acquired GECO, a company known for its innovative approaches in seismic analysis in Stavanger. Weatherford bought up Petroline in Aberdeen to consolidate its capabilities in tubular technology.

We also observe from figure 6-1 that U.S. assignees have recently posted slightly weaker performance in Stavanger than in Aberdeen. The number of patents issued to U.S. assignees flattened out after 1997 in Stavanger whereas it kept increasing in Aberdeen. In theory, the flattening out in Stavanger could have been the result of delocalization – that is, as oil fields are depleted, global companies may have little reason to stay unless they have already built unique capabilities in the area. However, other evidence concerning the depletion of oil resources suggests that this should have happened first in Aberdeen, not Stavanger. Hence, the explanation for the observed difference remains unclear.

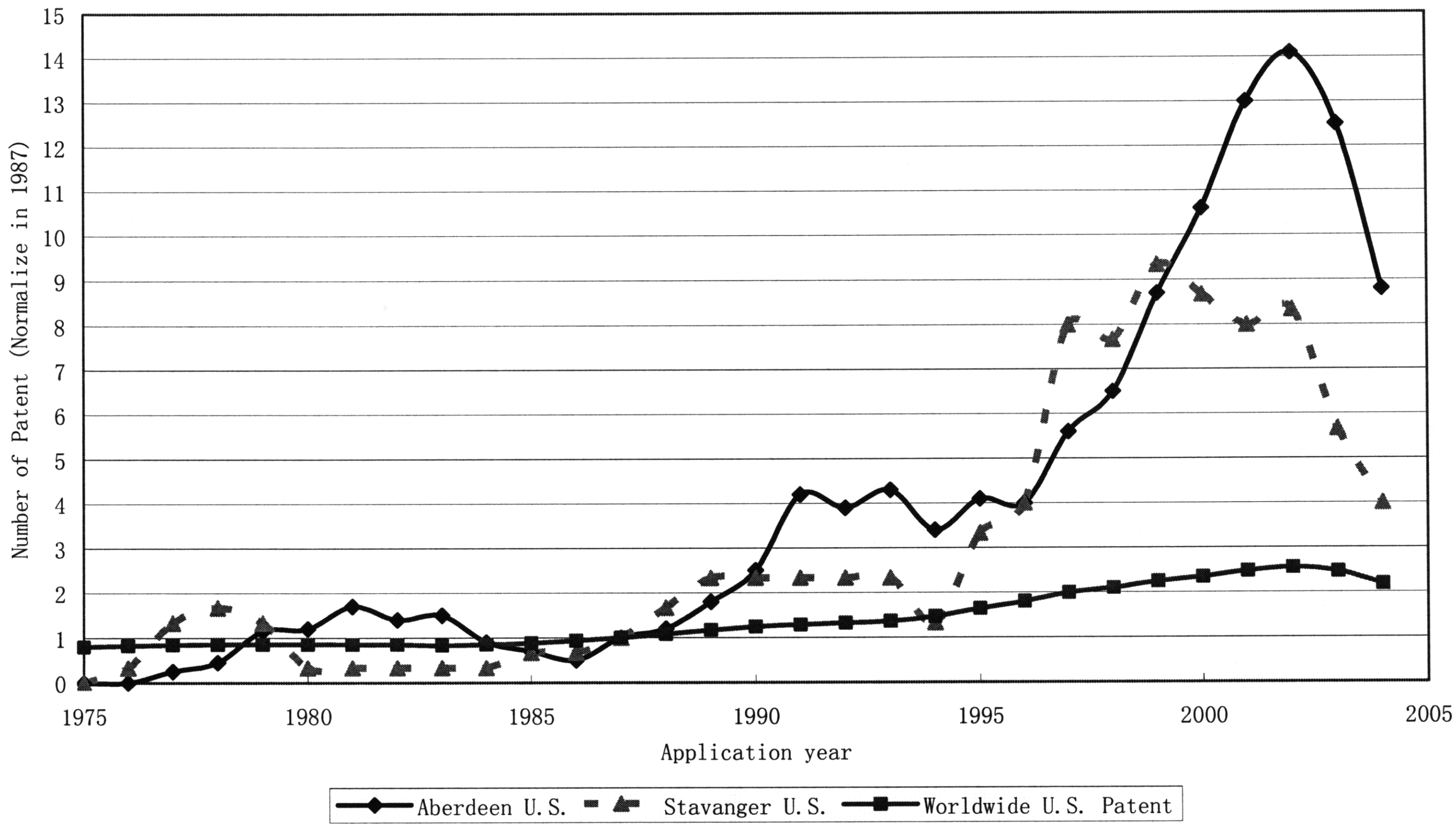

Figure 6-1 Distribution of Patents Granted to U.S. Assignee by Application Year (Normalized in 1987)

6.1.3 Establish Relationship with Local Communities

Because of the limited local capabilities in oil and gas extraction, the local authorities in both Stavanger and Aberdeen worked hard to attract key international industrial players into their regions. The arrival of multinational firms is an important boost to local innovation capabilities. When foreign firms sense the potential of the local economy, they will not hesitate to build up their local capabilities. Such capacities can help not only to bring in advanced knowledge from elsewhere, but also to educate local communities.

The results of the patent analysis reveal that after years of development in both Aberdeen and Stavanger, local innovation activities set up by U.S. firms grew to rely significantly on local inventors. Table 6-2 presents data on how inventors from different regions are matched with assignees from different countries. It shows that in both Aberdeen and Stavanger, the patents granted to U.S. assignees hire more local inventors than inventors from any other regions. For those patents granted to U.S. assignees in Aberdeen, 65.6% of the inventors are local to Aberdeen. For those patents granted to U.S. assignees in Stavanger, 54.7% of their inventors are from the local Stavanger area.

Aberdeen Related Patents										
Country of Assignee	Local Inventor					National Inventor				
	No. of Patent	Row Ratio	Column Ratio	No. of Inventors	Inventor per Patent	No. of Patent	Row Ratio	Column Ratio	No. of Inventors	Inventor per Patent
U.S.	272.49	65.58%	51.15%	563.5	2.07	24.16	5.81%	38.97%	69	2.86
U.K.	253.83	87.08%	47.65%	422.5	1.66	36.88	12.65%	59.50%	94.5	2.56
Others	6.37	33.51%	1.20%	17.00	2.67	0.95	5.00%	1.53%	3.50	3.68
Total	**532.69**	**73.37%**		**1003**	**1.88**	**61.99**	**8.54%**		**167**	**2.69**
Country of Assignee	Continental Inventor					International Inventor				
	No. of Patent	Row Ratio	Column Ratio	No. of Inventors	Inventor per Patent	No. of Patent	Row Ratio	Column Ratio	No. of Inventors	Inventor per Patent
U.S.	12.13	2.92%	73.23%	37	3.05	108.72	26.17%	94.74%	473.5	4.36
U.K.	2.17	0.74%	13.08%	8	3.69	1.62	0.55%	1.41%	5	3.09
Others	2.27	11.93%	13.69%	11.00	4.85	4.42	23.25%	3.85%	11.50	2.60
Total	**16.56**	**2.28%**		**56**	**3.38**	**114.75**	**15.81%**		**490**	**4.27**
Stavanger Related Patents										
Country of Assignee	Local Inventor					National Inventor				
	No. of Patent	Row Ratio	Column Ratio	No. of Inventors	Inventor per Patent	No. of Patent	Row Ratio	Column Ratio	No. of Inventors	Inventor per Patent
U.S.	50.27	54.65%	25.22%	119	2.37	4.33	4.71%	11.16%	14	3.23
Norway	143.45	77.54%	71.96%	243.5	1.70	32.54	17.59%	83.79%	106	3.26
Others	5.61	41.56%	2.81%	17.00	3.03	1.96	14.52%	5.05%	11.00	5.61
Total	**199.33**	**68.62%**		**379.5**	**1.90**	**38.83**	**13.37%**		**131**	**3.37**
Country of Assignee	Continental Inventor					International Inventor				
	No. of Patent	Row Ratio	Column Ratio	No. of Inventors	Inventor per Patent	No. of Patent	Row Ratio	Column Ratio	No. of Inventors	Inventor per Patent
U.S.	6.85	7.44%	38.12%	25.5	3.73	30.55	33.20%	88.85%	123	4.03
Norway	5.85	3.16%	32.57%	22	3.76	3.67	1.98%	10.66%	12.5	3.41
Others	5.26	38.98%	29.31%	28.50	5.42	0.17	1.23%	0.48%	0.50	3.00
Total	**17.96**	**6.18%**		**76**	**4.23**	**34.38**	**11.84%**		**136**	**3.96**

Table 6-2 Distribution of Patents by the Country of Assignee and the Region of Inventor

As we mentioned earlier, one of the multinational firms' contributions to the local innovation systems is that they help transfer advanced technology into the region from elsewhere. Since early on, the Norwegian government has had stronger policies to promote technology transfer from foreign to domestic organizations than the U.K. government. Therefore, we would expect to see much more knowledge transfer from the multinational firms to the local companies in Stavanger than in Aberdeen. However, our patent citation data show completely the opposite results.

Table 6-3 gives the distributions of the likelihood of forward citation by the assignee country of citation and the assignee country of the original patent. For the tables presented in this chapter, the "Ratio of Patent" unless specifically noted tells how much percent of the original patent from the subgroup of the row have at least a citation from the subgroup of the column. Table 6-3 shows that in both Aberdeen and Stavanger the original patents granted to U.S. assignees are less likely to have forward citation from the native assignee than the original patents granted to native assignees. However, the difference between U.S. assignee and the native assignee of the original patents are much greater in Stavanger than in Aberdeen. In Stavanger close 32% of the original patent issued to Norwegian assignee, and only less than 8% of the original patent granted to U.S. assignees have at least one forward citation granted to the Norwegian assignee.

Aberdeen					
Citation Assignee Country	U.S.		U.K.		Total
Original Patent Assignee Country	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	No. of Patent
U.S.	95.82%	9.54	21.95%	1.51	287
U.K.	91.74%	7.24	31.19%	1.47	218
Total	94.03%	8.49	26.01%	1.51	519
Stavanger					
Citation Assignee Country	U.S.		Norway		Total
Original Patent Assignee Country	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	No. of Patent
U.S.	92.21%	8.03	7.79%	1.08	77
Norway	89.08%	3.83	31.93%	1.68	119
Total	90.50%	5.58	21.50%	1.65	200

Table 6-3 Distribution of Likelihood of Forward Citation by the Assignee Country of the Citation and the Assignee Country of the Original Patent

Table 6-4 exhibits the distribution of forward citations by geographical distance and the country of assignee of the original patent. The "No. of Patent" and "Ratio of Patent" in table 6-4 and 6-6 give how many and how much percent of the original patent from the subgroup indicated by the first column have at least a citation from the subgroup indicated by the second column. The table shows that in Stavanger the original patents granted to U.S. assignees are much less likely to have forward citations from the local Stavanger area than the original patents granted to Norwegian assignees. Close to 25% of the original Stavanger-related patents issued to the Norwegian assignees have forward citations from local area, but less than 8% for the patents granted to U.S. assignees. However, in Aberdeen, 42% of the original Aberdeen related patents granted to U.K. assignees have forward citations from local region.

		Aberdeen		Stavanger	
Assignee Country (Original)	Geographical Distance	No. of Patent	Ratio of Patent	No. of Patent	Ratio of Patent
U.S.	Local	121	41.94%	6	7.89%
	National	182.5	63.26%	43.5	57.24%
	Continental	97.5	33.80%	36.5	48.03%
	International	151	52.34%	33.5	44.08%
U.K./Norway	Local	77	34.30%	29.5	24.58%
	National	73.5	32.74%	36	30.00%
	Continental	85.5	38.08%	58	48.33%
	International	199.5	88.86%	98.5	82.08%
Total	Local	201	38.07%	37	17.87%
	National	264	50.00%	80	38.65%
	Continental	191	36.17%	101	48.79%
	International	360	68.18%	141	68.12%

Table 6-4 Distribution of the Likelihood of Forward Citation by the Geographical Distance and the Assignee Country of the Original Patent

There could be many reasons behind this unexpected result. 1, Firms in Stavanger pay little attention to the patented knowledge from foreign companies. 2, When the Norwegian government emphasized on building domestic capabilities, they were more intent on building on their own rather than learning from others. 3, When the Stavanger local developers tried to learn from others, they did not gave enough attention to the local resources produced by foreign companies. 4, Somehow the foreign companies, especially U.S. firms did not have well communication with local communities in Stavanger. However, it will be difficult for us to discover the true reason using the patent data only. Some further qualitative studies are required to answer this question clearly.

After the multinational entered into the local innovation system, they not only make contribution, but also benefit from it. As the local innovation capacities have been built up, more and more new technology will be generated locally, of which the local multinational firms can take advantage.

Table 6-5 exhibits the distributions of the likelihood of backward citation by the assignee country of the citation and the assignee country of the original patent. What we want to highlight in this table is that in Aberdeen the original patents granted to U.S. assignees are more likely to cite previous patents granted to U.K. assignees than the original patents granted to assignees from other countries. More than 36% of original Aberdeen patents granted to U.S. assignees have backward citations to patents granted to U.K. assignees, but only 23% of the original patents granted to U.K. assignee do.. However, in Stavanger the original patents granted to U.S. assignees are much less likely to cite patents granted to Norwegian assignees than is true of other original patents. About 11% of the original Stavanger patents granted to U.S. assignees cite at least one earlier patent granted to a Norwegian assignee, which is less than the 18% average for all original patents.

Aberdeen							
Citation Assignee Country	U.S.		U.K.		France		Total
Original Patent Assignee Country	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	No. of Patent
U.S.	98.80%	12.91	36.63%	2.62	19.52%	1.38	415
U.K.	94.48%	4.45	23.10%	1.43	16.90%	1.45	290
Total	96.96%	9.44	31.12%	2.22	18.67%	1.41	723
Stavanger							
Citation Assignee Country	U.S.		Norway		France		Total
Original Patent Assignee Country	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	No. of Patent
U.S.	97.73%	12.66	11.36%	1.10	25.00%	2.18	88
Norway	96.79%	4.67	21.93%	1.27	19.79%	1.35	187
Total	96.79%	7.30	17.86%	1.27	21.43%	1.80	280

Table 6-5 Distribution of the Likelihood of Backward Citation by the Assignee Country of the Citation and the Assignee Country of the Original Patent

Table 6-6 displays the distribution of backward citations by geographical distance and by assignee country of the original patent. One of the findings in this table is that in Aberdeen the original patents granted to U.S. assignees are more likely to cite patents from the local area than is true of the original patents granted to U.K. assignees. But this is not true in Stavanger. The original Stavanger patents that were granted to U.S. assignees have about the same likelihood of citing patents from the local area as are patents granted to Norwegian assignees. In Aberdeen 40% of the original patents granted to U.S. assignees have backward citations to the local area, but this is true of less than 23% of the patents granted to U.K. assignees.

		Aberdeen		Stavanger	
Assignee Country (Original)	Geographical Distance	No. of Patent	Ratio of Patent	No. of Patent	Ratio of Patent
U.S.	Local	167	40.29%	9.5	10.67%
	National	277.5	66.95%	56	62.92%
	Continental	210	50.66%	53.5	60.11%
	International	263	63.45%	39	43.82%
U.K./Norway	Local	64	22.42%	26	14.36%
	National	79.5	27.85%	37	20.44%
	Continental	129	45.18%	107.5	59.39%
	International	275.5	96.50%	177	97.79%
Total	Local	236	32.82%	36	12.74%
	National	369	51.32%	96	33.98%
	Continental	348	48.40%	168.5	59.65%
	International	552	76.77%	227.5	80.53%

Table 6-6 Distribution of the Likelihood of Backward Citation by the Geographical Distance and the Assignee Country of the Original Patent

The results from the two tables above show that U.S. firms operating in the North Sea Province seem to benefit more from prior inventions made in the Aberdeen region than in the Stavanger region. Again, we cannot explain this finding. However, it suggests several interesting questions for future study, for example: 1. Are local innovation capabilities greater in Aberdeen than in Stavanger? 2 Does Stavanger generates less knowledge in the form of patents than Aberdeen? 3. Are there barriers in place that prevent U.S. firms from learning locally in Stavanger?

6.2 Learn to Grow

Prior to the discoveries of oil and natural gas, both Stavanger and Aberdeen had long served as important local economic centers, but neither was energy-focused. In general, we might expect it to be much easier and more efficient for local economies to take advantage of the opportunities created by oil and gas discoveries if they can master sufficient and sustainable related knowledge. In order to accumulate the necessary knowledge, there are at least two different possibilities. One is to learn from experienced individuals and organizations based outside the region. This is an efficient way for a region starting with nothing. By learning from outsiders, a large amount of essential knowledge can be brought in within a short period. Alternatively, innovative ideas can be created locally by building up internal innovation capability organically, which we will discuss more later in this chapter.

Table 6-7 presents the numbers of backward patent citations from the original Aberdeen and Stavanger-related patents.

	Aberdeen			Stavanger		
	Number	Ratio	Citation per Patent	Number	Ratio	Citation per Patent
Original Patents With Backward Citations	819			324		
All Backward Citations	15553		18.99	4678		14.44
Backward Citations to U.S. patents	13038	83.83%	15.92	3786	80.93%	11.69
Original Patents With Foreign Backward Citations	532			223		
Foreign Backward Citations	2515	16.17%	4.73	892	19.07%	4.00

Table 6-7 Numbers of Backward Patent Citations

There are a total of 15,553 backward patent citations associated with the 819 original Aberdeen-related patents. 13,038 of these are backward citations to U.S. patents. The other 2,515 are backward citations to 'foreign' (i.e., non-U.S.) patents. The latter are cited by 532 of the 819 original Aberdeen-related patents. In Stavanger, there is a total of 4,678 backward patent citations, of which 3,786 are to U.S. patents, and 892 are to foreign (non-U.S.) patents. 223 of the 324 original Stavanger patents include foreign citations.

The most striking difference between Aberdeen and Stavanger in table 6-7 is the number of backward citations to U.S. patents per patent. In Aberdeen, every original patent makes backward citations to about 16 U.S. patents on average, compared to less than 12 in Stavanger.

Figure 6-2 shows the trend in U.S. patent backward citations per patent by application year of the original patent. Before 1992, the number of backward citations to U.S. patents per patent in Aberdeen and Stavanger was about the same and had remained unchanged for years. These numbers both increased after 1992. However, after 1998 the number of backward citations to U.S. patents per patent went flat if not decreased in Stavanger, while in Aberdeen it kept rising.

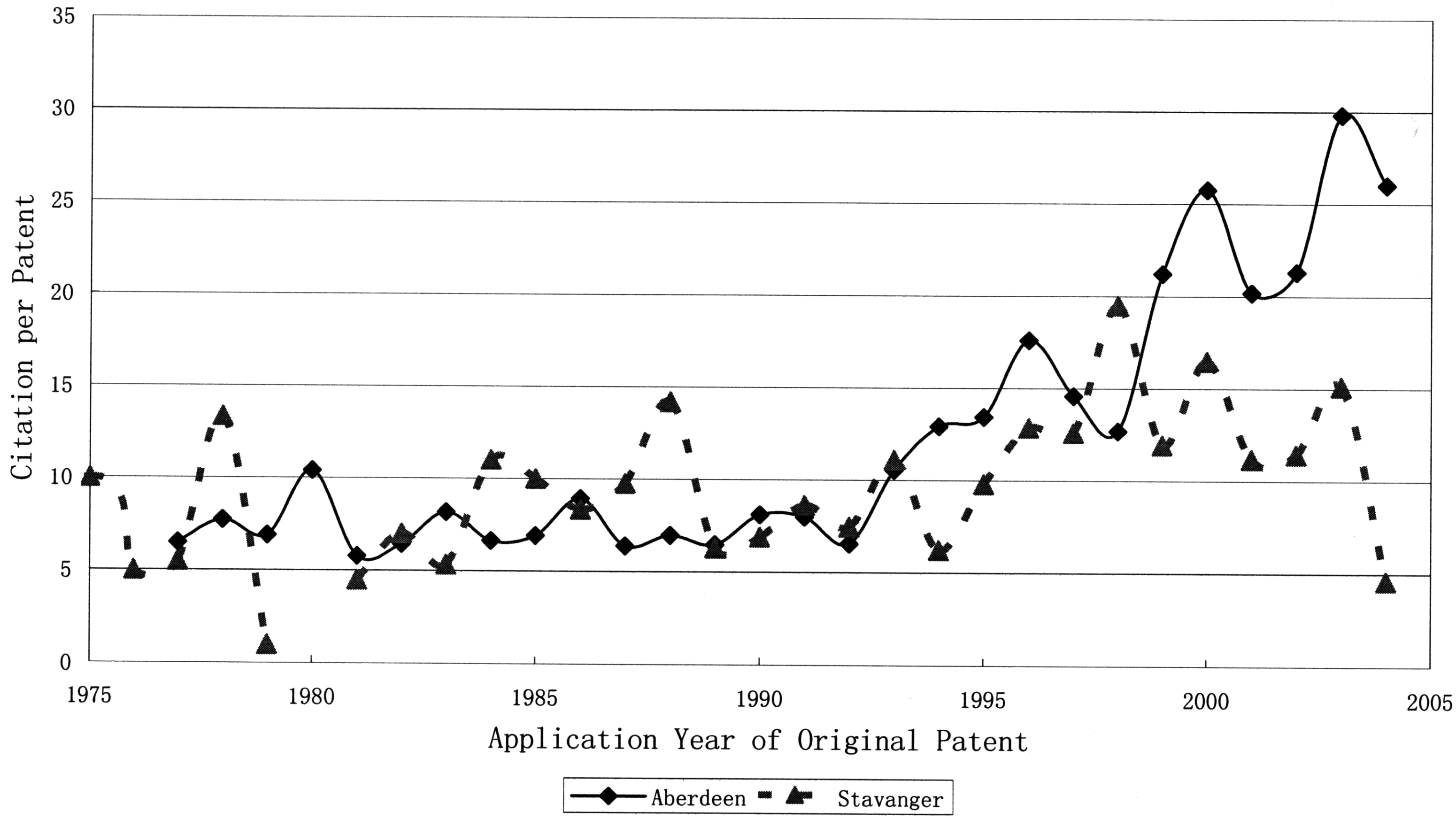

Figure 6-2 Distribution of U.S. Patent Backward Citation per Patent by the Application Year of the Original Patent

The reason for the difference in the number of backward citations to U.S. patents per patent between Stavanger and Aberdeen is revealed in table 6-8, which shows the distribution of backward citations to patents by country of assignee of the original patent. Table 6-8 shows that in both Aberdeen and Stavanger the patents granted to U.S. assignees have a much higher number of backward citations to U.S. patents than do other patents. For example, in Aberdeen a patent issuing to a U.S. assignee cites slightly less than 23 U.S. patents on average. This can be compared with an average of 8.5 citations for U.K. assignees, and 11.2 citations for assignees from all other countries. As we found out earlier, U.S. firms had much stronger exposure in Aberdeen than in Stavanger. About 57% of Aberdeen-related patents were granted to U.S. firms or other U.S. organizations, but this was true of less than 32% of the Stavanger-related patents. The curves in figure 6-2 also have similar patterns to the ones in figure 6-1. The number of patents issued to U.S. assignees flattened out after 1997 in Stavanger whereas it kept increasing in Aberdeen. Therefore, the difference in the U.S. firms' local presence in Stavanger and Aberdeen is the major reason for the difference in the frequency of backward citations to U.S. patents between these two cities.

Aberdeen							
Original Patent	U.S. Patent Backward Citation			Foreign Backward Citation			
Assignee Country	No. of Citation	Ratio of Citation	Citation per Patent	No. of Patent	No. of Citation	Ratio of Citation	Citation per Patent
U.S.	9485.5	86.02%	22.83	251	1541	13.98%	6.14
U.K.	2483	78.60%	8.52	207.5	676	21.40%	3.26
Others	213.5	72.25%	11.24	17.50	82	27.75%	4.69
Total	12182	84.12%	16.78	476	2299	15.88%	4.83
Stavanger							
Original Patent	U.S. Patent Backward Citation			Foreign Backward Citation			
Assignee Country	No. of Citation	Ratio of Citation	Citation per Patent	No. of Patent	No. of Citation	Ratio of Citation	Citation per Patent
U.S.	1715	88.75%	18.64	46	217.5	11.25%	4.73
Norway	1702.5	76.16%	9.20	142.5	533	23.84%	3.74
Others	108.5	75.87%	8.04	10.00	34.5	24.13%	3.45
Total	3526	81.79%	12.14	198.5	785	18.21%	3.95

Table 6-8 Distribution of Patent Backward Citation by the Assignee Country of Original Patent

The evidence here suggests that U.S. companies, the most common type of multinational firm operating in the North Sea region, are important contributors to the process of knowledge inflow. As the key players in the oil and gas industry, U.S. firms brought in advanced technology after they entered the local market, and also educated local residents and firms. Moreover, because of their abundant industrial network, they have special advantages in accessing knowledge from all over the world, especially the U.S. Being as important agents of knowledge transfer, U.S. firms help increase the efficiency of knowledge influx of the whole local system greatly.

Table 6-8 does not provide any evidence that U.S. firms' active learning capabilities have yet affected the local players, as in both Aberdeen and Stavanger, the patents granted to native assignees have similar numbers of backward citations to U.S. patents per patent, 8.5 in Aberdeen and 9.2 in Stavanger. However, the presence of U.S. companies does appear to have some influence on local inventors. Table 6-9 shows the distribution of backward citations to patents by location of inventor of the original patent. From the table we see that the number of backward citations to U.S. patents per patent for local Aberdeen inventors is about 14, compared with 10 for local Stavanger inventors. We suspect that this difference is caused by those local inventors who work for local U.S. companies currently. As the production of oil and gas continues to decline, some of these multinational firms may choose to leave, but many of their local employees will not do so. Those local people who choose to stay will keep not only their knowledge but also the learning skills which they developed from their previous working experience. This is one mechanism by which local learning capabilities can be improved by introducing advanced multinational firms into the local economy.

Aberdeen							
Original Patent	U.S. Patent Backward Citation			Foreign Backward Citation			
Inventor Region	No. of Citation	Ratio of Patent	Citation per Patent	No. of Patent	No. of Citation	Ratio of Patent	Citation per Patent
Local	8668.01	82.82%	14.05	402.54	1797.75	17.18%	4.47
National	680.74	81.40%	10.47	43.38	155.54	18.60%	3.59
Continental	216.76	77.57%	12.23	11.41	62.67	22.43%	5.49
International	3472.49	87.43%	29.10	74.68	499.04	12.57%	6.68
Total	13038	83.83%	15.92	532	2515	16.17%	4.73
Stavanger							
Original Patent	U.S. Patent Backward Citation			Foreign Backward Citation			
Inventor Region	No. of Citation	Ratio of Patent	Citation per Patent	No. of Patent	No. of Citation	Ratio of Patent	Citation per Patent
Local	2348.35	78.43%	10.33	159.67	645.78	21.57%	4.04
National	387.12	77.04%	8.95	33.58	115.40	22.96%	3.44
Continental	237.95	82.11%	13.25	12.40	51.85	17.89%	4.18
International	812.58	91.14%	22.97	17.35	78.98	8.86%	4.55
Total	3786	80.93%	11.69	223	892	19.07%	4.00

Table 6-9 Distribution of Patent Backward Citation by the Inventor Region of Original Patent

6.2.1 From Where to Locate the Resources

What we can see from tables 6-5 and 6-6 is that domestic firms operating in Stavanger and Aberdeen have very similar geographical inclinations when it comes to citing U.S. patents. They both have a strong preference for learning from international knowledge, especially that from the U.S., but pay less attention to local or national sources of technology. For example, table 6-5 shows that in Stavanger more than 95% of original patents granted to Norwegian assignees have backward citations to patents held by U.S. assignees, which is about the same percentage as for original Stavanger-related patents issued to U.S. assignees, though the citing intensity is lower for the native assignees. The percentage of original patents granted to Norwegian assignees citing prior Norwegian patents is much lower (22%). The situation is similar in Aberdeen.

However, in both regions, U.S. firms operating locally appear to give roughly similar weights to national and international knowledge. As shown in table 6-6, in Aberdeen 67% of the original patents granted to U.S. assignees have backward citations to the local area, and the ratio is about the same for citations to international patents (most of which are from U.S.)

It is not surprising that local inventors put strong emphasis on knowledge from outside of the region. It is always wise and effective to seek external help when local resources are limited. However, what we also see here is that U.S. firms, which might be expected to have more ready access to external knowledge than local firms, pay significant attention to the local knowledge, unlike the local companies. Any firms or individuals who do business locally can create local knowledge. But no matter who generates this knowledge, U.S. firms' attention implies that some useful information does exist within these regions.

Our next question is why local firms do not refer to this useful local information as much. It could be that local inventors pay such strong attention to the external knowledge that they ignore the local information. Or that they do not have easy access to local knowledge resources because of barriers created by foreign firms. We cannot address this question without additional information. However, our data does show that local Aberdeen firms did slightly better than their Stavanger counterparts in learning from local and national knowledge resources. For instance, table 6-6 shows that in Stavanger 14% of the original patents granted to Norwegian assignees have local backward citations, compared with 22% for their counterparts in Aberdeen.

Table 6-10 shows the distributions of the likelihood of backward citation by the assignee country of the citation and by the assignee type of the original patent. The evidence suggests that variations in the type of assignee do not have a strong effect. It would appear that the selection of citations from different locations is primary decided by the nationality of the assignees. Some evidences can be found in table 6-10 that, the original patents granted to the four U.S. major contractors have almost the same distribution of likelihood of the backward citation as the patents granted to U.S. assignees shown in table 6-5.

Aberdeen							
Citation Assignee Country	U.S.		U.K.		France		Total
Original Patent Assignee Type	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	No. of Patent
Major Contractors	98.52%	15.71	36.45%	3.36	23.15%	1.44	203
All Other Contractors	96.61%	7.44	30.54%	1.70	15.61%	1.40	442
Operators	100.00%	3.80	21.15%	1.18	25.00%	1.46	52
Total	97.15%	8.91	30.07%	2.14	18.69%	1.39	808
Stavanger							
Citation Assignee Country	U.S.		Norway		France		Total
Original Patent Assignee Type	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	No. of Patent
Major Contractors	98.33%	14.54	15.00%	1.11	28.33%	2.24	60
All Other Contractors	97.09%	6.30	16.50%	1.11	21.36%	1.73	103
Operators	96.46%	4.09	21.24%	1.39	16.81%	1.58	113
Total	96.14%	6.96	18.65%	1.32	20.58%	1.81	311

Table 6-10 Distribution of the Likelihood of Backward Citation by the Assignee Country of the Citation and the Assignee Type of the Original Patent

6.2.2 Who is the Best Teacher

Table 6-11 exhibits the distribution of the likelihood of backward Citation by type of assignee for both the cited and the original patent. In both Stavanger and Aberdeen an original patent is always more likely to cite a patent granted to the same type of assignee. For example, in Aberdeen 86% of the original patents granted to major contractors have at least one backward citation to a major contractor assignee, which is much greater than the ratio of citing to any other types of assignee. Similarly, in Stavanger close to 60% of the original patents granted to operators cite at least one U.S. patent granted to an operator, more than any other type of assignee. This is understandable as the technologies from the same group of firms are usually more relevant than those from other types of firm.

Aberdeen							
Citation Assignee Type	Major Contractors		All Other Contractors		Operators		Total
Original Patent Assignee Type	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	No. of Patent
Major Contractors	86.27%	6.46	70.10%	4.56	58.33%	3.47	204
All Other Contractors	41.08%	3.13	65.69%	3.44	37.70%	2.16	443
Operators	25.00%	1.38	50.00%	1.29	63.46%	1.86	52
Total	51.11%	4.38	62.07%	3.51	43.60%	2.54	812
Stavanger							
Citation Assignee Type	Major Contractors		All Other Contractors		Operators		Total
Original Patent Assignee Type	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	No. of Patent
Major Contractors	80.33%	8.05	63.93%	2.46	54.10%	2.29	61
All Other Contractors	33.65%	3.57	45.19%	2.30	40.38%	2.61	104
Operators	14.04%	1.66	38.60%	1.05	59.65%	2.45	114
Total	34.92%	5.12	45.08%	1.93	48.89%	2.44	315

Table 6-11 Distribution of the Likelihood of Backward Citation by the Assignee Type of the Citation and Assignee Type of the Original Patent

Table 6-12 gives the distribution of the likelihood of backward citation by assignee type for the cited patent and assignee country for the original patent. What is of interest here is that in Aberdeen patents with U.K. assignees are more likely to cite patents assigned to major contractors and all other contractors, and less likely to cite patents assigned to operators, than patents with Norwegian assignees in Stavanger. For instance, about 49% of the original Stavanger related patents granted to Norwegian assignees have backward citations to operators, but this is true of less than 35% of the Aberdeen related patents granted to U.K. assignees.

As we pointed out earlier, people are more likely to learn from the same type of firm because of the technology relevancy. Therefore, the results from table 6-12 may suggest that firms in Aberdeen have more focus on how to provide innovative equipment and services, and the companies in Stavanger are more focused on operation.

This is actually what is happening in the two cities. In Aberdeen, the total number of companies in the oil supply industry, excluding major contractors is about 800-900. However, there were only 457 such companies in the Stavanger-region in 2003 (Hatakenaka et al 2006).

The operators have differing presences in the two localities also. Stavanger has become the Norwegian headquarters of most operators who played significant roles in industrial innovation as demanding customers, project founders, and providers of information and expertise. In Aberdeen, operators have much less presences, and most of them maintain their headquarters in London.

Aberdeen							
Citation Assignee Type	Major Contractors		All Other Contractors		Operators		Total
Original Patent Assignee Country	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	No. of Patent
U.S.	62.83%	5.59	75.06%	4.38	50.60%	3.10	417
U.K.	37.80%	2.46	50.86%	2.12	34.71%	1.60	291
Total	51.79%	4.64	64.46%	3.64	44.49%	2.61	726
Stavanger							
Citation Assignee Type	Major Contractors		All Other Contractors		Operators		Total
Original Patent Assignee Country	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	No. of Patent
U.S.	61.11%	7.59	65.56%	2.48	54.44%	2.67	90
Norway	24.47%	2.85	37.77%	1.48	49.47%	2.22	188
Total	37.10%	5.30	45.94%	1.98	50.18%	2.50	283

Table 6-12 Distribution of the Likelihood of Backward Citation by the Assignee Type of the Citation and Assignee Country of the Original Patent

In our research, we are interested in exploring differences in the technical emphasis of inventive activity between the two regions, but we did not have sufficient information to identify the technical application field of each patent. We can only identify the broad functions of the firm, as we have done above. We also try to use the U.S. patent classification scheme, which identifies the technical field rather than the application field of patents, to understand more about the technological roots of local innovations.

Table 6-13 gives the statistical average results for ORIGINALITY of the original patents. Recall that ORIGINALITY describes the level of technological concentration of the backward citations of the original patents. A larger ORIGINALITY score (close to 1) implies broader technological roots of the underlying patents.

Table 6-13 shows that there is no significant difference in ORIGINALITY between Aberdeen and Stavanger. However, in both Aberdeen and Stavanger the ORIGINALITY considering only backward self-citations is smaller than the ORIGINALITY considering all backward citations. For example, in Stavanger the ORIGINALITY considering all backward citations is 0.57 ± 0.20, and the ORIGINALITY considering backward self-citations only is

0.33±0.28. We believe this matches the reality very well since self-citations are references to patents which are granted to the same assignee as the original patent. And usually one firm is more likely to focus on a few relatively narrow technological fields.

	Aberdeen		Stavanger	
	Originality	Error	Originality	Error
All Citation	0.51	0.23	0.57	0.20
Self-Citation	0.34	0.27	0.33	0.28

Table 6-13 ORIGINALITY of U.S. Patent Backward Citation

6.2.3 Ask Help from Academia

In many economies, universities and public institutions are considered responsible for basic science and technology research, while industrial firms focus on the applied research and development which is essential for transforming knowledge into commercial products and processes. Collaboration between university and industry has been more and more critical to the success of innovation and has generally strengthened over the past few decades. Universities are interested in cooperating with industry for the purpose of obtaining research funds and being able to apply empirical research on their own study. On the other hand, industry participants try to obtain access to advanced research for their new product development by seeking help from universities (Hall 2004).

Our qualitative study showed that local universities and research institutions in Stavanger and Aberdeen had very different responses to the emergence of the local oil and gas industry. In Stavanger the university in Stavanger (UiS) and Rogaland Research (RF) were established at the time of the founding of the oil industry in the region. Their subsequent development has been shaped by the needs of industry. In contrast, Aberdeen's two universities – Robert Gordon and the University of Aberdeen – were both well established before the initial discoveries of oil in the North Sea. And neither of them made many changes in internal research capabilities in response to the technological needs of the industry later on (Hatakenaka et al 2006).

Since the two institutions in Stavanger have developed closer ties to local industry than the universities in Aberdeen, we were expecting to see a more positive response to the knowledge crated by academic field from industry in Stavanger. We explored this question by looking at citations of the scientific and technical literature listed under the 'other reference' category in the patent. However, our results show that there is no difference in citing academic journals between Stavanger and Aberdeen.

Table 6-14 shows the distribution of other references by type. The table shows that the propensities to cite academic journals, conference papers, document from universities and magazines are about the same in Stavanger and Aberdeen. In both cities, around 10% of the original patents have references to academic journals. This conclusion remains valid when we break down the numbers by country of assignee, as shown in table 6-15, which gives the distribution of other references by type of citation and assignee country of the original patent.

It seems that the scientific references in the patents do not capture the industrial interest in cooperating with local universities and research institutions completely. There are many channels through which knowledge can be transferred from university to industry, such as consulting, informal meetings, recruiting, licensing, patents, joint ventures, research contracts, personal exchange, and others. Citing academic publications is just one of them. However, our results do imply that when companies choose to obtain knowledge from academic publications, the performance of local universities does not have a strong effect on firms' decisions. In other words, firms are always looking for the most advanced and relevant knowledge from academia, but care less about its geographical location.

	Aberdeen					Stavanger				
	Patents with Other Reference		Other Reference			Patents with Other Reference		Other Reference		
Type of Citation	Number	Ratio	Number	Ratio	Citation per Patent	Number	Ratio	Number	Ratio	Citation per Patent
Academic Journal	87	10.62%	284	23.89%	3.26	34	10.49%	108	38.30%	3.18
Conference and Symposium	22	2.69%	33	2.78%	1.5	7	2.16%	12	4.26%	1.71
University or Research Institution	6	0.73%	7	0.59%	1.17	4	1.23%	4	1.42%	1
Magazine	39	4.76%	65	5.47%	1.67	10	3.09%	11	3.90%	1.1
Book	28	3.42%	48	4.04%	1.71	8	2.47%	12	4.26%	1.5
Website	7	0.85%	10	0.84%	1.43	0	0.00%	0	0.00%	
Company Document	85	10.38%	267	22.46%	3.14	24	7.41%	73	25.89%	3.04
Patent Related	120	14.65%	382	32.13%	3.18	33	10.19%	53	18.79%	1.61
Others	42	5.13%	93	7.82%	2.21	7	2.16%	9	3.19%	1.29
Total	819		1189			324		282		

Table 6-14 Distribution of Other Reference by the Type of Citation

Aberdeen								
	Academic Journal				Conference and Symposium			
Assignee Country	No. of Patent	Ratio	No. of Reference	Reference per Patent	No. of Patent	Ratio	No. of Reference	Reference per Patent
U.S.	56	13.48%	240	4.29	18	4.33%	28	1.56
U.K.	20.5	7.03%	30	1.46	2	0.69%	3	1.5
Total	84	11.57%	281	3.35	21	2.89%	32	1.52
	Magazine				Total			
Assignee Country	No. of Patent	Ratio	No. of Reference	Reference per Patent	No. of Patent		No. of Reference	
U.S.	27	6.50%	49	1.81	415.5		972	
U.K.	3	1.03%	3	1	291.5		124.5	
Total	37	5.10%	62	1.68	726		1138	
Stavanger								
	Academic Journal				Conference and Symposium			
Assignee Country	No. of Patent	Ratio	No. of Reference	Reference per Patent	No. of Patent	Ratio	No. of Reference	Reference per Patent
U.S.	19	20.65%	72	3.79	5	5.43%	7	1.4
Norway	14	7.57%	33.5	2.39	2	1.08%	5	2.5
Total	34	11.70%	108	3.18	7	2.41%	12	1.71
	Magazine				Total			
Assignee Country	No. of Patent	Ratio	No. of Reference	Reference per Patent	No. of Patent		No. of Reference	
U.S.	7	7.61%	8	1.14	92		189	
Norway	2	1.08%	2	1	185		86.5	
Total	10	3.44%	11	1.1	290.5		281	

Table 6-15 Distribution of Other Reference by the Type of Citation and the Assignee Country of the Original Patent

Table 6-15 also shows that U.S. assignees are more likely to cite references from academic journals than native assignees in both Stavanger and Aberdeen. This is more clearly shown in table 6-16 and table 6-17.

Table 6-16 gives the distribution of other references by type of citation and the assignee type of the original patent. Table 6-17 presents the distribution of SPE references by assignee type for the original patents. The Society of Petroleum Engineers (SPE) is a public organization which engages in collecting, disseminating, and exchanging technical knowledge concerning the exploration, development and production of oil and gas resources. The SPE journal is widely read in the industry. Both tables show that in the two cities the four major contractors, which are all U.S. firms, are more likely to cite academic journal articles and SPE papers than other assignees. For example, in Aberdeen about 20% of the original patents granted to major contractors have references to academic journal, much greater than the Aberdeen average of 10.6%.

This is reasonable because for companies are more likely to obtain knowledge from academia when they are themselves doing scientific research. Such research is an indicator of greater innovation capability and investment ability, which in turn are more likely to be found in multinational firms.

Aberdeen								
	Academic Journal				Conference and Symposium			
Assignee Type	No. of Patent	Ratio	No. of Reference	Reference per Patent	No. of Patent	Ratio	No. of Reference	Reference per Patent
Major Contractors	40	19.66%	142	3.55	5	2.46%	11	2.2
All Other Contractors	35	7.83%	127	3.63	13	2.91%	17	1.31
Operators	4	7.77%	6	1.5	2	3.88%	2	1
Total	87	10.62%	284	3.26	22	2.69%	33	1.5
	Magazine				Total			
Assignee Type	No. of Patent	Ratio	No. of Reference	Reference per Patent	No. of Patent		No. of Reference	
Major Contractors	14	6.88%	20	1.43	203.5		560	
All Other Contractors	22	4.92%	41	1.86	447		553	
Operators	1	1.94%	1	1	51.5		25	
Total	39	4.76%	65	1.67	819		1189	
Stavanger								
	Academic Journal				Conference and Symposium			
Assignee Type	No. of Patent	Ratio	No. of Reference	Reference per Patent	No. of Patent	Ratio	No. of Reference	Reference per Patent
Major Contractors	13	20.97%	26	2	2	3.23%	2	1
All Other Contractors	7	6.78%	38.5	5.5	2	1.94%	5	2.5
Operators	12	10.50%	40	3.33	3	2.62%	5	1.67
Total	34	10.49%	108	3.18	7	2.16%	12	1.71
	Magazine				Total			
Assignee Type	No. of Patent	Ratio	No. of Reference	Reference per Patent	No. of Patent		No. of Reference	
Major Contractors	6	9.68%	7	1.17	62		124	
All Other Contractors	3	2.91%	3	1	103.17		73.5	
Operators	1	0.87%	1	1	114.33		78	
Total	10	3.09%	11	1.1	324		282	

Table 6-16 Distribution of Other Reference by the Type of Citation and the Assignee Type of the Original Patent

Aberdeen							
	SPE				Total		
Assignee Type	No. of Patent	Ratio	No. of Reference	Reference per Patent	No. of Patent	No. of Reference	
Major Contractors	28	13.76%	62	2.21	203.5	173	
All Other Contractors	14	3.13%	51	3.64	447	185	
Operators	3	5.83%	3	1	51.5	9	
Total	45	5.49%	116	2.58	819	382	
Stavanger							
	SPE				Total		
Assignee Type	No. of Patent	Ratio	No. of Reference	Reference per Patent	No. of Patent	No. of Reference	
Major Contractors	5	8.06%	7	1.4	62	35	
All Other Contractors	3	2.91%	18	6	103.17	46.5	
Operators	4	3.50%	6	1.5	114.33	46	
Total	13	4.01%	32	2.46	324	131	

Table 6-17 Distribution of SPE Reference by the Assignee Type of the Original Patent

6.3 Accumulate Internal Innovation Capability

In addition to acquiring them from advanced players outside the region, innovative ideas can be created locally by building up internal innovation capabilities organically. As regional economic centers for centuries, both Stavanger and Aberdeen may be more likely than the other city regions to have the desire to lead the development of the industry instead of acting as a follower. Such a strategy cannot succeed simply by learning from others. Incubating and developing local innovation capacity will make it easier to achieve the goal.

The national governments in Norway and the U.K. had very different approaches in domestic innovation capacity building. The policies of the Norwegian central government have consistently focused on developing internal capabilities for innovation since the beginning of the oil discoveries, in order to protect the relatively small Norwegian economy from being overwhelmed by foreign multinational firms. The tax system in Norway has promoted R&D spending by classifying R&D-related costs as immediately deductible. Norwegian national government also took a direct funding role for industry-relevant research. Public funding accounted for a significant fraction of total industrial R&D for many years. Many research programs are supported or co-supported by government and oil and gas companies. These programs include Ruth, Force, Offshore 2010, Demo 2000, Petromaks, and

OG_{21}.

The policy of the U.K. government was different. They decided to let industry undertake its own R&D. Government support for R&D focused mainly on licensing and regulatory-related issues.

The regional authorities in Stavanger and Aberdeen have also played different roles in promoting local innovation capabilities. The local Stavanger government made major and continuing contributions to the development of infrastructure, including human capital, by establishing both the University of Stavanger and Rogaland Research and the adjacent Research Park. Until the mid 1980s the regional authorities in Aberdeen focused mainly on enticing foreign companies to come to Aberdeen. It was only in the mid 1980s that the emphasis changed to innovation (Hatakenaka et al 2006).

We expect that these differences in government policies will result in differences between the local innovation capabilities of Stavanger and Aberdeen. From table 4-3 we can see that about 64% of Stavanger-related patents are granted to Norwegian assignees, but only about 40% of Aberdeen-related patents are owned by U.K. firms.

Figure 6-3 provides more details about the distribution of U.S. patents with at least one local inventor by application year and by the country of assignee. It shows that the numbers of U.S. patents granted to domestic assignees have been growing steadily over the years. The rate of growth of patents issued to native firms has apparently exceeded the rate of growth of total U.S. patents, which indicates that local innovation capabilities have been accumulating over time in both Stavanger and Aberdeen. However, the growth rates still lag well behind the growth of patents granted to U.S. assignees. We can also observe that the number of Stavanger-related patents granted to Norwegian assignees increased slightly faster than the number of Aberdeen-related patents granted to U.K. assignees. This provides further support to the idea that Stavanger does better job in promoting local innovation capability than Aberdeen.

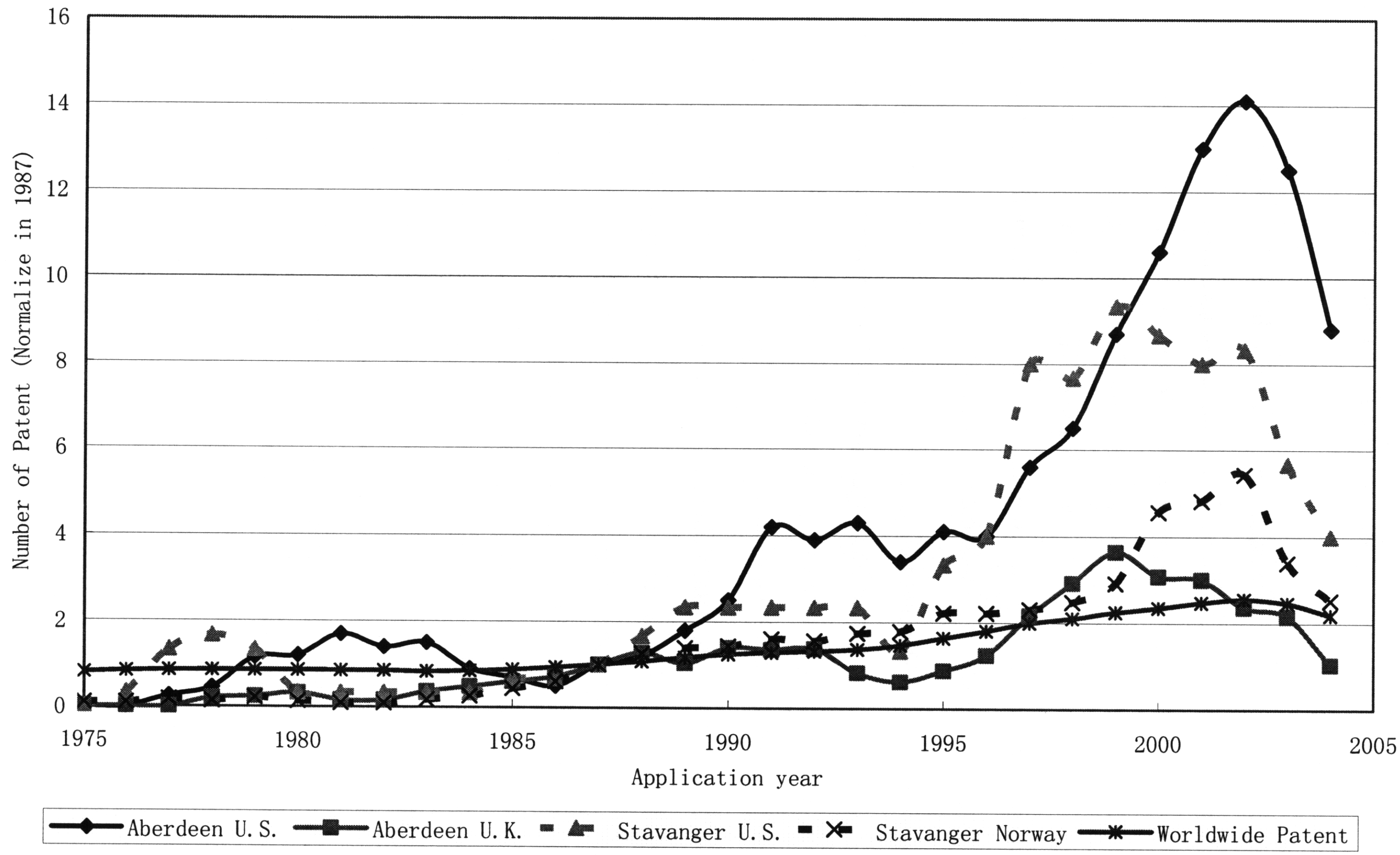

Figure 6-3 Distribution of Patents with at Least One Local Inventor by Application Year and Country of Assignee (Normalized in 1987)

In table 6-1 we find that the local operators in Stavanger play a significant role in obtaining U.S. patents. Almost half of the Stavanger-related patents granted to Norwegian assignees are owned by operators, but this is true of only 11% in Aberdeen. This is primarily because of the activity of the two big oil companies, Statoil and Norsk Hydro. In order to secure Norwegian participation in the development of the industry, Norwegian government established a national oil firm, Statoil in 1972. Later on the national government also acquired majority ownership of Norsk Hydro, which was already one of Norway's larges industrial companies. These companies have developed into two of Norway's largest firms in terms of both turnover and number of employees. Both of these two firms were privatized. However, Norwegian state still holds majority ownership. With the support of both national and local governments, Statoil and Norsk Hydro have played critical roles in building local innovation capabilities as demanding customers, project funders and providers of information and expertise. In contrast, the operators in Aberdeen do not appear to be consolidating their technological presence there. For example, BP's R&D groups used to be located in Aberdeen and in other cities. However, BP has dramatically reduced its R&D workforce in Aberdeen and only 25 out of its total of 800 R&D personnel are located there today (Hatakenaka et al 2006).

Another interesting finding concerning local innovation capabilities can be seen in table 6-2. We notice that in both Stavanger and Aberdeen, the domestic firms have relied heavily on local inventors and very little on international inventors. For instance, in Aberdeen about 87% of the original patents granted to U.K. assignees were created by local inventors, but less than 1% were generated by international inventors. We assume that this is because most of the domestic firms do not yet have any international research ability. Many of these firms are still at a fairly early stage of development, with small size and limited resources, and can only focus on local or regional business.

6.4 Distribute Knowledge Outwards

After more than three decades of development, recent data shows that oil and gas production in the U.K. peaked around 2000. With greater proven and probable reserves, Norwegian production is expected to peak several years later. One possible path that can lead to a sustainable economy even after the depletion of oil and gas resources within the region is for the region's firms to export products and services to locations where reserves of fossil fuel remain extensive. The process of exporting products and services can occur if, for example, the technology is less developed in the importing location and/or the cost of production is higher. Everyone, including local firms, regional institutions, multinational companies, and whoever is involved in the local innovation system, can contribute to the knowledge exporting process. In our study, the data on forward citations are used to help us understand the knowledge exporting process that occurred in the North Sea province. However, we need to notice that there are a few limitations of using forward citations. First, there are much less observations of forward citations than backward citations, which makes forward citations statistically less meaningful than backward citations. Second, forward citations are born to have truncation problem. Patents granted in recent years always have more severe truncation error than patents issued long time before. This certainly will bring some bias to out study.

Table 10-18 presents data on the number of citations in U.S. patents to the original Aberdeen and Stavanger related patents. Through December 2005, 606 out of 819 Aberdeen-related patents had been cited by at least one U.S. patent. The total number of forward U.S. patent citations in Aberdeen is 5585. In Stavanger there are a total of 1482 forward U.S. patent citations to 230 out of the 324 original Stavanger-related patents.

The figures show that the original Aberdeen patents have a much higher number of forward citations per patent (9.22) than the original Stavanger patents (6.44).

	Aberdeen		Stavanger	
Original Patent	Number	Citation per Patent	Number	Citation per Patent
Original Patent With Forward Citation	606		230	
U.S. Patent Forward Citation	5585	9.22	1482	6.44

Table 6-18 Numbers of Forward Patent Citations

Tables 6-19 and 6-20 exhibit the distribution of forward citations by type assignee and country of assignee for the original patent. For every subtype of assignee, there is a larger number of forward citations per patent in Aberdeen than in Stavanger. The figures suggest that the Aberdeen local innovation system may have greater international influence than the Stavanger local innovation system.

We suspect that there could be at least two reasons for this. First, Stavanger may have a less innovative system than Aberdeen. Perhaps, despite the efforts of both the Norwegian government and local industry in Stavanger to establish regional innovation capabilities, the outcome is not as good as expected. The absolute innovation capability of Stavanger is still behind the level of Aberdeen.

Second, it is possible that the innovations created in Stavanger have not received as much attention from the industry as the ideas generated in Aberdeen. As pointed out earlier, a significant part of the innovation activities in Stavanger are contributed by a small number of national oil companies, such as Statoil and Norsk Hydro, which are considered to be young firms and to have less international influence than other multinational companies. Therefore, it is possible that less attention is given to the knowledge created in Stavanger because there is less international involvement.

Original Patent	Aberdeen			Stavanger		
Assignee Type	No. of Patent	No. of Citation	Citation per Patent	No. of Patent	No. of Citation	Citation per Patent
Major Contractors	135.5	1666.5	12.30	49	457	9.33
All Other Contractors and Suppliers	329	2814	8.55	68.5	379.5	5.54
Operators	48.5	443.5	9.14	80.5	474.5	5.89
Total	606	5585	9.22	230	1482	6.44

Table 6-19 Distribution of Forward Citation by the Assignee Type of Original Patent

Aberdeen				Stavanger			
Assignee Country (Original)	No. of Patent	No. of Citation	Citation per Patent	Assignee Country (Original)	No. of Patent	No. of Citation	Citation per Patent
U.S.	290.5	3004.5	10.34	U.S.	76	682.5	8.98
U.K.	224.5	1899	8.46	Norway	120	619.5	5.16
Others	15	123.5	8.23	Others	11	55	5.00
Total	530	5027	9.48	Total	207	1357	6.56

Table 6-20 Distribution of Forward Citation by the Assignee Country of Original Patent

Tables 6-19 and 6-20 also show that in both Aberdeen and Stavanger, a patent issued to U.S. assignees, especially to major contractors, has more forward citations than a patent granted to other types of assignees. For example, in Stavanger a patent granted to U.S. assignees of all types has close to 9 forward citations on average, compared with 6.56 forward citations per patent for all Stavanger-related patents. In Aberdeen patents issued to major contractors have 12.3 forward citations on average, which is greater than the figure of 9.2 for all Aberdeen related patents.

This result suggests that multinational companies, especially the leading firms in the industry, can help not only establish local innovation capabilities, but also promote locally-created knowledge internationally. This is because, after years of development, such firms have already established strong reputations and a position of trust. They have such a strong influence on the industry that it is always easy for others to adopt and follow what they develop.

6.4.1 Who is Mostly Interested

Table 6-21 exhibits the distribution of the likelihood of forward citation by assignee type for both the citing and the original patent. It shows that in both Aberdeen and Stavanger an original patent is more likely to be cited by forward citations which are granted to the same type of assignee as the original patent. There is one exception: in Aberdeen, the original patents granted to operators are more likely to be cited by other contractors than by operator. About 60% of the Aberdeen original patents granted to operators have at least one forward citation from other contractors, but less than 50% from operator. However, the general result again indicates that people are more interested in learning from relevant technological fields. And it is generally easier to obtain closely related information from the same type of firms because of similar interests.

Aberdeen							
Citation Assignee Type	Major Contractors		All Other Contractors		Operators		Total
Original Patent Assignee Type	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	No. of Patent
Major Contractors	85.29%	8.15	41.91%	2.18	23.53%	9.42	136
All Other Contractors	40.61%	6.31	64.55%	3.83	15.15%	5.24	330
Operators	40.82%	4.10	59.18%	3.79	48.98%	3.26	49
Total	53.30%	6.61	56.44%	3.35	20.46%	5.72	606
Stavanger							
Citation Assignee Type	Major Contractors		All Other Contractors		Operators		Total
Original Patent Assignee Type	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	No. of Patent
Major Contractors	75.51%	7.12	34.69%	1.97	32.65%	2.47	49
All Other Contractors	33.80%	4.58	40.85%	2.01	26.76%	1.76	71
Operators	24.39%	1.85	34.15%	1.79	41.46%	3.64	82
Total	38.70%	4.91	34.35%	1.89	32.61%	2.76	230

Table 6-21 Distribution of the Likelihood of Forward Citation by the Assignee Type of the Citation and the Assignee Type of the Original Patent

It is also interesting to look at the distribution of the likelihood of forward citation by geographical proximity and by the assignee country of the original patent in table 6-4 posted earlier.

First, we note once again that less than 8% of the Stavanger-related patents granted to U.S. assignees have forward citations from the Stavanger area, which is significantly smaller than any other percentages in table 6-4. As we mentioned in the previous section, in both Stavanger and Aberdeen local firms appear to pay relatively little attention to local knowledge resources. Here we further discover that in Stavanger local developers have particularly ignored the knowledge created by the locally-based U.S. companies. More studies are needed to find out why this might be the case.

Table 6-4 also shows that Stavanger-related patents are more likely to have forward citations from European countries than Aberdeen-related patents, regardless of the country of the original patents' assignee. In Stavanger, about 49% of the original patents have forward citations from European countries, but only 36% for the original Aberdeen-related patents.

This is consistent with the earlier finding that European firms are more interested in working with Stavanger companies than with Aberdeen firms. We suspect that this is because of the strong collaborative environment set up by the Norwegian central government and Stavanger local authorities, and because there is less competition from U.S. firms in Stavanger, as we have shown previously that U.S. company have less presence in Stavanger than in Aberdeen.

What we also find in table 6-4 is that in both places the original patents granted to U.S. assignees are less likely to have forward citations from countries outside of Europe than patents granted to native assignees. For instance, in Aberdeen close to 89% of the original patents granted to U.K. assignees have international forward citations, but only about 52% for patents granted to U.S. assignees.

However, this result conflicts with the numbers in table 6-3. Table 6-3 shows that in both places, the original patents granted to U.S. assignees are actually slightly more likely to have forward citations from U.S. firms than the original patents issued to native assignees. For example, in Stavanger close to 92% of the original patents issued to U.S. assignees, and about 89% of the original patents granted to Norwegian assignees, have at least one forward citation from patents assigned to U.S. firms.

We believe that what we found in table 6-4 is probably a phantom signal. As we pointed out earlier, after U.S. firms entered the local market, some of them built up their regional research facilities to meet their needs for local expansion, and started producing technology locally. The establishment of these regional research capabilities makes it easy for U.S. companies in the region to access advanced knowledge locally. It is not always necessary for them to obtain useful information from U.S. anymore. Therefore, from the table 6-3 we see that many original patents granted to U.S. assignees have forward citations from U.S. firms. However, table 6-4 implies that many of these citations granted to U.S. assignee are actually not geographically from U.S.

We will further discuss the geographical distribution of citing and cited patents in the section on knowledge spillovers below.

6.5 The Study of Knowledge Spillovers

6.5.1 Regression Model Review

In chapter 5, we provided a detailed introduction to the regression model of knowledge spillovers. Our final model is as below

$$\frac{C_{o,s}}{P_o P_s} = \frac{\Psi_{o,s}}{\theta_o \Psi_o \Psi_s} \delta_{importance} \delta_o \delta_G e^{-\beta_{basiceness} \beta_{state} \beta_G (T_o - T_s)} (1 - e^{-\gamma_{importance} \gamma_G (T_o - T_s) + \lambda_{transmission} (X_o - X_s)})$$

O represents the citing cohort or, as we called it, the absorber. S represents the cited cohort or the source of knowledge. $C_{O,S}$ is the number of citations linking the citing and cited cohorts. P_O is the number of U.S. patents in the citing cohort. P_S represents the number of U.S. patents in the cited cohort. We refer to the ratio $\frac{C_{O,S}}{P_O * P_S}$ as the citation frequency.

We use capital T and X to denote the time and location of the cited cohort, and small case t and x to denote the time and location of the citing cohort.

$\Psi_{O,S}$(x,X,t,T) is what we call the absorbers' propensity to cite U.S. patents as we assume that the number of patent citations with real knowledge spillover is proportional to the overall "used ideas" between the cited group and the citing group.

Ψ_S(X,T) represents the innovators' propensity to patent in the U.S. We know that not all the ideas created by innovators are presented in the form of patents. Only a small portion of them have been 'uploaded' to patents, which we treat as the information carrier.

Similarly, Ψ_O(X,T) represents the absorbers' propensity to patent in the U.S.

θ_o gives the 'add-on' effect caused by patent examiners. As we know, not all the citations in patents are added by their inventors. Some are listed by the patent examiners. Therefore, we assume that the number of patent citations connected with real knowledge spillover is proportional to the total number of patent citations with factor θ_o.

Then we have a parameter $\delta_{importance}(x,t)$ representing the importance of knowledge created by innovators. The more important the knowledge created by the innovators, the more likely it is that we will observe its successors, which means a greater value of $\delta_{importance}(x,t)$ in the citation function.

$\delta_O(X,T)$ indicates the level of the absorbers' creativity and absorptiveness. The stronger the combined absorptive and innovative ability of the absorbers, the more secondary generation knowledge will be available, the more backward citations there will be, and the larger the value of $\delta_O(X,T)$.

The term $\frac{\Psi_{o,s}}{\theta_o \Psi_o \Psi_s} \delta_{importance} \delta_o \delta_G$ is an elaboration of the parameter δ in Caballer and Jaffe's regression model (Caballer and Jaffe 1993). δ is a shift parameter that depends on the attributes of both the citing patent and cited patent. A higher δ means more citations at all lags. δ_G catches all the other possible effects which have not been modeled in.

In Jaffe's model, parameter β determines the rate of obsolescence of the knowledge. A higher value of β means a higher rate of knowledge 'decay'. A lower β means more citations at later lags. In our model we try to understand β in more detail.

$\beta_{basicness}(x,t)$ is the link between the rate of obsolescence β and the basic character of the original knowledge. We assume that inventions of a more basic character should be useful across a wider range of industries and over longer periods of time. This means that the rate of obsolescence should be slower for ideas with greater 'basicness'.

$\beta_{state}(x,t,X,T)$ is introduced to solve a practical problem in the citation function. We assume that knowledge obsolesces with the advance of the knowledge state rather than with time. The knowledge state is represented as the accumulated body of ideas N, which we are unable to measure. To solve this problem, we change the accumulated ideas N in the citation function to time T. To adjust for the difference, we introduce another factor $\beta_{state}(x,t,X,T)$.

$$N_o - N_s = \beta_{state}(x,t,X,T)(T_o - T_s)$$

For the same time difference (T_o-T_s), a greater β_{state} means a larger difference of knowledge states between citing and cited groups.

β_G is used to capture all the other possible effects which have not been considered, as with δ_G.

The last term $1-e^{-\gamma_{importance}\gamma_G(T_o-T_s)+\lambda_{transmission}(X_o-X_s)}$ describes the geographical diffusion process. $\gamma_{importance}(l,t)$ is used to connect the importance of original knowledge and the geographical diffusion speed. We assume that the knowledge with greater importance spreads faster than knowledge with lesser importance. Therefore the faster diffusion speed leads to a greater $\gamma_{importance}(l,t)$.

$\lambda_{transmission}(l,t,L,T)$ represents the efficiency of the diffusion channel. In our diffusion model we consider that the transmission media and carriers together can affect the diffusion speed. The more efficient the diffusion channel, the faster the diffusion speed, which gives a smaller $\lambda_{transmission}(l,t,L,T)$.

Again λ_G acts as a general parameter to represent the effects of all other phenomena.

6.5.2 General Results

In our Aberdeen and Stavanger-related U.S. patent dataset, we have a limited number of observations. However, there are thousands of estimators in our knowledge spillover regression model because of the variations by time and location within the citing and cited cohorts. It is not possible to obtain believable results for all these estimators with acceptable deviation for such a great degree of freedom.

Therefore, we reassembled the data into 16 groups according to the application year of the original patents, the application year of the citing and cited patents, and the geographical distance separating the cited and citing patents. We divided the original patents into two periods, one with application year before 1987, and the other with application year after 1987. The reason we choose year 1987 is because we can see in Figure 6-1 that after 1987 the number of granted U.S. patents increased steadily in both Aberdeen and Stavanger. We did the same separation of time periods for the citations. Then we further sub-divided the citations into 4 subgroups based on their geographical proximity to the original patents---local citations, national citations, continental citations, and international citations. After all this, we have 4 sets of data---Aberdeen backward, Aberdeen forward, Stavanger backward, and Stavanger forward. And for each set of data, there are 16 subgroups, determined by the application year of the original patent, the application year of the citation, and the geographical proximity of the citation to the original patent.

We ran the regression model for each data set. The results are based on two assumptions. First, we assume that within a defined period none of the estimators varies by the application year of either the original patent or the citation. Second, we assume that within a defined category of geographical proximity none of the estimators varies by location of the citation. Based on these two assumptions, our regression can be simplified as

$$\frac{C_{o,s}}{P_o P_s} = \delta\, e^{-\beta\,(T_o - T_s)}\left(1 - e^{-\gamma\,(T_o - T_s) + \lambda\,(X_o - X_s)}\right)$$

$$\delta = \frac{\Psi_{o,s}}{\theta_o \Psi_o \Psi_s}\,\delta_{importance}\,\delta_o\,\delta_G$$

$$\beta = \beta_{basiceness}\,\beta_{state}\,\beta_G$$

In this new model, all estimators, including $\Psi_{o,s}$, Ψ_o no longer vary by time and location of citing and cited cohorts.

Table 6-22 presents the results of the regression on overall backward and forward citations from the original Aberdeen and Stavanger related patents. The regression program shows that the value of γ is too big to reach a convergent result. And the estimation of λ is small but with large standard deviation which gives no meaningful result. This implies that the geographical diffusion speed is so fast that we will not be able to measure the speed precisely with the observed scales of time and location. Therefore we will only consider the estimators δ and β from now on.

We look at the results of backward citations first. Table 6-22 shows that for backward citations, the δ in Stavanger is about 8.7±2E-04, which is slightly greater than the δ in Aberdeen of 6.1±0.7E-04. Recall that for backward citations, $\delta = \frac{\Psi_{o,s}}{\theta_o \Psi_o \Psi_s}\delta_{importance}\delta_o\delta_G$. We assume that the knowledge sources are the same for both Aberdeen and Stavanger backward citations. Therefore, θ_o, Ψ_s, $\delta_{importance}$, and δ_G are the same for both places. Hence, there are three possible reasons for greater δ in Stavanger than in Aberdeen. First, Stavanger inventors may have higher propensity to cite U.S. patents ($\Psi_{o,s}$) than Aberdeen inventors. Second, Stavanger inventors may have lower propensity to patent in the U.S. (Ψ_o) than Aberdeen inventors. Third, Stavanger inventors may have better combined absorptive and creative ability (δ_o) than Aberdeen inventors. However, we will not be able to tell which of these possible causes make the primary contribution to the greater δ in Stavanger by looking at the regression results alone.

Table 6-22 also shows a greater β in Stavanger (0.155) than in Aberdeen (0.080) for the backward citation study. Since $\beta = \beta_{basiceness}\beta_{state}\beta_G$ and we assume that Aberdeen and Stavanger inventors share the same source of knowledge, $\beta_{basiceness}$ and β_G should be the same for the two locations. Hence only variations in β_{state} will be responsible for differences in β between Aberdeen and Stavanger. This implies that the difference of knowledge state between Aberdeen and the worldwide average is less than the equivalent difference for Stavanger.

The results of the forward citation study are similar to the results for the backward citations. We obtained greater δ and β in Stavanger than in Aberdeen from the study of forward citations. For example, β for forward citations in Stavanger is 0.082, much greater than 0.021 in Aberdeen. For forward citations, we assume that Aberdeen and Stavanger share the same cohort of knowledge absorbers. In this case θ_o, Ψ_o, δ_o, δ_G and β_G will be the same in both places. Therefore there are three possible reasons for the slightly greater δ in Stavanger than in Aberdeen. First, worldwide inventors may have a higher propensity to cite Stavanger-related U.S. patents ($\Psi_{o,s}$) than Aberdeen-related U.S. patents. Second, Stavanger inventors may have a lower propensity to patent in the U.S. (Ψ_S) than Aberdeen inventors. Third, the knowledge created by Stavanger inventors may have a greater importance value ($\delta_{importance}$) than the knowledge created by Aberdeen inventors. We still will not be able to distinguish among these factors.

The greater value of β in Stavanger also suggests, first, that the knowledge created by

Stavanger inventors may be less basic ($\beta_{basiceness}$) than the knowledge created by Aberdeen inventors. Second, the difference of knowledge state between Aberdeen and the worldwide average (β_{state}) may be less than the difference between Stavanger and the world, as we saw from the study of backward citations.

Study of Backward Citation				
	Aberdeen		Stavanger	
	Result	Error	Result	Error
Delta	6.1E-04	7.2E-05	8.7E-04	2.0E-04
Beta	0.080	0.017	0.155	0.051
Gamma	100	.	100	.
Lambda	-0.023	0.071	-0.052	0.151
Study of Forward Citation				
	Aberdeen		Stavanger	
	Result	Error	Result	Error
Delta	5.4E-04	7.6E-05	8.5E-04	2.5E-04
Beta	0.021	0.016	0.082	0.053
Gamma	100	.	100	.
Lambda	-0.038	0.121	-0.070	0.218

Table 6-22 General Results of Knowledge Spillover Regression

6.5.3 The Variation of Regression Results across Locations

Now we will dig slightly deeper to see how these results may be influenced by differences in geographic proximity.

Table 6-23 gives the variation of regression results for backward citations across different geographical distances. A few findings from this table deserve note. First the δ for backward citations in Stavanger is greater than that for Aberdeen at all levels of geographical distance but is not significant for local citations. The δ for local backward citations in Stavanger is 3.0±0.8E-03, and the δ for local backward citations in Aberdeen is 2.4±0.2E-03. Recall that $\delta = \frac{\Psi_{o,s}}{\theta_o \Psi_o \Psi_s} \delta_{importance} \delta_o \delta_G$. Since we are looking at local backward citations, the citing cohort is the same as the cited cohort. The value of δ is decided by all estimators except θ_o and δ_G. Table 6-22 showed that Stavanger may have greater $\delta_{importance}$, δ_o and lower propensity to patent in U.S. (Ψ) than Aberdeen. Therefore the similarity of δ between Stavanger and

Aberdeen suggests that Stavanger inventors may have lower propensity to cite local backward citations ($\Psi_{o,s}$) than Aberdeen inventors.

Second, in both Aberdeen and Stavanger the values of δ for local backward citations are significantly greater than for backward citations to other locations. For example in Aberdeen the δ for local backward citations is 2.4±0.2E-03, but is only 5.4±0.3E-06 for international backward citations. We believe this large difference is primarily attributable to the high fraction of oil and gas-related patents in both Stavanger and Aberdeen. Our earlier data showed that almost half of all U.S. patents granted to local Stavanger and Aberdeen inventors were oil and gas related. We were unable to estimate the corresponding fraction for the entire pool of U.S. patents, but it is certainly smaller than this. Therefore, it is reasonable to expect that the international citation frequency will be smaller than the local citation frequency, and hence that there will be a corresponding difference in the values of δ .

Third, the δ for national backward citations in Stavanger is significantly greater than the one in Aberdeen. The δ for national backward citations in Stavanger is 1.8±1.4E-03, and only 2.6±0.3E-05 in Aberdeen. A possible reason for this difference is that local Stavanger inventors have a high propensity to cite Norwegian patents relative to the propensity of local Aberdeen inventors to cite patents granted to U.K. inventors.

Fourth, after dividing the data into subgroups of citations with fewer observations, we obtain a greater standard deviation for β , as expected. However the results from table 6-23 show that the β for backward citations in Stavanger is generally greater than the one in Aberdeen, which is consistent with the results in Table 6-22. In both Aberdeen and Stavanger the β for international backward citations is smaller than the β for backward citations to other locations. This implies that the $\beta_{basiceness}$ of international backward citations is small which means that the knowledge from outside Europe, especially from the U.S., has a relatively high basic character.

Geographical Distance of the Citation	Estimator	Aberdeen Result	Aberdeen Error	Stavanger Result	Stavanger Error
Local	Delta	2.4E-03	2.4E-04	3.0E-03	7.7E-04
	Beta	0.029	0.012	-0.056	0.030
National	Delta	2.6E-05	2.6E-06	1.8E-03	1.4E-03
	Beta	0.032	0.010	0.055	0.136
Continental	Delta	4.9E-06	3.6E-07	1.1E-05	1.3E-06
	Beta	0.011	0.005	0.031	0.012
International	Delta	5.4E-06	2.6E-07	6.8E-06	4.6E-07
	Beta	0.002	0.003	0.021	0.005

Table 6-23 Variation of Regression Results of Backward Citation across Different Geographical Distance of the Citations

There are relatively few observations on forward citations in our U.S. patent and patent citations data set. When we applied the regression model to the subsets of forward citations, we obtained high standard deviations for the estimators β , high which leads to insignificant results. Therefore we will only discuss the δ in this case.

Table 6-24 shows the variation of regression results for forward citations across different geographical distances. There are two findings from this table. First, in both Aberdeen and Stavanger the δ for local forward citations are significantly greater than the δ for forward citations from elsewhere. For example in Aberdeen the δ for local forward citations is 2.2±0.2E-03, but is only 4.7±0.3E-06 for the international forward citations. We suspect that the reason for this huge difference is primarily caused by the higher propensity of local inventors to cite local patents than patents from other places.

Second, the δ for national forward citations in Stavanger is significantly greater than the one in Aberdeen. The δ for national forward citations in Stavanger is 1.5±1.1E-03, but is only 1.7±0.2E-05 in Aberdeen. One of the possible reasons for this difference could be that Norwegian inventors have a high propensity to cite Norwegian patents compared with the propensity of U.K. inventors to cite British patents. Here we need to be clear that when we estimated the δ in this case we set the number of U.S. patents in the citing cohort, P_O, to be equal to the total number of U.S. patents of all kinds granted to national inventors (i.e., to Norwegian inventors and to U.K. inventors.) It is possible that the ratio of U.S. patents of all kinds granted to Norwegian inventors and to U.K. inventors is significantly different from the ratio of oil-and-gas-related U.S. patents granted to inventors from the two countries. Therefore, if we had only considered oil-and-gas-related patents, the results might have been different.

Geographical Distance of the Citation	Estimator	Aberdeen		Stavanger	
		Result	Error	Result	Error
Local	Delta	2.2E-03	2.1E-04	3.5E-03	1.0E-03
	Beta	0.014	0.010	-0.039	0.038
National	Delta	1.7E-05	1.8E-06	1.5E-03	1.1E-03
	Beta	-0.021	0.010	0.037	0.108
Continental	Delta	4.7E-06	4.8E-07	6.4E-06	1.3E-06
	Beta	-0.009	0.010	-0.053	0.013
International	Delta	4.7E-06	2.8E-07	4.9E-06	7.7E-07
	Beta	0.027	0.007	-0.0001	0.014

Table 6-24 Variation of Regression Results of Forward Citation across Different Geographical Distance of the Citations

Besides the tables and figures presented above, all other statistical results have been put in the Appendix II to chapter 6.

6.6 Future Work

The research presented in this thesis primarily focused on using patent data to study the local innovation systems in the North Sea region. Other work might provide additional insight into these innovation systems.

6.6.1 Publications and Others

We chose patents as our data source because patents record the occurrence of knowledge and of knowledge flows systematically and consistently, and patent data provide us with an effective way to review innovation trajectories. Patent data also make it possible to implement quantitative analyses of knowledge creation and knowledge diffusion.

However, patent data also has its limitations. The most important is that patents only represent a very small portion of knowledge creation. Much knowledge exists in other forms, such as publications, private documents, internet databases, and, of course, as 'tacit' knowledge. By no means all inventors choose to protect their inventions by patenting them. Even if a decision to patent is made, moreover, the outcome will not necessarily be successful, since not all inventions can meet the criteria of patentability set by the patent office.

Therefore, using patent data exclusively could have introduced a source of bias into our research since we only observe a small fraction of the work of innovation and, moreover, of a certain type. For this reason it may be useful to consider other types of data, especially scientific and technical publications, for which there is also a historical record and which also may allow quantitative analysis.

6.6.2 Do Not Forget about Houston

It is generally agreed that the oil and gas industry is one of the most highly globalized of all industries. Each local innovation system can benefit from the knowledge and technology developed globally in this industry, and each will contribute to it. Our research has focused mainly on two city regions in the North Sea area without considering any other community where there is a strong focus on the oil and gas industry. It will also be useful to study other regional oil and gas industry centers so as to make comparisons with Stavanger and Aberdeen. A likely candidate is Houston.

Houston has been at the center of the oil and gas industry in the United States for many years because of its proximity to the Mexico Gulf. Many oil companies, including well-known multinational firms, decided to locate their company headquarters there. Houston is also the primary innovation center for the oil and gas industry. The technologies developed here include seismic, measurement-while-drilling tools, horizontal drilling, and many more. As the world headquarters for oil and gas innovation, Houston may affects the path of development of Stavanger and Aberdeen greatly. It will be interesting to explore the similarities and differences in the innovation systems of Houston, Stavanger and Aberdeen.

Appendix II -- Study of Patents and Patent Citations

Distribution of the U.S. patents by the Year of Application

Year of Application	Aberdeen	Stavanger
1969	0	1
1970	0	0
1971	0	0
1972	0	0
1973	0	0
1974	0	0
1975	0	1
1976	0	1
1977	4	4
1978	7	3
1979	10	1
1980	5	0
1981	9	2
1982	7	1
1983	12	3
1984	8	3
1985	11	5
1986	13	3
1987	19	12
1988	20	10
1989	15	7
1990	36	8
1991	37	13
1992	13	9
1993	28	12
1994	24	14
1995	30	18
1996	40	14
1997	62	23
1998	61	20
1999	83	26
2000	65	42
2001	82	23
2002	70	31
2003	40	9
2004	8	5
Total	**819**	**324**

Table 6-25 Distribution of Patents with at Least One Local Inventor by Year of Application

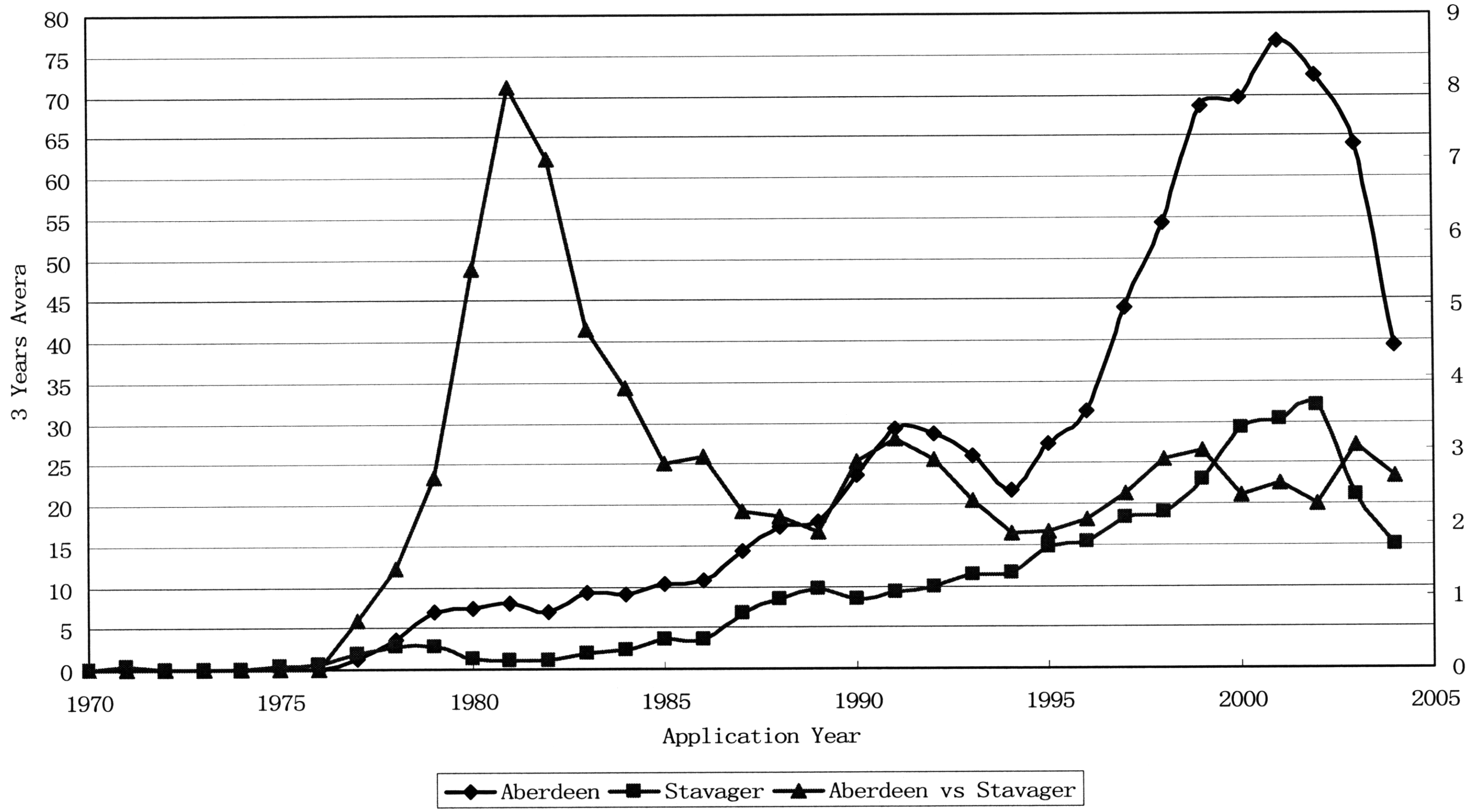

Figure 6-4 Distribution of Patents with at Least One Local Inventor by Year of Application (3 Year Average)

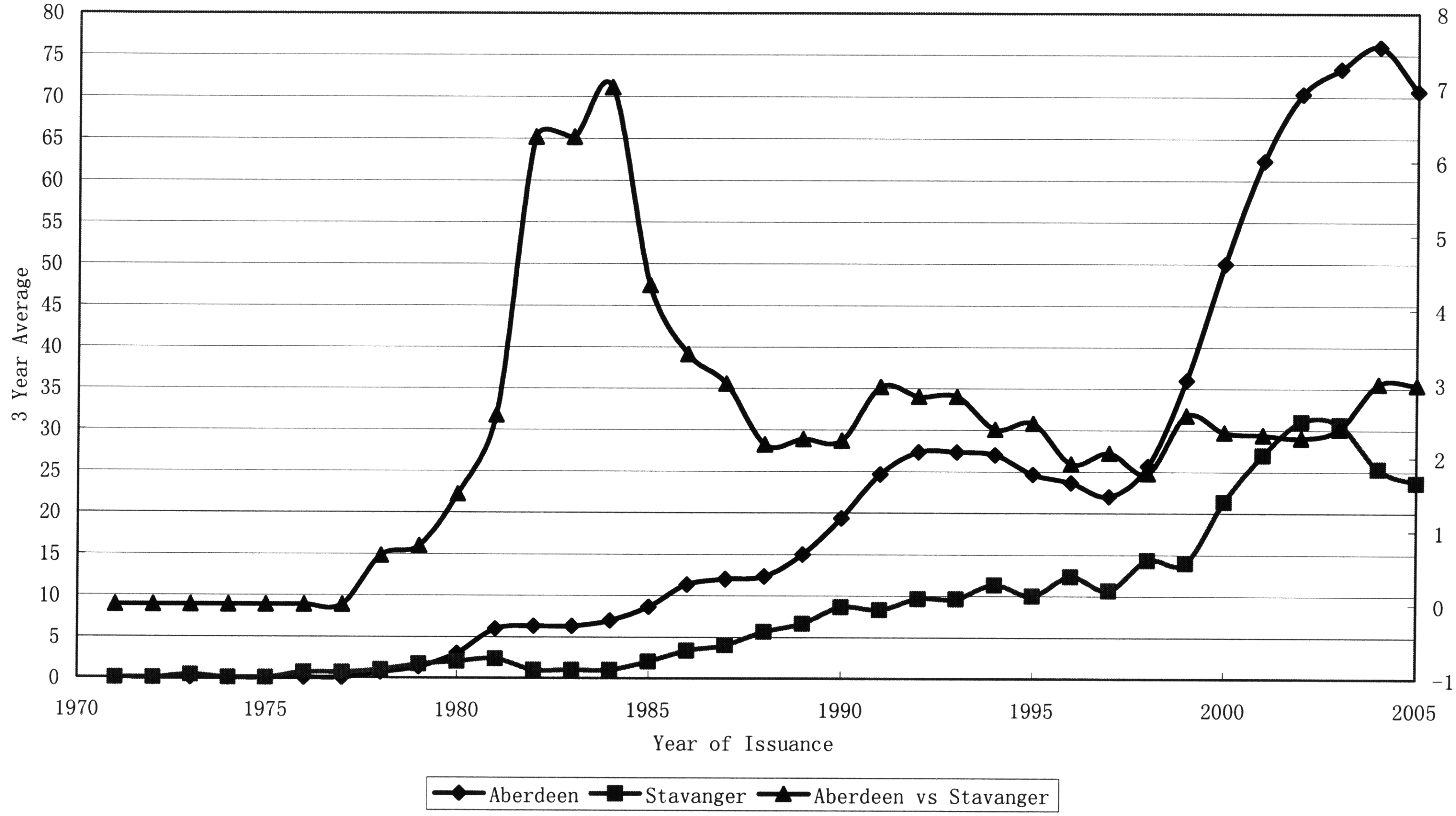

Figure 6-5 Distribution of Patents with at Least One Local Inventor by Year of Issuance (3 Year Average)

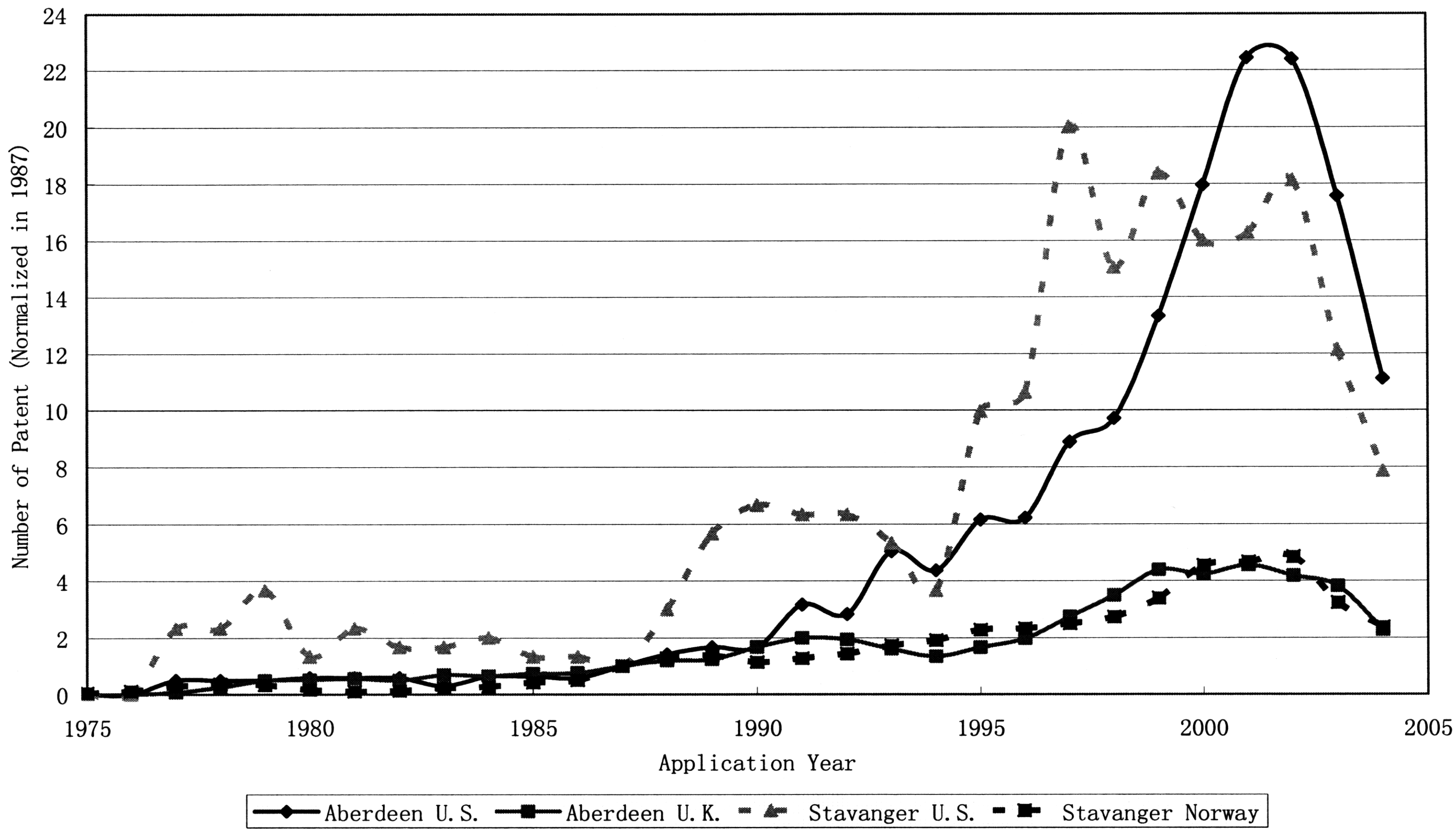

Figure 6-6 Distribution of Patents with at Least One Local Inventor by Application Year and Country of Inventor (Normalized in 1987)

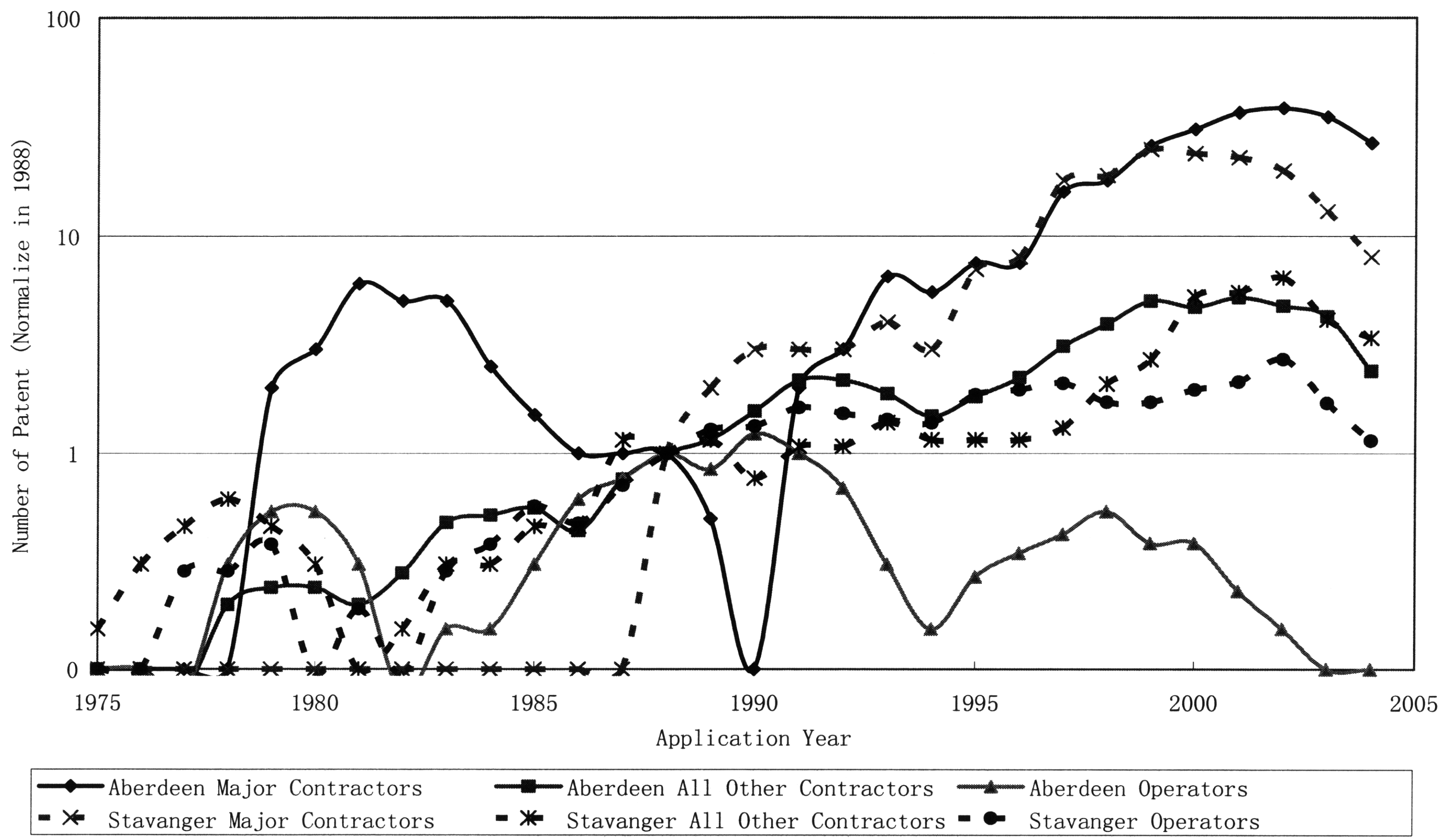

Figure 6-7 Distribution of Patents with at Least One Local Inventor by Application Year and Type of Assignee (Normalized in 1988)

Distribution of U.S. patents by type of inventor

We use a fractional allocation scheme to account for patents with multiple inventors from different countries and/or regions. For example, if a patent has two inventors (say, one from the U.K., and one from the U.S.) we assume that they have made an equal contribution to the innovation activity involved in the patent, regardless of the order in which their names are listed. Therefore, when counting the number of patents, 0.5 of the patent belongs to the U.K. group, and the other half is counted in the U.S. category. We refer to this phenomenon as the multi-inventor effect.

The inventor regions are defined in relation to the greater Aberdeen and greater Stavanger areas, as discussed in a previous chapter. If the inventor has an address within the greater Aberdeen area or the greater Stavanger area, we consider that he/she is a local inventor. If he/she is from the U.K. or Norway but not the local area, he/she is a 'national' inventor. If he/she is from another European country, he/she is a 'continental' inventor. All others are considered as 'international' inventors.

Patents with one or more Aberdeen inventors					
Inventor Country	No. of Patents	Ratio	No. of Inventors	Ratio	Inventors per Patent
U.K.	681.94	83.26%	1294	69.64%	1.90
U.S.	111.76	13.65%	476	25.62%	4.26
Other Countries	**25.31**	**3.09%**	**88**	**4.74%**	3.48
France	4.99	0.61%	14	0.75%	2.81
Netherlands	4.04	0.49%	14	0.75%	3.47
Norway	2.90	0.35%	9	0.48%	3.10
Canada	2.64	0.32%	8	0.43%	3.03
Germany	2.60	0.32%	13	0.70%	5.00
Singapore	1.28	0.16%	5	0.27%	3.90
Italy	1.20	0.15%	4	0.22%	3.33
Oman	0.74	0.09%	3	0.16%	4.06
Arab Emirates	0.67	0.08%	2	0.11%	3.00
Sweden	0.67	0.08%	2	0.11%	3.00
Viet Nam	0.67	0.08%	2	0.11%	3.00
Austria	0.50	0.06%	2	0.11%	4.00
Denmark	0.50	0.06%	2	0.11%	4.00
Japan	0.50	0.06%	1	0.05%	2.00
Brunei	0.33	0.04%	1	0.05%	3.00
Switzerland	0.33	0.04%	1	0.05%	3.00
New Zealand	0.29	0.03%	2	0.11%	7.00
Venezuela	0.20	0.02%	1	0.05%	5.00
South Africa	0.14	0.02%	1	0.05%	7.00
Saudi Arabia	0.13	0.02%	1	0.05%	8.00
Total	**819**		**1858**		**2.27**
Patents with one or more Stavanger inventors					
Norway	270.66	83.54%	562	72.33%	2.08
U.S.	33.90	10.46%	133	17.12%	3.92
Other Countries	**19.43**	**6.00%**	**82**	**10.55%**	4.22
France	4.92	1.52%	16	2.06%	3.25
U.K.	4.20	1.29%	18	2.32%	4.29
Sweden	3.43	1.06%	22	2.83%	6.42
Germany	3.42	1.05%	15	1.93%	4.39
Netherlands	1.25	0.39%	3	0.39%	2.40
Canada	0.57	0.18%	2	0.26%	3.50
Belgium	0.50	0.15%	1	0.13%	2.00
Indonesia	0.33	0.10%	1	0.13%	3.00
Japan	0.33	0.10%	1	0.13%	3.00
Austria	0.25	0.08%	1	0.13%	4.00
Brazil	0.17	0.05%	1	0.13%	6.00
Oman	0.07	0.02%	1	0.13%	14.00
Total	**324**		**777**		**2.08**

Table 6-26 Distribution of Patents by Country of Inventor

Patents with one or more Aberdeen inventors					
Inventor Region	No. of Patents	Ratio	No. of Inventors	Ratio	Inventor per patent
Local	616.94	75.33%	1121	60.33%	1.82
National	64.99	7.94%	173	9.31%	2.66
Continental	17.73	2.16%	61	3.28%	3.44
International	119.34	14.57%	503	27.07%	4.21
Total	**819**		**1858**		**2.27**
Patents with one or more Stavanger inventors					
Local	227.42	70.19%	419	53.93%	1.84
National	43.25	13.35%	143	18.40%	3.31
Continental	17.96	5.54%	76	9.78%	4.23
International	35.38	10.92%	139	17.89%	3.93
Total	**324**		**777**		**2.40**

Table 6-27 Distribution of Patents by Region of Inventor

For each patent, the inventor who has the address that is farthest away from the local area (the greater Aberdeen or the greater Stavanger area) is the most distant inventor.

	Patents with one or more Aberdeen inventors		Patents with one or more Stavanger inventors	
Inventor Region	No. of Patents	Ratio	No. of Patents	Ratio
Local	475	58.00%	162	50.00%
National	111	13.55%	72	22.22%
Continental	32	3.91%	30	9.26%
International	201	24.54%	60	18.52%
Total	819		324	

Table 6-28 Distribution of Patents by Region of the most distant Inventor

Aberdeen Related Patents										
Country of Assignee	U.K. Inventor					U.S. Inventor				
	No. of Patent	Row Ratio	Column Ratio	No. of Inventors	Inventor per Patent	No. of Patent	Row Ratio	Column Ratio	No. of Inventors	Inventor per Patent
U.S.	296.65	71.40%	49.88%	632.5	2.13	102.31	24.62%	95.16%	449.5	4.39
U.K.	290.72	99.73%	48.89%	517	1.78	1.28	0.44%	1.19%	4	3.12
Others	7.32	38.51%	1.23%	20.50	2.80	3.92	20.61%	3.64%	10.50	2.68
Total	**594.69**	**81.91%**		**1170**	**1.97**	**107.51**	**14.81%**		**464**	**4.32**
Country of Assignee	Inventors from Other Countries					**Total**				
	No. of Patent	Row Ratio	Column Ratio	No. of Inventors	Inventor per Patent	**No. of Patent**	**Row Ratio**	**Column Ratio**	**No. of Inventors**	**Inventor per Patent**
U.S.	16.54	3.98%	65.36%	59	3.57	**415.50**		**57.23%**	**1141**	**2.75**
U.K.	0.00	0.00%	0.00%	0	0.00	**291.50**		**40.15%**	**527**	**1.81**
Others	7.77	40.88%	30.69%	17	2.19	**19.00**		**2.62%**	**48.00**	**2.53**
Total	**23.81**	**3.28%**		**82**	**3.44**	**726.00**			**1716**	**2.36**
Stavanger Related Patents										
Country of Assignee	Norwegian Inventor					U.S. Inventor				
	No. of Patent	Row Ratio	Column Ratio	No. of Inventors	Inventor per Patent	No. of Patent	Row Ratio	Column Ratio	No. of Inventors	Inventor per Patent
U.S.	54.61	59.36%	22.93%	133	2.44	29.40	31.96%	89.36%	118	4.01
Norway	175.99	95.13%	73.89%	349.5	1.99	3.50	1.89%	10.64%	12	3.43
Others	7.57	56.08%	3.18%	28.00	3.70	0.00	0.00%	0.00%	0.00	0.00
Total	**238.16**	**81.98%**		**510.5**	**2.14**	**32.90**	**11.33%**		**130**	**3.95**
Country of Assignee	Inventors from Other Countries					**Total**				
	No. of Patent	Row Ratio	Column Ratio	No. of Inventors	Inventor per Patent	**No. of Patent**	**Row Ratio**	**Column Ratio**	**No. of Inventors**	**Inventor per Patent**
U.S.	7.99	8.68%	41.11%	30.50	3.82	**92.00**		**31.67%**	**281.5**	**3.06**
Norway	5.51	2.98%	28.38%	22.00	3.99	**185.00**		**63.68%**	**383.5**	**2.07**
Others	5.93	43.92%	30.51%	29.50	4.98	**13.50**		**4.65%**	**57.50**	**4.26**
Total	**19.43**	**6.69%**		**82.00**	**4.22**	**290.50**			**722.5**	**2.49**

Table 6-29 Distribution of Patents by the Country of Assignee and the Country of Inventor

Distribution of U.S. patents by type of assignee

As with multiple inventors, a patent can be granted to more than one assignee. We call this phenomenon as the multi-assignee effect. We deal with multi-assignee effect in the same way we treated multi-inventor effects we assume that each assignee owns an equal portion of the patent.

	Patents with one or more Aberdeen inventors		Patents with one or more Stavanger inventors	
Type of Assignee	No. of Patents	Ratio	No. of Patents	Ratio
Major Contractors	203.50	24.85%	62.00	19.14%
All Other Contractors	447.00	54.58%	103.17	31.84%
Operators	51.50	6.29%	114.33	35.29%
Operators Exclusive Den Norkse	–	–	39.33	12.14%
Research Institutes	6.00	0.73%	4.00	1.23%
Unknown	18.00	2.20%	7.00	2.16%
Individuals	93.00	11.36%	33.50	10.34%
Total	**819**		**324**	

Table 6-30 Distribution of Patents by Type of Assignee

Patents with one or more Aberdeen inventors				
Assignee Name	No. of Patents	Ratio	Type of Assignee	Patent per Assignee
Baker Hughes	76.00	10.47%	Major Contractors	
Vetco Gray	74.00	10.19%	All Other Contractors	
Weatherford	68.00	9.37%	Major Contractors	
Halliburton	35.00	4.82%	Major Contractors	
Smith International	31.00	4.27%	All Other Contractors	
Schlumberger	24.50	3.37%	Major Contractors	
BP	24.00	3.31%	Operators	
Expro	21.00	2.89%	All Other Contractors	
Coflexip	16.00	2.20%	All Other Contractors	
Specialised Petroleum Services	12.00	1.65%	All Other Contractors	
Top 10 Firms	381.50	52.55%	No. of Assignees	38.15
Other Firms	344.50	47.45%	154	2.24
Total	726		**164**	**4.43**
Patents with one or more Stavanger inventors				
Den Norkse Stats Oljeselskap	75.00	25.82%	Operators	
Baker Hughes	19.00	6.54%	Major Contractors	
Weatherford	19.00	6.54%	Major Contractors	
Halliburton	15.00	5.16%	Major Contractors	
Schlumberger	9.00	3.10%	Major Contractors	
Statoil	9.00	3.10%	Operators	
Phillips Petroleum	7.00	2.41%	Operators	
Bakke Technology	7.00	2.41%	All Other Contractors	
Exxon	7.00	2.41%	Operators	
Smedvig	6.50	2.24%	All Other Contractors	
Top 10 Firms	173.50	59.72%	No. of Assignees	17.35
Other Firms	117.00	40.28%	84	1.39
Total	290. 5		**94**	**3.09**

Table 6-31 Distribution of Patents by Assignee

Aberdeen Related Patents										
Type of Assignee	U.K. Inventor					U.S. Inventor				
	No. of Patent	Row Ratio	Column Ratio	No. of Inventors	Inventor per Patent	No. of Patent	Row Ratio	Column Ratio	No. of Inventors	Inventor per Patent
Major Contractors	139.52	68.56%	20.46%	291.5	2.09	57.99	28.50%	51.89%	255	4.40
All Other Contractors	387.75	86.75%	56.86%	760	1.96	43.93	9.83%	39.31%	190	4.33
Operators	46.58	90.45%	6.83%	76.5	1.64	2.92	5.66%	2.61%	10	3.43
Total	**681.94**	**83.26%**		**1294**	**1.90**	**111.76**	**13.65%**		**476**	**4.26**
Type of Assignee	Inventors from Other Countries					**Total**				
	No. of Patent	Row Ratio	Column Ratio	No. of Inventors	Inventor per Patent	**No. of Patent**	**Row Ratio**	**Column Ratio**	**No. of Inventors**	**Inventor per Patent**
Major Contractors	5.99	2.94%	23.66%	24	4.01	**203.50**		**24.85%**	**570.5**	**2.80**
All Other	15.32	3.43%	60.54%	51.5	3.36	**447.00**		**54.58%**	**1001.5**	**2.24**
Operators	2.00	3.88%	7.90%	5.5	2.75	**51.50**		**6.29%**	**92**	**1.79**
Total	**25.31**	**3.09%**		**88**	**3.48**	**819.00**			**1858**	**2.27**
Stavanger Related Patents										
Type of Assignee	Norwegian Inventor					U.S. Inventor				
	No. of Patent	Row Ratio	Column Ratio	No. of Inventors	Inventor per Patent	No. of Patent	Row Ratio	Column Ratio	No. of Inventors	Inventor per Patent
Major Contractors	37.12	59.88%	13.72%	92.0	2.48	19.80	31.94%	58.41%	85	4.29
All Other Contractors	91.72	88.91%	33.89%	172.2	1.88	3.83	3.72%	11.31%	11	2.87
Operators	99.49	87.01%	36.76%	230.3	2.32	8.93	7.81%	26.35%	33	3.69
Total	**270.66**	**83.54%**		**562.0**	**2.08**	**33.90**	**10.46%**		**133**	**3.92**
Type of Assignee	Inventors from Other Countries					**Total**				
	No. of Patent	Row Ratio	Column Ratio	No. of Inventors	Inventor per Patent	**No. of Patent**	**Row Ratio**	**Column Ratio**	**No. of Inventors**	**Inventor per Patent**
Major Contractors	5.07	8.18%	26.10%	21.00	4.14	62.00		19.14%	198.0	3.19
All Other Contractors	7.61	7.38%	39.17%	39.67	5.21	103.17		31.84%	222.8	2.16
Operators	5.91	5.17%	30.44%	19.33	3.27	114.33		35.29%	282.7	2.47
Total	**19.43**	**6.00%**		**82.00**	**4.22**	**324.00**			**777.0**	**2.40**

Table 6-32 Distribution of Patents by the Type of Assignee and the Country of Inventor

Aberdeen Related Patents										
Type of Assignee	Local Inventor					National Inventor				
	No. of Patent	Row Ratio	Column Ratio	No. of Inventors	Inventor per Patent	No. of Patent	Row Ratio	Column Ratio	No. of Inventors	Inventor per Patent
Major Contractors	132.76	65.24%	21.52%	272.5	2.05	6.76	3.32%	10.40%	19	2.81
All Other Contractors	341.77	76.46%	55.40%	634	1.86	45.98	10.29%	70.75%	126	2.74
Operators	40.58	78.80%	6.58%	63.5	1.56	6.00	11.65%	9.23%	13	2.17
Total	616.94	75.33%		1121	1.82	64.99	7.94%		173	2.66
Type of Assignee	Continental Inventor					International Inventor				
	No. of Patent	Row Ratio	Column Ratio	No. of Inventors	Inventor per Patent	No. of Patent	Row Ratio	Column Ratio	No. of Inventors	Inventor per Patent
Major Contractors	1.76	0.86%	9.93%	9	5.12	62.22	30.58%	52.14%	270	4.34
All Other Contractors	12.55	2.81%	70.80%	41	3.27	46.70	10.45%	39.13%	200.5	4.29
Operators	1.75	3.40%	9.87%	5	2.86	3.17	6.15%	2.65%	10.5	3.32
Total	17.73	2.16%		61	3.44	119.34	14.57%		503	4.21
Stavanger Related Patents										
Type of Assignee	Local Inventor					National Inventor				
	No. of Patent	Row Ratio	Column Ratio	No. of Inventors	Inventor per Patent	No. of Patent	Row Ratio	Column Ratio	No. of Inventors	Inventor per Patent
Major Contractors	34.37	55.44%	15.12%	84.0	2.44	2.75	4.44%	6.36%	8	2.91
All Other Contractors	80.55	78.08%	35.42%	130.7	1.62	11.17	10.83%	25.82%	41.5	3.72
Operators	75.47	66.01%	33.19%	151.8	2.01	24.01	21.00%	55.52%	78.5	3.27
Total	227.42	70.19%		419.0	1.84	43.25	13.35%		143	3.31
Type of Assignee	Continental Inventor					International Inventor				
	No. of Patent	Row Ratio	Column Ratio	No. of Inventors	Inventor per Patent	No. of Patent	Row Ratio	Column Ratio	No. of Inventors	Inventor per Patent
Major Contractors	4.76	7.68%	26.52%	18.0	3.78	20.11	32.44%	56.85%	88	4.38
All Other Contractors	7.45	7.22%	41.47%	39.2	5.26	4.00	3.88%	11.31%	11.5	2.88
Operators	5.25	4.59%	29.23%	17.8	3.40	9.60	8.40%	27.13%	34.5	3.59
Total	17.96	5.54%		76.0	4.23	35.38	10.92%		139	3.93

Table 10-33 Distribution of Patents by the Type of Assignee and the Region of Inventor

General Comparison of Backward Patent Citations

Aberdeen							
Original Patent	U.S. Patent Backward Citation			Foreign Backward Citation			
Assignee Type	No. of Citation	Ratio	Citation per Patent	No. of Patent	No. of Citation	Ratio	Citation per Patent
Major Contractors	5610.5	85.19%	27.57	143.5	975	14.81%	6.79
All Other Contractors and Suppliers	5981.5	83.11%	13.38	289	1215.5	16.89%	4.21
Operators	402	86.54%	7.81	25.5	62.5	13.46%	2.45
Total	13038	83.83%	15.92	532	2515	16.17%	4.73
Stavanger							
Original Patent	U.S. Patent Backward Citation			Foreign Backward Citation			
Assignee Type	No. of Citation	Ratio	Citation per Patent	No. of Patent	No. of Citation	Ratio	Citation per Patent
Major Contractors	1348	88.51%	21.74	35.00	175.00	11.49%	5.00
All Other Contractors and Suppliers	1137.66	81.30%	11.03	81.67	261.67	18.70%	3.20
Operators	920.83	74.19%	8.05	72.83	320.33	25.81%	4.40
Total	3786	80.93%	11.69	223.00	892.00	19.07%	4.00

Table 6-34 Distribution of Patent Backward Citation by the Assignee Type of Original Patent

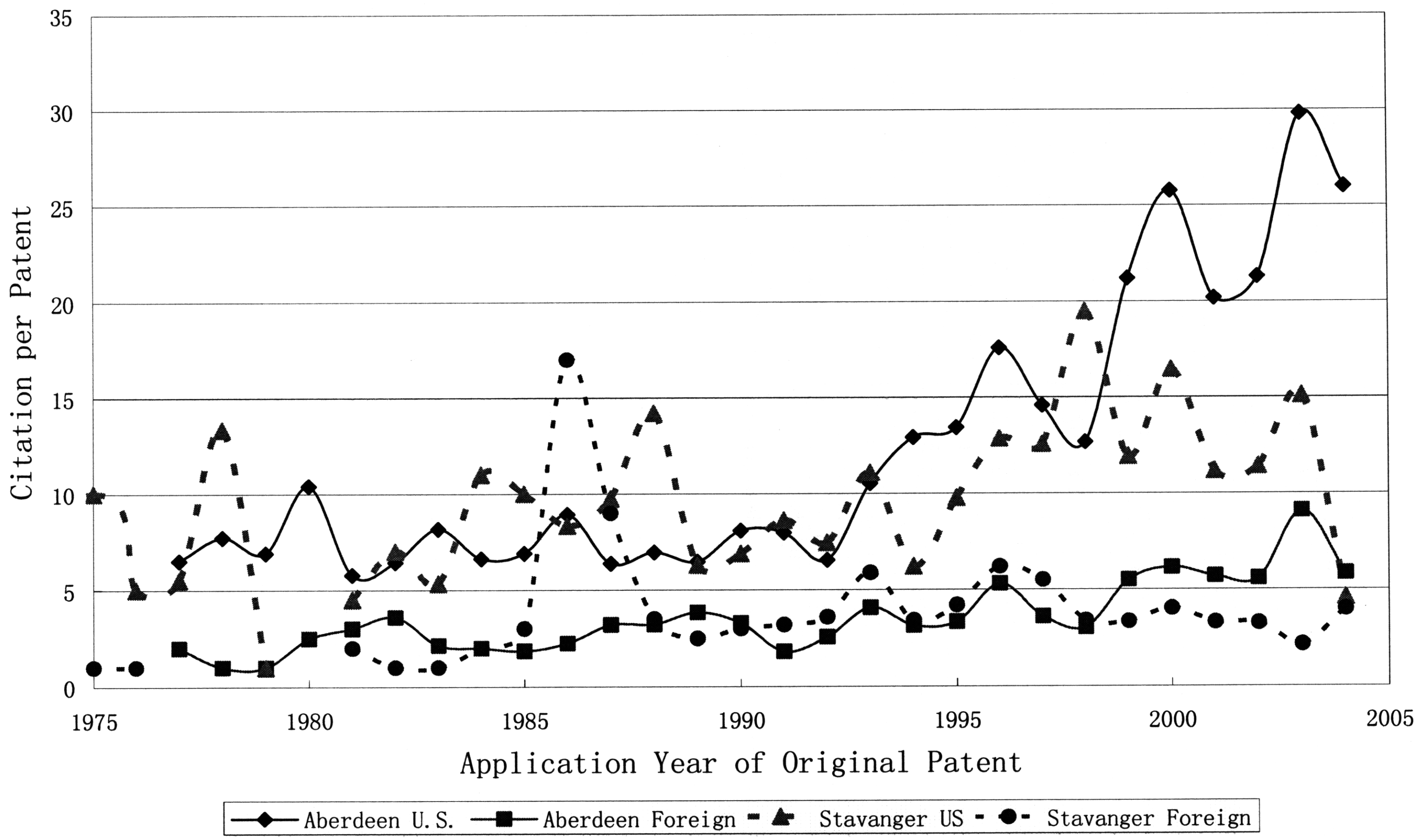

Figure 6-8 Distribution of Backward Citation per Patent by the Application Year of the Original Paten

Aberdeen							
Original Patent	U.S. Patent Backward Citation			Foreign Backward Citation			
Inventor Country	No. of Citation	Ratio	Citation per Patent	No. Patent	No. of Citation	Ratio	Citation per Patent
U.S.	3145.55	87.90%	28.15	69.75	433.1	12.10%	6.21
U.K.	9348.75	82.72%	13.71	445.91	1953.29	17.28%	4.38
Others	543.70	80.87%	21.49	16.34	128.61	19.13%	7.87
Total	13038	83.83%	15.92	532	2515	16.17%	4.73
Stavanger							
Original Patent	U.S. Patent Backward Citation			Foreign Backward Citation			
Inventor Country	No. of Citation	Ratio	Citation per Patent	No. Patent	No. of Citation	Ratio	Citation per Patent
U.S.	794.67	91.51%	23.44	16.71	73.76	8.49%	4.41
Norway	2735.47	78.23%	10.11	193.25	761.18	21.77%	3.94
Others	255.86	81.76%	13.17	13.04	57.06	18.24%	4.38
Total	3786	80.93%	11.69	223	892	19.07%	4.00

Table 6-35 Distribution of Patent Backward Citation by the Inventor Country of Original Patent

Aberdeen							
Original Patent	U.S. Patent Backward Citation			Foreign Backward Citation			
Inventor Region	No. of Citation	Ratio	Citation per Patent	No. Patent	No. of Citation	Ratio	Citation per Patent
Local	8668.01	82.82%	14.05	402.54	1797.75	17.18%	4.47
National	680.74	81.40%	10.47	43.38	155.54	18.60%	3.59
Continental	216.76	77.57%	12.23	11.41	62.67	22.43%	5.49
International	3472.49	87.43%	29.10	74.68	499.04	12.57%	6.68
Total	13038	83.83%	15.92	532	2515	16.17%	4.73
Stavanger							
Original Patent	U.S. Patent Backward Citation			Foreign Backward Citation			
Inventor Region	No. of Citation	Ratio	Citation per Patent	No. Patent	No. of Citation	Ratio	Citation per Patent
Local	2348.35	78.43%	10.33	159.67	645.78	21.57%	4.04
National	387.12	77.04%	8.95	33.58	115.40	22.96%	3.44
Continental	237.95	82.11%	13.25	12.40	51.85	17.89%	4.18
International	812.58	91.14%	22.97	17.35	78.98	8.86%	4.55
Total	3786	80.93%	11.69	223	892	19.07%	4.00

Table 6-36 Distribution of Patent Backward Citation by the Inventor Region of Original Patent

General Comparison of Forward Patent Citation

Aberdeen				Stavanger			
Inventor Country (Original)	No. of Patent	No. of Citation	Citation per Patent	Inventor Country (Original)	No. of Patent	No. of Citation	Citation per Patent
U.S.	82.75	825.08	9.97	U.S.	26.77	257.66	9.62
U.K.	505.02	4624.91	9.16	Norway	187.43	1124.27	6.00
Others	18.23	135.02	7.41	Others	15.80	100.08	6.33
Total	606	5585	9.22	Total	230	1482	6.44

Table 6-37 Distribution of Forward Citation by the Inventor Country of Original Patent

Original Patent	Aberdeen			Stavanger		
Inventor Region	No. of Patent	No. of Citation	Citation per Patent	No. of Patent	No. of Citation	Citation per Patent
Local	461.41	4207.96	9.12	158.03	945.18	5.98
National	43.61	416.94	9.56	29.40	179.08	6.09
Continental	12.42	101.68	8.19	14.49	94.38	6.51
International	88.56	858.41	9.69	28.08	263.35	9.38
Total	606	5585	9.22	230	1482	6.44

Table 6-38 Distribution of Forward Citation by the Inventor Region of Original Patent

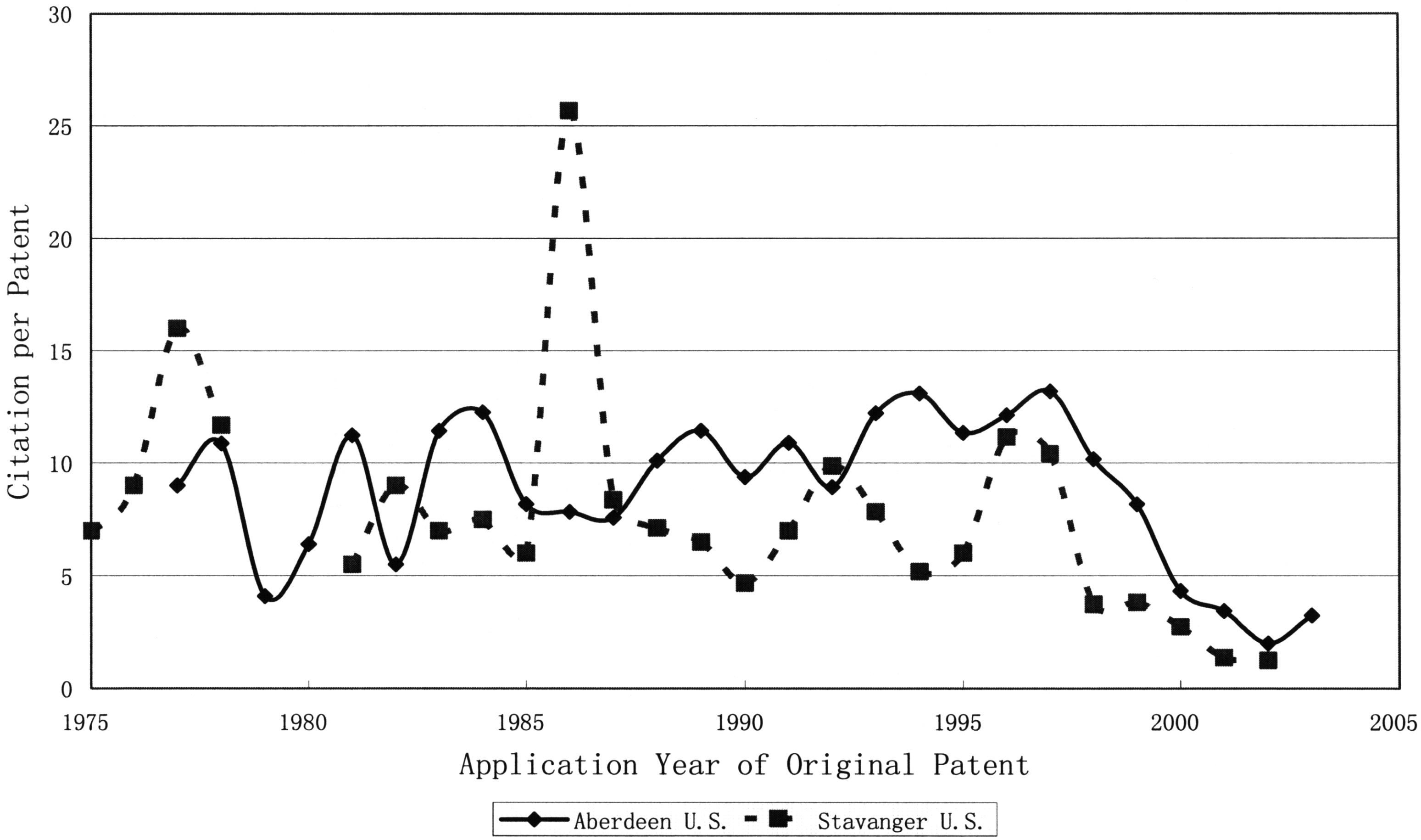

Figure 6-9 Distribution of Forward Citations per Patent by the Application Year of Original Patent

The Study of Backward Self-Citation

We consider two kinds of self-citation. The first involves backward-citing patents whose inventors are entirely located in the same local area as the inventors of the original patent. We assume that there is no geographic knowledge spillover involved in this case. All other self-citations, which have at least one inventor from an area outside the local area of the inventors of the original patent, are called type II self-citation. We assume type II self-citations are at least partially associated with knowledge spillover.

	Aberdeen				Stavanger			
	No. of Patent	No. of Citation	Ratio of Citation	Citation per Patent	No. of Patent	No. of Citation	Ratio of Citation	Citation per Patent
US Patent Backward Citation	819	13038		15.92	323	3786		11.72
All Backward Self-Citation	285	788	6.04%	2.76	72	189	4.99%	2.63
Backward Self-Citation with Local Inventors only	77	126	0.97%	1.64	1	1	0.03%	1.00

Table 6-39 Number of Backward Self-Citation

Aberdeen				Stavanger			
Assignee Country (Original)	No. of Patent	No. of Citation	Citation per Patent	Assignee Country (Original)	No. of Patent	No. of Citation	Citation per Patent
U.S.	254	749	2.95	U.S.	52.5	166.5	3.17
U.K.	30	38	1.27	Norway	18	21	1.17
Total	285	788	2.76	Total	72	189	2.63

Table 6-40 Distribution of Backward Self-Citation by the Assignee Country of Original Patent

Aberdeen				Stavanger			
Inventor Country (Original)	No. of Patent	No. of Citation	Citation per Patent	Inventor Country (Original)	No. of Patent	No. of Citation	Citation per Patent
U.S.	67.39	230.06	3.41	U.S.	23.57	82.67	3.51
U.K.	204.47	517.97	2.53	Norway	41.82	88.03	2.11
Total	285	788	2.76	Total	72	189	2.63

Table 6-41 Distribution of Backward Self-Citation by the Inventor Country of Original Patent

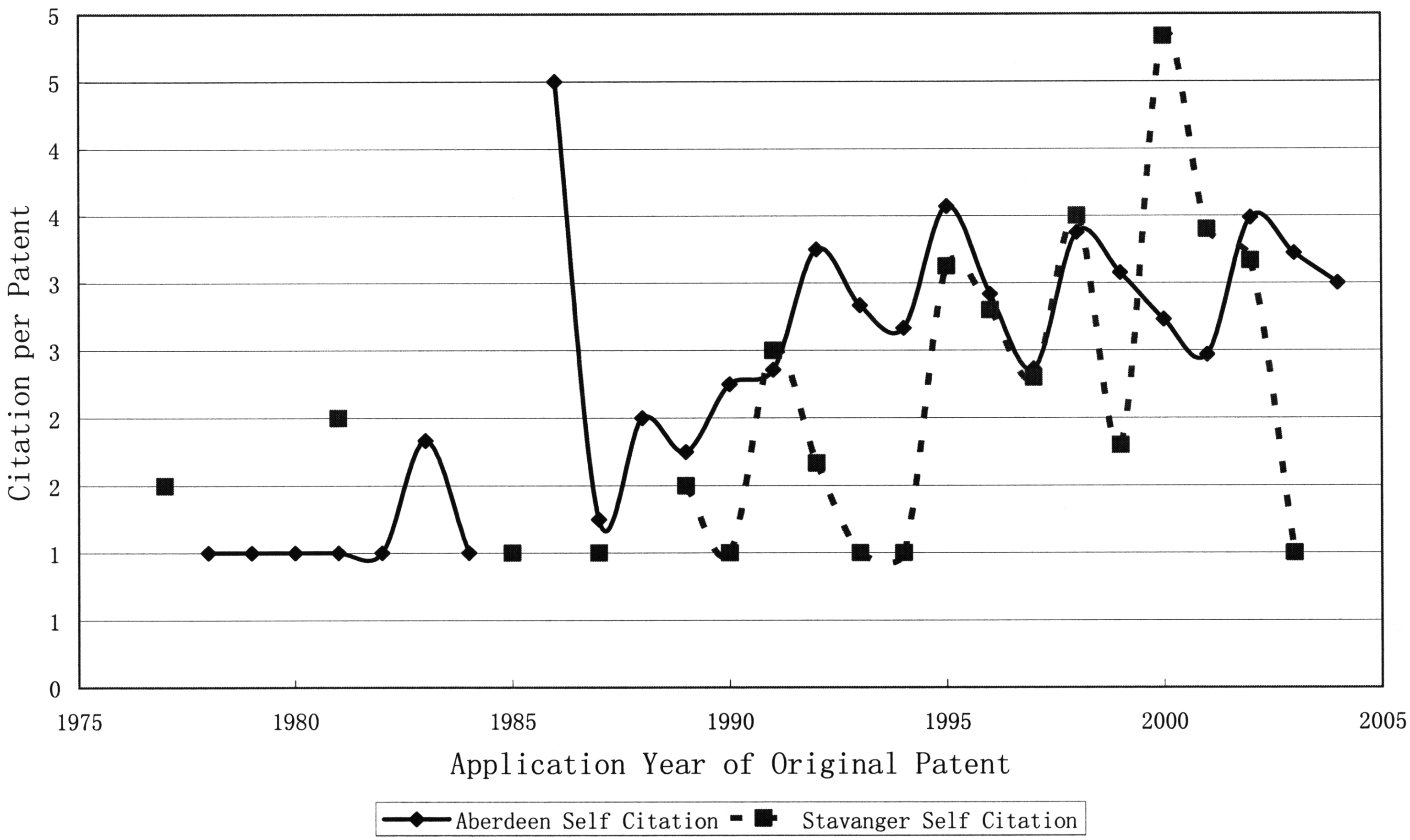

Figure 6-10 Distribution of Number of Backward Self-Citations per Patent by the Application Year of Original Patent

The Study of Forward Self-Citation

	Aberdeen				Stavanger			
Original Patent	No. of Patent	No. of Citation	Ratio	Citation per Patent	No. of Patent	No. of Citation	Ratio	Citation per Patent
US Patent Forward Citation	606	5585		9.22	230	1482		6.44
All Forward Self-Citation	190	718	12.86%	3.78	55	193	13.02%	3.51
Forward Self-Citation with Local Inventors only	55	95	1.70%	1.73	1	2	0.13%	2.00

Table 6-42 Number of Forward Backward Self-Citation

Aberdeen				Stavanger			
Assignee Country (Original)	No. of Patent	No. of Citation	Citation per Patent	Assignee Country (Original)	No. of Patent	No. of Citation	Citation per Patent
U.S.	156.5	659.5	4.21	U.S.	38	164	4.32
U.K.	27.5	43	1.56	Norway	16.5	28.5	1.73
Total	190	718	3.78	Total	55	193	3.51

Table 6-43 Distribution of Forward Self-Citation by the Assignee Country of Original Patent

Aberdeen				Stavanger			
Inventor Country (Original)	No. of Patent	No. of Citation	Citation per Patent	Inventor Country (Original)	No. of Patent	No. of Citation	Citation per Patent
U.S.	40.25	146.83	3.65	U.S.	14.62	50.76	3.47
U.K.	141.72	540.74	3.82	Norway	36.81	131.93	3.58
Total	190	718	3.78	Total	55	193	3.51

Table 6-44 Distribution of Forward Self-Citation by the Inventor Country of Original Patent

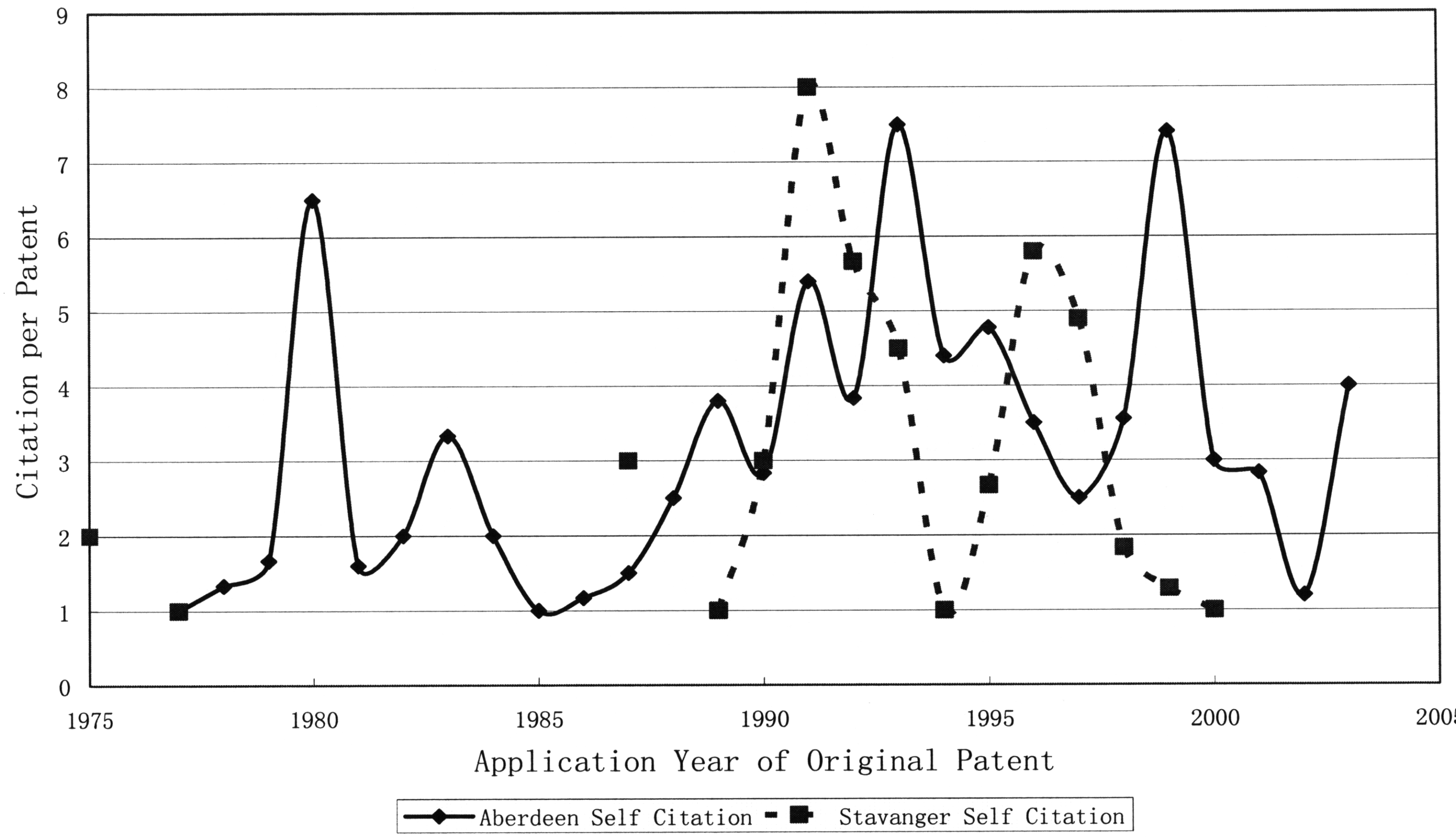

Figure 6-11 Distribution of Forward Self-Citation per Patent by the Application Year of the Original Patent

Distributions of Backward Citation by the Assignee Type of Citation

	Aberdeen				Stavanger			
Citation Assignee Type	No. of Patent	Ratio	No. of Citation	Citation per Patent	No. of Patent	Ratio	No. of Citation	Citation per Patent
Major Contractors	415	51. 11%	1819. 5	4. 38	110	34.92%	563	5. 12
All Other Contractors	504	62.07%	1767	3. 51	142	45.08%	273.75	1. 93
Operators	354	43.60%	897.64	2. 54	154	48.89%	375.7	2. 44
Total	812		9646	11.88	315		3009	9.55

Table 6-45 Distribution of U.S. Patent Backward Citation by the Assignee Type of Citation

Aberdeen							
Citation Assignee Type	Major Contractors		All Other Contractors		Operators		Total
Original Patent Inventor Country	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	No. of Patent
U.S.	68.39%	3.72	74.61%	2.27	55.96%	1.71	193
U.K.	51.11%	3.01	62.07%	2.69	43.60%	1.91	812
Total	51.11%	4.38	62.07%	3.51	43.60%	2.54	812
Stavanger							
Citation Assignee Type	Major Contractors		All Other Contractors		Operators		Total
Original Patent Inventor Country	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	No. of Patent
U.S.	66.07%	5.83	67.86%	1.69	58.93%	1.88	56
Norway	34.92%	2.91	45.08%	1.31	48.89%	1.77	315
Total	34.92%	5.12	45.08%	1.93	48.89%	2.44	315

Table 6-46 Distribution of Backward Citing Interests by the Assignee Type of the Citation and the Inventor Country of the Original Patent

Distributions of Forward Citation by the Assignee Type of Citation

	Aberdeen				Stavanger			
Citation Assignee Type	No. of Patent	Ratio	No. of Citation	Citation per Patent	No. of Patent	Ratio	No. of Citation	Citation per Patent
Major Contractors	323	53.30%	2134.5	6.61	89	38.70%	437	4.91
All Other Contractors	342	56.44%	1144.5	3.35	79	34.35%	149.16	1.89
Operators	124	20.46%	709.3	5.72	75	32.61%	207.33	2.76
Total	606		5545	9.15	230		1470	6.39

Table 6-47 Distribution of Forward Citation by the Assignee Type of the Citation

Aberdeen							
Citation Assignee Type	Major Contractors		All Other Contractors		Operators		Total
Original Patent Assignee Country	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	No. of Patent
U.S.	62.12%	7.12	60.41%	3.38	20.82%	6.75	293
U.K.	40.35%	6.60	51.32%	3.61	19.74%	5.08	228
Total	52.15%	6.88	57.01%	3.49	20.37%	5.91	535
Stavanger							
Citation Assignee Type	Major Contractors		All Other Contractors		Operators		Total
Original Patent Assignee Country	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	No. of Patent
U.S.	58.44%	6.23	37.66%	2.29	33.77%	2.48	77
Norway	29.60%	3.62	35.20%	1.57	34.40%	3.05	125
Total	40.58%	5.00	35.27%	1.95	33.33%	2.90	207

Table 6-48 Distribution of Forward Citing Interests by the Assignee Type of the Citation and the Assignee Country of the Original Patent

Aberdeen							
Citation Assignee Type	Major Contractors		All Other Contractors		Operators		Total
Original Patent Inventor Country	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	No. of Patent
U.S.	68.53%	3.88	56.64%	1.42	16.78%	4.93	143
U.K.	53.30%	5.30	56.44%	2.85	20.46%	4.70	606
Total	53.30%	6.61	56.44%	3.35	20.46%	5.72	606
Stavanger							
Citation Assignee Type	Major Contractors		All Other Contractors		Operators		Total
Original Patent Inventor Country	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	No. of Patent
U.S.	65.22%	3.47	41.30%	1.31	32.61%	1.82	46
Norway	38.70%	3.49	34.35%	1.32	32.61%	2.29	230
Total	38.70%	4.91	34.35%	1.89	32.61%	2.76	230

Table 6-49 Distribution of Forward Citing Interests by the Assignee Type of Citation and the Inventor Country of the Original Patent

Distributions of Backward Citation by the Assignee Country of Citation

	Aberdeen				Stavanger			
Citation Assignee Country	No. of Patent	Ratio	No. of Citation	Citation per Patent	No. of Patent	Ratio	No. of Citation	Citation per Patent
U.S.	785	97.15%	6997	8.91	299	96.14%	2081.5	6.96
U.K./Norway	243	30.07%	521	2.14	58	18.65%	76.5	1.32
France	151	18.69%	209.5	1.39	64	20.58%	116	1.81
Total	808		8264	10.23	311		2567	8.25

Table 6-50 Distribution of U.S. Patent Backward Citation by the Assignee Country of Citation

Aberdeen							
Citation Assignee Country	U.S.		U.K.		France		Total
Original Patent Assignee Type	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	No. of Patent
Major Contractors	98.52%	15.71	36.45%	3.36	23.15%	1.44	203
All Other Contractors	96.61%	7.44	30.54%	1.70	15.61%	1.40	442
Operators	100.00%	3.80	21.15%	1.18	25.00%	1.46	52
Total	97.15%	8.91	30.07%	2.14	18.69%	1.39	808
Stavanger							
Citation Assignee Country	U.S.		Norway		France		Total
Original Patent Assignee Type	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	No. of Patent
Major Contractors	98.33%	14.54	15.00%	1.11	28.33%	2.24	60
All Other Contractors	97.09%	6.30	16.50%	1.11	21.36%	1.73	103
Operators	96.46%	4.09	21.24%	1.39	16.81%	1.58	113
Total	96.14%	6.96	18.65%	1.32	20.58%	1.81	311

Table 6-52 Distribution of Backward Citing Interests by the Assignee Country of the Citation and the Assignee Type of the Original Patent

Aberdeen							
Citation Assignee Country	U.S.		U.K.		France		Total
Original Patent Inventor Country	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	No. of Patent
U.S.	99.48%	8.92	37.31%	1.31	21.76%	0.92	193
U.K.	97.15%	6.35	30.07%	1.64	18.69%	1.08	808
Total	97.15%	8.91	30.07%	2.14	18.69%	1.39	808
Stavanger							
Citation Assignee Country	U.S.		Norway		France		Total
Original Patent Inventor Country	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	No. of Patent
U.S.	100.00%	9.39	10.71%	0.63	32.14%	1.75	56
Norway	96.14%	4.70	18.65%	1.22	20.58%	1.18	311
Total	96.14%	6.96	18.65%	1.32	20.58%	1.81	311

Table 6-52 Distribution of Backward Citing Interests by the Assignee Country of the Citation and the Inventor Country of the Original Patent

Distributions of Forward Citation by the Assignee Country of Citation

	Aberdeen				Stavanger			
Citation Assignee Country	No. of Patent	Ratio	No. of Citation	Citation per Patent	No. of Patent	Ratio	No. of Citation	Citation per Patent
U.S.	550	93.54%	4544.5	8. 26	197	89.55%	1075	5. 46
U.K./Norway	155	26.36%	232.5	1. 50	46	20.91%	74.5	1. 62
Total	588		5099	8.67	220		1302	5.92

Table 6-53 Distribution of Forward Citation by the Assignee Country of the Citation

Aberdeen					
Citation Assignee Country	U.S.		U.K.		Total
Original Patent Assignee Type	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	No. of Patent
Major Contractors	97.73%	11.66	21.21%	1.39	132
All Other Contractors	92.81%	7.49	25.63%	1.55	320
Operators	95.83%	7.13	37.50%	1.56	48
Total	93.54%	8.26	26.36%	1.50	588
Stavanger					
Citation Assignee Country	U.S.		Norway		Total
Original Patent Assignee Type	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	No. of Patent
Major Contractors	91.84%	8.93	8.16%	1.13	49
All Other Contractors	88.06%	4.50	23.88%	1.02	67
Operators	88.61%	4.59	29.11%	2.17	79
Total	89.55%	5.46	20.91%	1.62	220

Table 6-54 Distribution of Forward Citing Interests by the Assignee Country of the Citation and the Assignee Type of the Original Patent

Aberdeen					
Citation Assignee Country	U.S.		U.K.		Total
Original Patent Inventor Country	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	No. of Patent
U.S.	96.45%	5.33	17.73%	0.92	141
U.K.	93.54%	6.75	26.36%	1.32	588
Total	93.54%	8.26	26.36%	1.50	588
Stavanger					
Citation Assignee Country	U.S.		Norway		Total
Original Patent Inventor Country	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	No. of Patent
U.S.	95.65%	4.78	10.87%	0.57	46
Norway	89.55%	4.00	20.91%	1.52	220
Total	89.55%	5.46	20.91%	1.62	220

Table 6-55 Distribution of Forward Citing Interests by the Assignee Country of Citation and the Inventor Country of the Original Patent

Distributions of Backward Citation by the Inventor Country of Citation

	Aberdeen				Stavanger			
Citation Inventor Country	No. of Patent	Ratio	No. of Citation	Citation per Patent	No. of Patent	Ratio	No. of Citation	Citation per Patent
U.S.	796	98.03%	7253.93	9. 11	310	98.41%	2327.73	7. 51
U.K./Norway	427	52.59%	1062.38	2. 49	70	22.22%	90	1. 29
France	198	24.38%	262.17	1. 32	92	29.21%	158.11	1. 72
Total	812		9646	11.88	315		3009	9.55

Table 6-56 Distribution of U.S. patent Backward Citation by the Inventor Country of Citation

Aberdeen							
Citation Inventor Country	U.S.		U.K.		France		Total
Original Patent Assignee Type	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	No. of Patent
Major Contractors	98.04%	15.57	61.76%	3.86	30.39%	1.42	204
All Other Contractors	98.42%	7.73	53.72%	2.04	22.35%	1.28	443
Operators	100.00%	4.42	40.38%	1.22	28.85%	1.40	52
Total	98.03%	9.11	52.59%	2.49	24.38%	1.32	812
Stavanger							
Citation Inventor Country	U.S.		Norway		France		Total
Original Patent Assignee Type	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	No. of Patent
Major Contractors	98.36%	15.57	21.31%	1.14	39.34%	2.32	61
All Other Contractors	98.08%	6.92	17.31%	1.00	25.96%	1.63	104
Operators	98.25%	4.46	25.44%	1.43	28.07%	1.36	114
Total	98.41%	7.51	22.22%	1.29	29.21%	1.72	315

Table 6-57 Distribution of Backward Citing Interests by the Inventor Country of the Citation and the Assignee Type of the Original Patent

Aberdeen							
Citation Inventor Country	U.S.		U.K.		France		Total
Original Patent Assignee Country	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	No. of Patent
U.S.	98.56%	12.95	62.59%	3.09	28.06%	1.30	417
U.K.	97.59%	4.86	42.96%	1.58	20.62%	1.38	291
Total	98.07%	9.60	54.41%	2.56	24.93%	1.33	726
Stavanger							
Citation Inventor Country	U.S.		Norway		France		Total
Original Patent Assignee Country	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	No. of Patent
U.S.	97.78%	13.30	15.56%	1.13	32.22%	2.26	90
Norway	98.94%	5.27	25.00%	1.26	28.72%	1.31	188
Total	98.23%	7.91	21.20%	1.26	30.04%	1.76	283

Table 6-58 Distribution of Backward Citing Interests by the Inventor Country of the Citation and the Assignee Country of the Original Patent

Aberdeen							
Citation Inventor Country	U.S.		U.K.		France		Total
Original Patent Inventor Country	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	No. of Patent
U.S.	99.48%	9.47	64.77%	1.47	31.09%	0.90	193
U.K.	98.03%	6.46	52.59%	1.93	24.38%	1.00	812
Total	98.03%	9.11	52.59%	2.49	24.38%	1.32	812
Stavanger							
Citation Inventor Country	U.S.		Norway		France		Total
Original Patent Inventor Country	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	No. of Patent
U.S.	100.00%	10.07	12.50%	0.74	35.71%	1.88	56
Norway	98.41%	5.19	22.22%	1.17	29.21%	1.20	315
Total	98.41%	7.51	22.22%	1.29	29.21%	1.72	315

Table 6-59 Distribution of Backward Citing Interests by the Inventor Country of the Citation and the Inventor Country of the Original Patent

Distributions of Forward Citation by the Inventor Country of Citation

	Aberdeen				Stavanger			
Citation Inventor Country	No. of Patent	Ratio	No. of Citation	Citation per Patent	No. of Patent	Ratio	No. of Citation	Citation per Patent
U.S.	555	91.58%	3995.72	7.20	195	84.78%	1038.67	5.33
U.K./Norway	336	55.45%	879.97	2.62	66	28.70%	101.65	1.54
Total	606		5545	9.15	230		1470	6.39

Table 6-60 Distribution of Forward Citation by the Inventor Country of the Citation

Aberdeen					
Citation Inventor Country	U.S.		U.K.		Total
Original Patent Assignee Country	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	No. of Patent
U.S.	92.15%	8.38	59.04%	2.59	293
U.K.	89.47%	6.29	52.19%	2.93	228
Total	91.03%	7.43	55.89%	2.70	535
Stavanger					
Citation Inventor Country	U.S.		Norway		Total
Original Patent Assignee Country	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	No. of Patent
U.S.	90.91%	7.48	15.58%	1.10	77
Norway	80.00%	3.87	37.60%	1.68	125
Total	84.54%	5.41	28.50%	1.58	207

Table 6-61 Distribution of Forward Citing Interests by the Inventor Country of the Citation and the Assignee Country of the Original Patent

Aberdeen					
Citation Inventor Country	U.S.		U.K.		Total
Original Patent Inventor Country	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	No. of Patent
U.S.	95.80%	4.99	50.35%	1.00	143
U.K.	91.58%	5.81	55.45%	2.36	606
Total	91.58%	7.20	55.45%	2.62	606
Stavanger					
Citation Inventor Country	U.S.		Norway		Total
Original Patent Inventor Country	Ratio of Patent	Citation per Patent	Ratio of Patent	Citation per Patent	No. of Patent
U.S.	95.65%	4.70	15.22%	0.60	46
Norway	84.78%	3.91	28.70%	1.42	230
Total	84.78%	5.33	28.70%	1.54	230

Table 6-62 Distribution of Forward Citing Interests by the Inventor Country of the Citation and the Inventor Country of the Original Patent

The Study of Originality and Generality

The ORIGINALITY describes the level of technological concentration of the backward citations of the original patents. A larger ORIGINALITY score (close to 1) implies broader technological roots of the underlying patents.

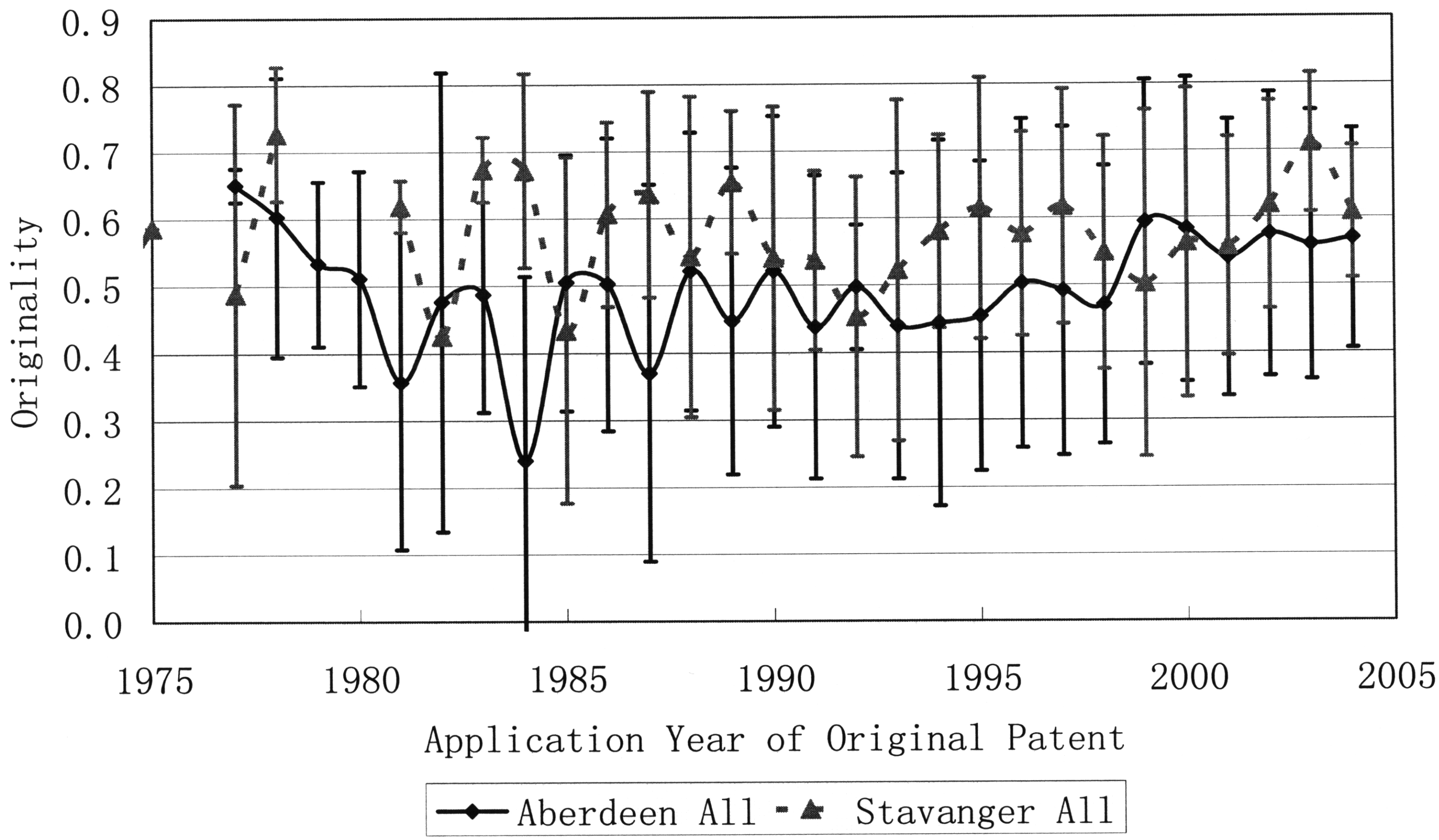

Figure 6-12 Distribution of ORIGINALITY by the Application Year of the Original Patent

The GENERALITY reflects the extent to which the forward citations of the original patent spread across different technical fields. A larger GENERALITY score (close to 1) implies that the underlying patents may have a more widespread impact because they influence subsequent innovations in a variety of technical fields.

	Aberdeen		Stavanger	
	Generality	Error	Generality	Error
All Citation	0.39	0.26	0.50	0.27
Self-Citation	0.24	0.35	0.33	0.29

Table 6-63 GENERALITY of Forward Citation

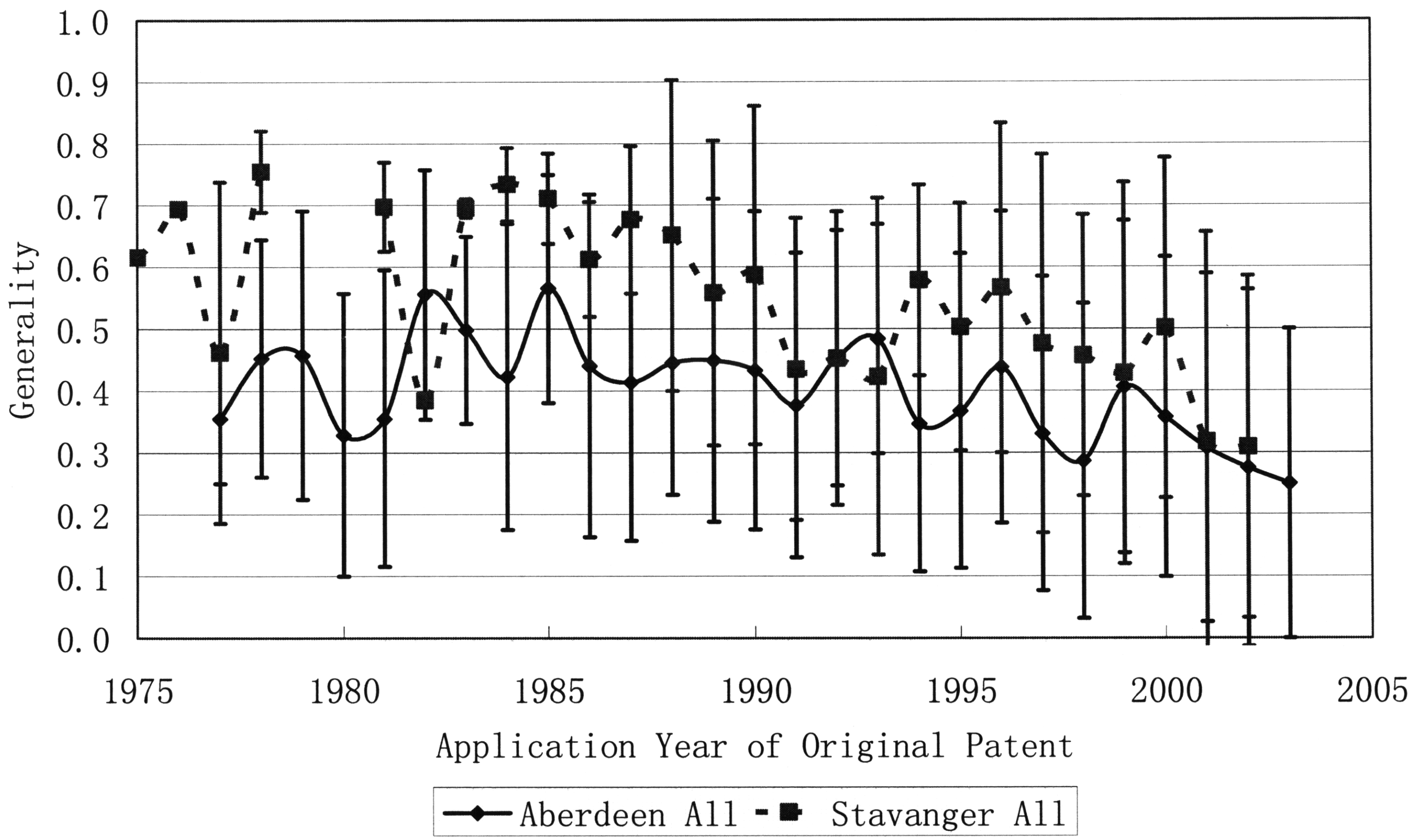

Figure 6-13 Distribution of GENERALITY by the Application Year of the Original Patent

The Study of Time Lags

Aberdeen				
	All Citation		Self-Citation Only	
	Time Distance (month)	Error	Time Distance (month)	Error
Backward Citation	45	45	60	69
Forward Citation	32	27	40	40
Stavanger				
Backward Citation	50	47	47	52
Forward Citation	33	30	37	38

Table 6-64 Time Difference between the Original Patent and the Earliest Citation

The Study of Geographical Reach

Geographical reach describes the extent to which the citations by the original patent spread across different geographical locations. A large score for geographical reach (close to 1) implies that the underlying patents may have citations from wider geographical bases.

	Aberdeen		Stavanger	
	Geographical Spread	Error	Geographical Spread	Error
All Citation	0.26	0.22	0.24	0.21
Self-Citation	0.14	0.21	0.13	0.21

Table 6-65 Geographical Spread of Backward Citation

	Aberdeen		Stavanger	
	Geographical Spread	Error	Geographical Spread	Error
All Citation	0.27	0.23	0.24	0.24
Self-Citation	0.23	0.23	0.22	0.24

Table 6-66 Geographical Spread of Forward Citation

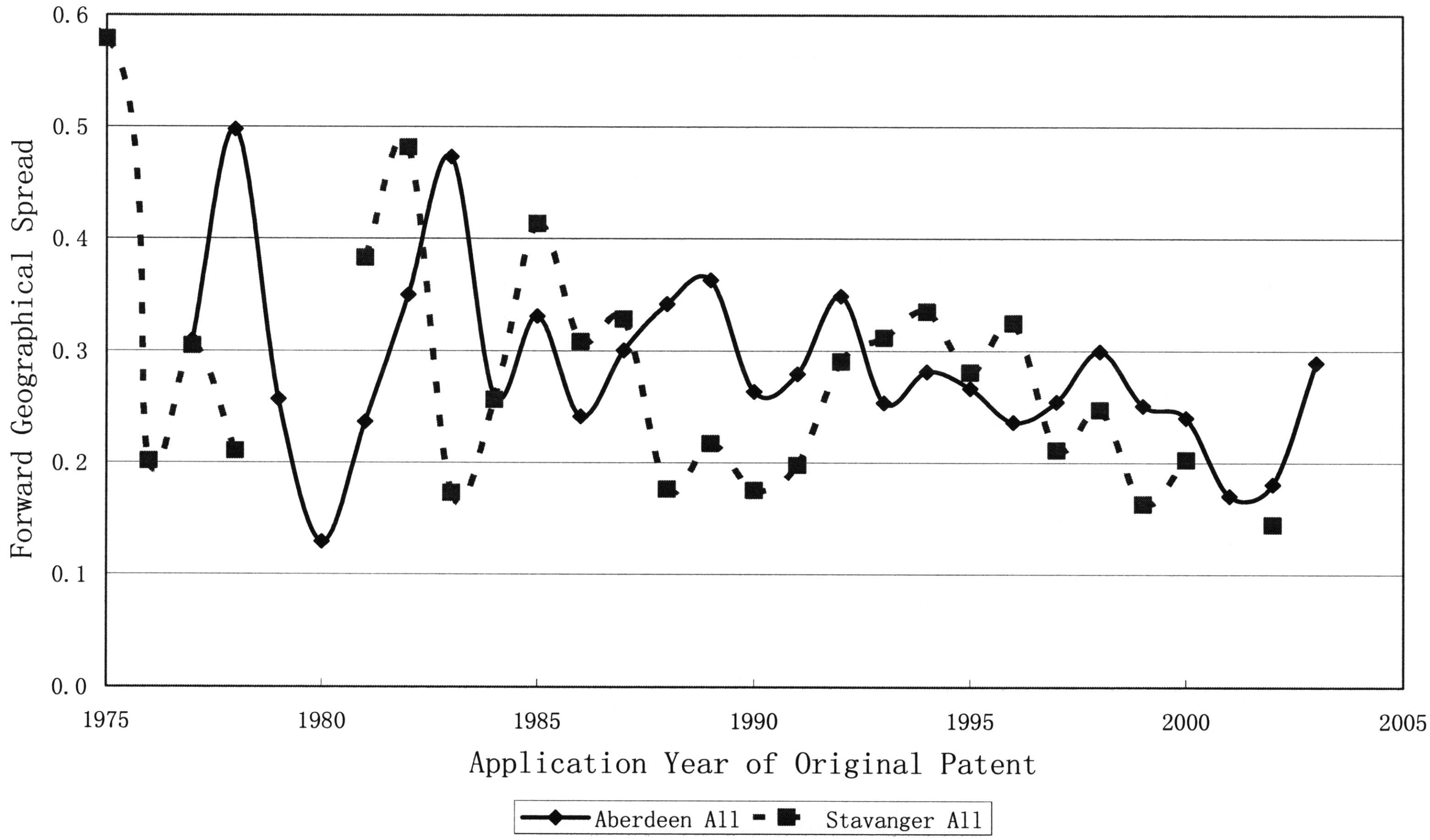

Figure 6-14 Distribution of Geographical Spread of the Forward Citation by the Application Year of the Original Patent

Distribution of Backward Citation by the Geographical Distance

	Aberdeen				Stavanger			
Geographical Distance	No. of Patent	Ratio	No. of Citation	Citation per Patent	No. of Patent	Ratio	No. of Citation	Citation per Patent
Local	253	31.23%	586	2.32	42	13.33%	55	1.31
National	395	48.77%	3321	8.41	104	33.02%	993	9.55
Continental	390	48.15%	1138	2.92	190	60.32%	455	2.39
International	635	78.40%	4475	7.05	259	82.22%	1506	5.81
Total	810		9520	11.75	315		3009	9.55

Table 6-67 Distribution of Backward Citation by the Geographical Distance

		Aberdeen		Stavanger	
Assignee Type (Original)	Geographical Distance	No. of Patent	Ratio	No. of Patent	Ratio
Major Contractors	Local	83	40.79%	9	14.75%
	National	141.5	69.53%	37	60.66%
	Continental	120	58.97%	37	60.66%
	International	121	59.46%	28	45.90%
All Other Contractors and Suppliers	Local	139	31.59%	8.17	8.15%
	National	196.5	44.66%	25.17	25.12%
	Continental	197	44.77%	59.67	59.57%
	International	367.5	83.52%	92.17	92.01%
Operators	Local	8	15.53%	17.33	15.71%
	National	20	38.83%	31.83	28.85%
	Continental	22	42.72%	64.33	58.31%
	International	46.5	90.29%	97.33	88.22%
Total	Local	253	31.23%	42	13.33%
	National	395	48.77%	104	33.02%
	Continental	390	48.15%	190	60.32%
	International	635	78.40%	259	82.22%

Table 6-68 Distribution of the Backward Citing interests by the Geographical Distance and the Assignee Type of the Original Patent

		Aberdeen		Stavanger	
Inventor Country (Original)	Geographical Distance	No. of Patent	Ratio	No. of Patent	Ratio
U.S.	Local	49.35	44.36%	4.05	12.43%
	National	110.59	99.40%	32.57	100.00%
	Continental	65.43	58.81%	18.29	56.16%
	International	20.15	18.11%	2.55	7.82%
U.K./Norway	Local	192.58	28.60%	35.42	13.43%
	National	266.52	39.58%	61.81	23.44%
	Continental	311.23	46.21%	162.99	61.82%
	International	596.71	88.61%	240.98	91.40%
Total	Local	253	31.23%	42	13.33%
	National	395	48.77%	104	33.02%
	Continental	390	48.15%	190	60.32%
	International	635	78.40%	259	82.22%

Table 6-69 Distribution of the Backward Citing interests by the Geographical Distance and the Inventor Country of the Original Patent

Distribution of Forward Citation by Geographical Distance

	Aberdeen				Stavanger			
Geographical Distance	No. of Patent	Ratio	No. of Citation	Citation per Patent	No. of Patent	Ratio	No. of Citation	Citation per Patent
Local	230	38.08%	712	3.10	40	17.39%	58	1.45
National	289	47.85%	1458	5.04	87	37.83%	450	5.17
Continental	221	36.59%	539	2.44	112	48.70%	264	2.36
International	426	70.53%	2741	6.43	160	69.57%	696	4.35
Total	604		5450	9.02	230		1468	6.38

Table 6-70 Distribution of Forward Citation by the Geographical Distance

		Aberdeen		Stavanger	
Assignee Type (Original)	Geographical Distance	No. of Patent	Ratio	No. of Patent	Ratio
Major Contractors	Local	59	44.19%	6	12.24%
	National	87.5	65.54%	29	59.18%
	Continental	46	34.46%	21	42.86%
	International	63	47.19%	20	40.82%
All Other Contractors and Suppliers	Local	120	36.47%	10.5	15.33%
	National	144.5	43.92%	22	32.12%
	Continental	119.5	36.32%	34.5	50.36%
	International	244.5	74.32%	51.5	75.18%
Operators	Local	17	35.05%	19	23.60%
	National	23	47.42%	27	33.54%
	Continental	20.5	42.27%	40.5	50.31%
	International	42.5	87.63%	62	77.02%
Total	Local	230	38.08%	40	17.39%
	National	289	47.85%	87	37.83%
	Continental	221	36.59%	112	48.70%
	International	426	70.53%	160	69.57%

Table 6-71 Distribution of the Forward Citing interests by the Geographical Distance and the Assignee Type of the Original Patent

		Aberdeen		Stavanger	
Inventor Country (Original)	Geographical Distance	No. of Patent	Ratio	No. of Patent	Ratio
U.S.	Local	31.37	38.22%	2.75	10.27%
	National	80.17	97.67%	25.47	95.14%
	Continental	24.82	30.23%	13.10	48.93%
	International	4.59	5.59%	2.17	8.09%
U.K.	Local	192.22	38.16%	36.75	19.61%
	National	198.30	39.37%	54.06	28.84%
	Continental	189.98	37.72%	90.93	48.51%
	International	411.58	81.71%	146.86	78.35%
Total	Local	230	38.08%	40	17.39%
	National	289	47.85%	87	37.83%
	Continental	221	36.59%	112	48.70%
	International	426	70.53%	160	69.57%

Table 6-72 Distribution of the Forward Citing interests by the Geographical Distance and the Inventor Country of the Original Patent

The Study of Scientific Citation

	Other Reference					Patent Backward Citation		
	No. of Patent	Ratio	No. of Reference	Reference per Patent	Reference /Citation	No. of Patent	No. of Citation	Citation per Patent
Aberdeen	251	30.65%	1189	4.74	0.08	819	15553	18.99
Stavanger	79	24.38%	282	3.57	0.06	324	4678	14.44

Table 6-73 the Numbers of Other Reference

Distributions of Other Reference by the Type of Citation

Aberdeen								
	Academic Journal				Conference and Symposium			
Inventor Country	No. of Patent	Ratio	No. of Reference	Reference per Patent	No. of Patent	Ratio	No. of Reference	Reference per Patent
U.S.	20.4	18.25%	107.33	5.26	7	6.26%	10.81	1.55
U.K.	61.63	9.04%	156.94	2.55	13.12	1.92%	19.64	1.5
Total	83.18	10.16%	275.63	3.31	20.9	2.55%	31.9	1.53
	Magazine				Total			
Inventor Country	No. of Patent	Ratio	No. of Reference	Reference per Patent	No. of Patent		No. of Reference	
U.S.	12.12	10.84%	23.63	1.95	111.76		367.07	
U.K.	24.37	3.57%	37.58	1.54	681.94		766.13	
Total	37.63	4.59%	63.49	1.69	819		1,163.29	
Stavanger								
	Academic Journal				Conference and Symposium			
Inventor Country	No. of Patent	Ratio	No. of Reference	Reference per Patent	No. of Patent	Ratio	No. of Reference	
U.S.	10.35	30.53%	34.95	3.38	2.77	8.17%	5.87	2.12
Norway	20.82	7.69%	53.55	2.57	2.65	0.98%	4.55	1.72
Total	34	10.49%	108	3.18	6.25	1.93%	11.25	1.8
	Magazine				Total			
Inventor Country	No. of Patent	Ratio	No. of Reference	Reference per Patent	No. of Patent		No. of Reference	Reference per Patent
U.S.	3.43	10.12%	4.26	1.24	33.90		79.64	
Norway	6.29	2.32%	6.45	1.03	270.66		165.79	
Total	10	3.09%	11	1.1	324		280.5	

Table 6-74 Distribution of Other Reference by the Type of Citation and the Inventor Country of the Original Patent

References from the Society of Petroleum Engineers (SPE)

Aberdeen						
		Patents with Other Reference		Other Reference		
Reference	Type of Reference	Number	Ratio	Number	Ratio	Reference per Patent
SPE	Academic Journal or Organization	45	40.18%	116	30.37%	2.58
World Oil	Magazine	12	10.71%	24	6.28%	2
Oil and Gas Journal	Magazine	16	14.29%	21	5.50%	1.31
Experimental Mechanics	Academic Journal or Organization	1	0.89%	18	4.71%	18
OTC Offshore Technology Conference	Conference	6	5.36%	15	3.93%	2.5
Total		112		382		3. 41
Stavanger						
		Patents with Other Reference		Other Reference		
Source of Reference	Type of Reference	Number	Ratio	Number	Ratio	Reference per Patent
SPE	Academic Journal or Organization	13	31.71%	32	24.43%	2.46
Geophysics	Academic Journal or Organization	8	19.51%	9	6.87%	1.13
SEG	Academic Journal or Organization	2	4.88%	9	6.87%	4.5
The Leading Edge	Academic Journal or Organization	3	7.32%	7	5.34%	2.33
World Oil	Magazine	5	12.20%	6	4.58%	1.2
Total		41		131		3. 20

Table 6-75 Distribution of Other Reference by the Source of Citation

Aberdeen							
	SPE				Total		
Assignee Country	No. of Patent	Ratio	No. of Reference	Reference per Patent	No. of Patent	No. of Reference	
U.S.	39	9.39%	110	2.82	415.5	317	
U.K.	5	1.72%	5	1	291.5	36	
Total	45	6.20%	116	2.58	726	375	
Stavanger							
	SPE				Total		
Assignee Country	No. of Patent	Ratio	No. of Reference	Reference per Patent	No. of Patent	No. of Reference	
U.S.	7	7.61%	23	3.29	92	87	
Norway	5	2.70%	8	1.6	185	40.5	
Total	13	4.48%	32	2.46	290.5	131	

Table 6-76 Distribution of SPE Reference by the Assignee Country of the Original Patent

Aberdeen							
	SPE				Total		
Inventor Country	No. of Patent	Ratio	No. of Reference	Reference per Patent	No. of Patent	No. of Reference	
U.S.	16.27	14.56%	41.86	2.57	111.76	141.77	
U.K.	26.93	3.95%	66.86	2.48	681.94	214.16	
Total	43.85	5.35%	114.28	2.61	819	371.02	
Stavanger							
	SPE				Total		
Inventor Country	No. of Patent	Ratio	No. of Reference	Reference per Patent	No. of Patent	No. of Reference	
U.S.	2.97	8.76%	8.3	2.8	33.90	45.08	
Norway	7.53	2.78%	14.2	1.88	270.66	64.55	
Total	13	4.01%	32	2.46	324	130.25	

Table 6-77 Distribution of SPE Reference by the Inventor Country of the Original Patent

The Variation of Regression Results across Time Periods

Time Period of the Original Patent		Aberdeen		Stavanger	
	Estimator	Result	Error	Result	Error
>=1987	Delta	6.2E-04	7.2E-05	9.3E-04	2.1E-04
	Beta	0.074	0.015	0.166	0.052
<1987	Delta	3.2E-03	2.1E-03	6.3E-04	6.9E-04
	Beta	0.934	0.500	0.116	0.231

Table 6-78 Variation of Regression Results of Backward Citation across Different Time Periods of the Original Patents

Time Period of the Citation		Aberdeen		Stavanger	
	Estimator	Result	Error	Result	Error
>=1987	Delta	5.3E-04	9.7E-05	9.0E-04	3.0E-04
	Beta	0.013	0.026	0.114	0.074
<1987	Delta	6.0E-04	1.2E-04	4.2E-04	2.3E-04
	Beta	0.124	0.029	0.124	0.078

Table 6-79 Variation of Regression Results of Backward Citation across Different Time Periods of the Citations

Time Period of the Original Patent		Aberdeen		Stavanger	
	Estimator	Result	Error	Result	Error
>=1987	Delta	8.5E-05	1.0E-03	3.3E-04	5.0E-04
	Beta	0.025	0.153	0.085	0.022
<1987	Delta	1.9E-04	1.1E-03	7.0E-04	7.2E-04
	Beta	0.025	0.063	0.069	0.037

Table 6-80 Variation of Regression Results of Forward Citation across Different Time Periods of the Original Patent

Time Period of the Citation		Aberdeen		Stavanger	
	Estimator	Result	Error	Result	Error
>=1987	Delta	4.9E-04	6.9E-05	8.1E-04	2.5E-04
	Beta	0.016	0.015	0.089	0.054
<1987	Delta	5.9E-04	5.2E-04	1.1E-03	1.8E-03
	Beta	-0.063	0.167	0.003	0.315

Table 6-81 Variation of Regression Results of Forward Citation across Different Time Periods of the Citations

Chapter 7 Conclusions

It has been nearly forty years since the initial discoveries of oil and gas in the North Sea. During this period, the cities of Stavanger in Norway and Aberdeen in Scotland have experienced a significant economic transition and are now strongly focused on oil and gas development. Prior to the oil and gas discoveries, both cities had long served as important regional economic centers, but neither was energy-focused.

After decades of oil and gas exploration and production, both Stavanger and Aberdeen are today facing a new challenge because the precious natural resources in the North Sea are expected to be depleted at some point. Oil and gas production from the U.K. peaked around 2000. With greater proven and probable reserves, the production of oil from the Norwegian continental shelf peaked a few years later. Given these developments, a second economic transition will have to be made if the two cities are to survive and prosper as oil and gas production decline.

When the first transition started in the 1960s, Stavanger and Aberdeen both took steps to restructure their local systems of technological development and application so that they could adapt to a natural resource-based economy. These actions helped Stavanger and Aberdeen realize the first transition successfully and both cities emerged as national centers of the oil and gas industry. The local innovation systems in Stavanger and Aberdeen will also likely play a critical role in helping the two local economies negotiate the inevitable decline of oil and gas production.

The principal goals of this research are to evaluate and compare the local innovation capabilities of Stavanger and Aberdeen. The study has explored how technical knowledge from elsewhere was acquired and introduced into the two local innovation systems, how and to what extent local innovation capabilities were developed, and how knowledge created locally has spread elsewhere.

Our study shows, first, that the local economies in Stavanger and Aberdeen had many common features before the regional economic environment changed.

Before the initial discoveries of oil and gas, Stavanger and Aberdeen had served as hubs of their respective regional economies for centuries. Both had at most a very limited relationship to the oil and gas industry. Given that the two cities were starting essentially from scratch and with very limited relevant knowledge, neither they nor their national governments had the ability to build up the local oil and gas sector on their own. The local developers in both Stavanger and Aberdeen sought help from the world's most advanced industry players. They put strong emphasis on learning from outside of the region, especially from the U.S. This was an effective way to bring a large amount of essential knowledge into the region within a short period at low cost. However, the evidence also suggests that in both cities local firms paid less attention than their locally-based foreign counterparts to locally-generated knowledge resources that were also accumulating during this period. This appears to have been particularly true in Stavanger, where the local developers essentially ignored the knowledge created by the locally-based U.S. companies.

On the other hand, the very large proven reserves of oil and gas in the North Sea and the enormous potential benefits from exploration and production also attracted many international players to both Stavanger and Aberdeen. The majority of foreign companies in both locations were U.S. firms. The number of U.S. firms that operated in the two regions increased gradually over the years. As the market grew bigger and more mature, more and more small oil firms followed in the footsteps of the giants. As the foreign firms grew more confident about the future of the local economies, some of them were happy to strengthen their local capabilities so as to capture the potential rewards. The industry's four leading integrated service providers all greatly expanded their innovation capacities in the North Sea region.

The participation of multinational firms in the local innovation systems helped reinforce local innovation capabilities. Our study shows that in both Stavanger and Aberdeen, the presence of U.S. firms not only helped to bring in advanced knowledge from outside, but also served to educate local communities. When the U.S. firms arrived, they brought their own technology and experience with them, and were also instrumental in transferring advanced technology into the region from elsewhere. After setting up local branches, U.S. firms drew intensively on local researchers and inventors in both regions. In this way, many local people were trained in an advanced innovation system, and their research skills were raised.

Besides learning from advanced players from outside the region, firms in both Stavanger and Aberdeen tried to build up their own innovation capabilities. One indication of these accumulating capabilities is that the number of U.S. patents granted to domestic assignees in both city regions has been increasing much faster than the overall rate of increase of U.S. patents. However, there is also evidence to suggest that most of the domestic firms were small and had very limited capability to expand their business globally. For most of this period, they were only able to conduct their research and development locally.

In addition to these similarities, there have also been significant differences in government policies at the national and local levels with respect to local innovation capability-building.

Since the initial oil discoveries were made, the policies of the Norwegian central government have consistently focused on developing national and regional innovation capabilities. These policies have helped to protect the relatively small Norwegian economy from being overwhelmed by foreign multinational firms, and have also provided a measure of control of the local system. The tax system in Norway has promoted R&D spending by classifying R&D-related costs as immediately deductible at a special tax rate of 78%, which implies that the state covers 78% of the costs. The central government has taken a direct role in funding industry-relevant research. Public funding accounted for a significant fraction of total industry R&D for years. The Norwegian national government also helped establish a national oil firm, Statoil, in 1972, and later acquired majority ownership of Norsk Hydro. Today these companies are two of Norway's largest firms and they have played critical roles in building local innovation capabilities. The local Stavanger government also made major contributions to the development of local infrastructure, including human capital, by establishing both the University of Stavanger and Rogaland Research and the adjacent Research Park.

The policy of the U.K. government was different. Because of the massive balance of payment deficits and high unemployment during the initial period of North Sea oil development, the U.K. adopted a fast depletion policy in the early years. An important aspect of this policy was to encourage foreign companies to enter the oil business on the United Kingdom continental shelf (UKCS) quickly and easily. In pursuit of this goal, both the national and local governments focused on enticing foreign companies to come to Aberdeen, and they continued to do this until the mid 1980s. It was only in the mid-1980s that the focus of policy changed to innovation (Hatakenaka et al 2006). The research and technology policies pursued in the U.K. were also different from those in Stavanger. The U.K. authorities chose to give industry great flexibility to make their own R&D decisions. Government support for R&D was mainly limited to licensing and regulatory-related issues.

In part because of these policy differences, the structures of the local innovation systems that have developed in Stavanger and Aberdeen are different. The rapid depletion policy carried out in the U.K. made it easier for multinational firms to move into the region. The findings of the current study confirm this. U.S. firms, the international leaders in the petroleum engineering field, have played more important roles in Aberdeen than in Stavanger. They have made much greater contributions to patenting activities in Aberdeen than in Stavanger. This is particularly clear when we look at small U.S. contractors, which have been granted 189 U.S. patents in Aberdeen, but only 10 in Stavanger.

In the Stavanger region, as a direct result of the government's strong intention to build local innovation capabilities, innovation activities have been led by a few national oil companies, such as Statoil and Norsk Hydro. After thirty years of development, these two firms have become the leading operators on the Norwegian continental shelf (NCS) and have played significant roles in industrial innovation as demanding customers, project founders, and providers of information and expertise. The influence of the domestic-innovation-capability-establishment policy has been so strong that even most of the patenting carried out by small contractors has been contributed by Norwegian firms.

The lesser presence of U.S. firms in Stavanger gave European companies a better chance to enter the oil business and to participate in innovation activities in the NCS. Many European firms are not as big as their U.S. counterparts. In order to compete with U.S. companies and win market share, European firms have been more willing to cooperate with local firms than have U.S. firms. To promote knowledge imports, the Norwegian government and local Stavanger industry also set up a much more cooperative environment and brought in more European participants than can be found in Aberdeen. However, after the foreign firms moved in, instead of asking only for capital investment as was the case in Aberdeen, the Norwegian government required continuous knowledge transfer from foreign companies to domestic organizations.

The lesser presence of U.S. firms in Stavanger has also had other side effects. As already mentioned, the presence of U.S. firms in Aberdeen increases the efficiency of knowledge inflow, and provides better training opportunities to local people, and Stavanger has not been able to benefit from these advantages to the same degree. Besides this, multinational companies, especially the leading industry players, also help to promote the use of regionally created knowledge by exploiting their strong international networks and influence. With less involvement by international firms, innovations generated in Stavanger have not received as much attention from the industry as innovations created in Aberdeen.

Reference

Bernstein, I., Garbin, C., and Teng G. 1988. *Applied Multivariate Analysis.* New York: Springer-Verlag, 1988.

Bondt, R. 1996. *Spillovers and Innovative Activities.* International Journal of Industrial Organization 15 (1996) 1-28

Bower, D. Jane. 1992. *Company and Campus Partnership.* London: Routledge.

Bower, D. Jane. 1993. *Successful joint ventures in science parks.* Long Range Planning, 26, 6: 114-120.

Branstetter, L. 1998. *Looking for International Knowledge Spillovers --- A Review of the Literature with Suggestions for New Approaches.* Annales D'Economie ET DE Statistique 49/50 1998

Breznitz, D. 2004. *Diffusion of Academic R&D Capabilities an Industrial Innovation Policy? – the Development of Israel's IT Industry.* MIT IPC-LIS 04-005

Caballero, R., and Jaffe, A. 1993. *How High Are the Giants' Shoulders: An Empirical Assessment of Knowledge Spillovers and Creative Destruction in a Model of Economic Growth. Macroeconomics.* Annual Meeting 1993, National Bureau of Economic Research.

Chakrabarti, A. 2002. *Role of University in the Product Development Process: Strategic Considerations for the Telecommunications Industry.* MIT IPC-LIS 02-003

Chakrabarti, A. and Lester, R. 2002. *Regional Economic Development: Comparative Case Studies in the US and Finland.* MIT IPC-LIS 02-004

Coe, D. and Helpman, E. 1995. *International R&D Spillovers.* European Economic Review, 39(5).

Cohen, W.M. and Levinthal, D.A., 1989. *Innovation and learning: the two faces of R&D.* The Economic Journal 99, pp. 569–596.

Cook, J. 2005. *On Understanding the Increase in U.S. Patent Litigation.* American Law and Economics Review 2007 9(1):48-71

Cooke, P. and K. Morgan. 1998. *The Associational Economy.* New York: Oxford University Press

Fombrun, C. 1996. *Reputation: Realizing Value From The Corporate Image.* Boston: Harvard Business School Press.

Griliches, Z. 1979. *Issues in Accessing the Contribution of Research and Development to Productivity Growth.* Bell Journal of Economics 10:92-116

Griliches, Z. ed. 1984. *R&D, Patent and Productivity.* Chicago: University of Chicago Press.

Griliches, Z. 1990. *Patent Statistics as Economic Indicators: A Survey Part I.* National Bureau of Economic Research Working Paper 3301

Griliches, Z. 1992. *The Search for R&D Spillovers.* Scandinavian Journal of Economics, 94, Supplement, pp. 29-47.

Griliches, Z., and Mairesse, J. 1995. *Production Functions – the Search for Identification.* NBER Working Paper.

Grossman, G.M. and Helpman, E. 1990. *Comparative Advantage and Long-Run Growth.* American Economic Review, vol. 80, No. 4.

Grossman, G.M. and Helpman, E. 1991. *Innovation and Growth in the Global Economy.* Cambridge, MA: MIT Press, 1991

Grossman, G.M. and Helpman, E. 1995. *Technology and Trade.* Handbook of International Economics, vol. 3.

Hall, B. 2004. *University-Industry Research Partnership in the United States.* Kansai Conference Paper February 2004.

Hall, B., Jaffe, A., and Trajtenberg, M. 2001. *The NBER Patent Citations Data File: Lessons, Insights and Methodological Tools.* National Bureau of Economic Research, Working Paper 8498

Hall, B., Link, A., and Scott, J. 2001. *Barriers Inhibiting Industry from Partnering with Universities: Evidence from the Advanced Technology Program.* Journal of Technology Transfer, 26, 87-98, 2001

Hatakenaka, S., Westnes, P., Gjelsvik, M., and Lester, R. 2006. *From 'Black Gold' to 'Human Gold'.* MIT IPC-LIS 06-002

Hatakenaka, S., Westnes, P., Gjelsvik, M., and Lester, R. 2006. *The Regional Dynamics of Innovation: A Comparative Case Study of Oil and Gas Industry Development in Stavanger and Aberdeen.* SPRU 40th Anniversary Conference 2006.

Henderson, R., Jaffe, A., and Trajtenberg, M. 1995. *Universities as a Source of Commercial Technology: A Detailed Analysis of University Patenting 1965-1988.* National Bureau of Economic Research Working Paper 5068

Hu, G.Z. and Jaffe, A. 2003. *Patent Citations and International Knowledge Flow: the Cases of Korea and Taiwan.* International Journal of Industrial Organization 21(2003) 849-880

Jaffe, A., and Trajtenberg, M. 1996. *Flows of Knowledge Spillovers.* Strasbourg Conference on the Economics and Econometrics of Innovation.

Jaffe, A., and Trajtenberg, M. 1998. *International Knowledge Flows: Evidence from Patent Citations.* National Bureau of Economic Research Working Paper 6507

Jaffe, A., and Trajtenberg, M. 2002. *Patent, Citations, and Innovations --- A Window on the Knowledge Economy.* The MIT Press 2002.

Jaffe, A., Trajtenberg, M., and Henderson, R. 1993. *Geographic Localization of Knowledge Spillover as Evidenced by Patent Citations.* The Quarterly Journal of Economics, Vol. 108, No. 3 (Aug., 1993), 577-598.

Kim, J., Lee, S., and Marschke, G. 2005. *The Influence of University Research on Industrial Innovation.* National Bureau of Economic Research, Working Paper 11447

Kolehmainen, J. 2003. *Territorial Agglomeration as a Local Innovation Environment.* MIT IPC-LIS Working Paper 03-002

Kosonen, K.J. 2005. *Strengthening the Research and Educational Basis Regional Development in Less-Favored Regions.* MIT IPC-LIS 05-003

Lester, R. 2005. *Universities, Innovation, and the Competitiveness of Local Economies.* MIT IPC-LIS 05-010

Porter, M. 1990. *The Competitive Advantage of Nations.* Macmillan. London.

Safford, S. 2004. *Searching for Silicon Valley in the Rust Belt: the Evolution of Knowledge Networks in Akron and Rochester.* MIT IPC-LIS 04-002

Safford, S. 2004. *Why the Garden Club Couldn't Save Youngstown: Civic Infrastructure and Mobilization in Economic Crises.* MIT IPC-LIS 04-003

Santoro, M., and Chakrabarti, A. 2002. *Firm Size and Technology Centrality in University-Industry Interactions.* MIT IPC-LIS 02-001

Schankerman, M., and Pakes, A. 1986. *Estimates of the Value of Patent Rights in European Countries During the Post-1950 Period.* Economic Journal 96: 1077-1083.

Schmookler, J. 1996. *Invention and Economic Growth.* Cambridge, MA: Harvard University Press.

Sotarauta, M., and Kosonen, K.J. 2003. *Institutional Capacity and Strategic Adaptation in Less Favored Regions.* MIT IPC-LIS 03-003

Sotarauta, M., and Srinivas, S. 2005. *The Co-Evolution of Policy and Economic Development --- A Discussion on Innovative Regions.* MIT IPC-LIS 05-001

Spence, M., 1984. *Cost reduction, competition and industry performance.* Econometrica 52, pp. 101–121.

Srinivas, S. and Viljamaa K. 2005. *Economic Institutionalization in Practice: Development and the "Third Role" of Universities.* MIT IPC-LIS 05-002

Thompson, P., and Fox-Kean, M. 2004. *Patent Citations and the Geography of Knowledge Spillovers: A Reassessment.* American Economic Review, 95(1):450-460 2005

Trajtenberg, M., Henderson, R., and Jaffe, A. 1992. *Ivory Tower versus Corporate Lab: An Empirical Study of Basic Research and Appropriability.* National Bureau of Economic Research, Working Paper 4146

Aberdeenshire Profile 2007. Aberdeenshire Council

National Science Board. 1996. *Science and Engineering Indicators.* National Science Foundation. Washington, DC: US Government Printing Office.

National Science Board. 2000. *Science and Engineering Indicators.* National Science Foundation. Washington, DC: US Government Printing Office.

Society of Petroleum Engineers' Journal of Petroleum Technology (JPT) 1999. *Frontiers of Technology.* SPE Foundation

WIPO Patent Report --- Statistics on Worldwide Patent Activities. 2007 Edition

www.aberdeenshire.gov.uk

www.aberdeencity.gov.uk

www.ssb.no

www.eia.doe.gov