PhD Thesis : Examination Copy:

University of Tasmania

Sources of inventive activity and the IPR system:

An empirical analysis of a changing relationship in a small open economy (Norway)

Eric James Iversen

2010

Sources of inventive activity and the IPR system: An empirical analysis of a changing relationship in a small open economy (Norway)

Examination copy

by
Eric J. Iversen, BA (University of Chicago) MA (University of Oslo)
Submitted in fulfillment of the
requirements for the Degree of
Doctor of Philosophy (Management)
University of Tasmania (November 2010)

General Declarations

DECLARATION OF ORIGINALITY

This thesis contains no material which has been accepted for a degree or diploma in any other institute, college or university, except by way of background information duly acknowledged in the thesis and, to the best of my knowledge and belief, it contains no material previously published or written by another person except where due acknowledgement is made in the text of the thesis.

……………..……………………..

Eric J. Iversen

November 2010

Statement regarding published work contained in thesis

The publishers of the papers comprising Chapters 2, 3, & 5 hold the copyright for that content, and access to the material should be sought from the respective journals. The remaining non published content of the thesis may be made available for loan and limited copying in accordance with the Copyright Act 1968.

Norwegian patent and trademark databases were made available by the Norwegian Patent Office: European patent data were extracted from EPO Worldwide Patent Statistical Database (Patstat), October 2007 edition. The registry data for Norwegian Firms is put together by Statistics Norway on the bases of firm-level information from the Brønnøysund Register Centre (http://www.brreg.no/english/) register of Norwegian enterprises and companies and the National Insurance Service's (Rikstrygdeverket) registry of active employees and employers.

Data covering Norwegian researchers (Forskerregisteret) was made available by NIFU STEP. All results are anonymized. The external data were linked at the NIFU STEP through an agreement with the Norwegian Statistical Office (SSB). Access to the Community Innovation Survey was also made by agreement with SSB.

STATEMENT OF AUTHORITY OF ACCESS

This thesis may be made available for loan. Copying of any part of this thesis is prohibited for two years from the date this statement was signed; after that time limited copying is permitted in accordance with the Copyright Act 1968.

…………………………………….

Eric J. Iversen, November 2010

Statement regarding published work

This thesis includes 3 original papers published in peer reviewed journals (1) and peer reviewed book chapters (2) as well as 3 unpublished essays. The core theme of the thesis is <<The patent system and patterns of innovation>>. The ideas, development and writing up of all the papers in the thesis were the principal responsibility of myself, the candidate, working within the AIRC under the supervision of Jonathan West and Keith Smith.

In the case of Chapter 5 my contribution to the work involved the following: initiator and active contributor to the conception and design of the study, head responsibility for the compilation of the database and its analysis, and was the leading contributor of the text as published.

Thesis chapter	Publication title	Publication status*	Nature and extent of candidate's contribution
2	IPRs and Norwegian enterprises: diversification of innovative efforts in Norwegian firms	Published book chapter (peer reviewed)	Sole authorship
3	'The bearer of the mechanism of change': Small-firm inventiveness and patenting in Norway	Published book chapter (peer reviewed)	Sole authorship
5	A baseline for the impact of academic patenting legislation in Norway.	Published in peer reviewed journal	Main author (see Statement of Authorship, below)

I have renumbered sections of submitted or published papers in order to generate a consistent presentation within the thesis.

Signed:

Date: 12.November 2010………………………………

Statement of Authorship

We the co-authors confirm that Eric Iversen was the primary author of the following article:

> *Iversen EJ, Klitkou A & Gulbrandsen M (2007) A baseline for the impact of academic patenting legislation in Norway. In Leydesdorff L & M Meyer (eds) Scientometrics on Triple Helix indicators. Vol 70, 2.*

We confirm that Eric participated actively in the conception and design of the study, was responsible for the compilation of the database and its analysis, and was the leading contributor of the text as published.

Antje Klitkou 5.11.2010 Oslo

____

Antje Klitkou (date and place)

Magnus Gulbrandsen 17 Nov 2010, Oslo

____

Magnus Gulbrandsen (date and place)

Note

The thesis consists of 68,000 words. As noted in the introductory section, much of the work that went into the thesis involved compiling the matched-data sets used and conducting the analysis, especially that in Essay 6. This is work where standardized approaches are still under development. As an early implementer of the matched-data technique, the author has participated in collective work to standardize these techniques at the Nordic level (see chapter 4) and internationally (including participation in OECD work). The author also took part in the OECD work (see OECD, 2009) on using micro-level survey data (chapter 4 and chapter 6). The extent of the data and analysis work should be factored in when assessing the overall length of the thesis.

Acknowledgements

The final version of the thesis will list my debts to others. In terms of organizations, I will acknowledge the support of my institutions (AIRC and NIFU STEP) to accommodate the research (including university stipend and granting of leave) in addition to office and library support, etc. I will in particular acknowledge the help and support I have received from my advisors. In addition, the individual chapters include acknowledgments of the input I have received from others.

Summary (400 words)

This thesis examines and analyzes changing patterns of IPR use (particularly patenting) in the specific context of a national system of innovation (Norway). Norway has, like many other OECD countries, seen a significant expansion of IPR usage during the past two decades. The increase in patenting in particular is a defining feature of the contemporary innovation landscape, as are related policy efforts to promote wider IPR use. (e.g. among SMES, service sector, academic research) This has led to a shift in the variety of actors who patent and to an increase in overall patent applications. In turn the rationale for patenting is also evolving.

Several factors are thus contributing to a shift in how patents are used, by whom and why. This change has potentially important implications for the innovation system and the wider economy: it can affect the orientation of knowledge accumulation over time; it can condition the way new knowledge is utilized; and, thereby, it can influence pathways for industrial development. However, several challenges have impeded comprehensive analysis of who uses IPR over time and why.

The contribution of the thesis to the theoretical and empirical understanding of IPR-use is structured in six stand-alone chapters. The first applies a systems-approach to examine the role IPRs play in the wider innovation system. This analysis links the role and position of the patent system particularly to underlying industrial dynamics and points to changing areas of use, e.g. to promote collaboration. A set of empirically-oriented articles follows and expands on themes introduced here.

The empirical chapters all use new or adapted empirical approaches to examine aspects of IPR use that are important both to theoretical discourse and to current innovation policy. The first examines diversification of innovation activity in Norway using unique firm-level IPR data. (1994-2003) IPR growth is found to be driven more by smaller firms—especially in knowledge intensive services—than traditional IPR-holders (large manufacturers). Two chapters then focus on SME patenting, at home—in the lead up to the IT bubble, and in Europe—in the lead up to Norwegian membership in the EPC. A co-authored article then examines academic patenting, which recent legislation was introduced to promote. It shows that public sector researchers played a substantial but field-dependent role in patenting before legislation. The final chapter rounds off by examining patent-based collaboration, where patenting increases rather than decreases the odds of research collaboration.

Summary (40 words)

The thesis revisits the role patents play in knowledge formation in light of current changes and concerns. It synthesizes new empirical analysis on changes in who patents and why, with a focus on small (service) firms, academic researchers, and collaboration.

Table of Contents

Tables and figures

0. Introduction: Thesis motivation, approach and summary

Half a century ago, Schmookler (1957) demonstrated that invention had 'changed character' during the previous fifty years. That pioneering study of 'who engages in inventive activity, why, when and how' showed that the traditional dominance that entrepreneurial sole inventors held as a source of industrial innovation had been overtaken in the US by industrial research conducted inside manufacturing firms. This finding lent support to the Schumpeterian Mark II (1942) conjecture that a greater proportion of the economy's inventive activity was in fact taking place inside the R&D laboratories of large firms. In doing so, the finding undercut the earlier Schumpeter Mark I conjecture (1911) about the importance of entrepreneurial inventiveness.

Today, the ways innovative activity is organized in the economy have continued to evolve. So too has the related question of patenting activity, which formed the basis for Schmookler's study. In train with a set of interrelated technological, competitive, and not least regulatory factors, patent activity has shifted during the past two decades. Patenting has increased faster than R&D expenditure and the number and the variety of actors who patent have grown. An important aspect of the shift is that a growing proportion of patents appears to be coming from sources outside the walls of the R&D labs of manufacturing firms, not least from smaller enterprises in the service sector.

This thesis reinvestigates the question of 'who engages in inventive activity, why, when and how'. It goes beyond the traditional focus of patenting by large manufacturing firms (Schumpeterian Mark II) to investigate the role of small firms (Schumpeterian Mark 1)— particularly knowledge intensive service sector firms—, the role of academic researchers, as well as the role of inter-mural research collaboration involving different economic actors. It uses a systems-perspective to examine the role IPRs play in the wider innovation system; and it uses a new set of empirical lenses to explore changing IPR usage in the economy, given the same caveats about patenting noted by Schmookler. The approach is designed to contribute new light to the empirical shadow surrounding the 'sources of inventive activity', (Schmookler, 1962) upon which implications about how knowledge accumulates in the economy may be drawn.

The thesis thus addresses the relationship between inventive activity, the IPR system, and knowledge formation. It does so in light of several trends, current policy concerns, as well as a paradox. Before introducing details of the thesis' research agenda, this section takes stock of noted changes in patterns of IPR use; it reviews factors that have contributed to a shift in patent usage in particular, and it discusses what these changes mean in terms of knowledge formation in the innovation system of a small open economy (Norway). In introducing the chapters of the thesis, this section presents the basis of an empirical strategy which helps the thesis deal with problems that have beset empirical research in the area from Schmookler on down.

0.1. Background

The past two decades have seen a significant expansion of intellectual property rights (IPR) use. The increase in patenting in particular is an important feature of the contemporary innovation landscape. IPRs have also become a highly active area of innovation policy. Policy objectives – such as those promoting software patents, SMEs innovativeness, innovation in the Service Sector, and patenting of academic research—have served to extend the range of patent applicants. In turn, the growth in the number of patent applications and the range of applicants has affected why the increasing range of economic actors use the patent system, for example to facilitate collaboration, to secure venture capital, to fulfill other funding requirements.

Growth in the number of patent applications and the range of applicants is expected to reflect growing innovative activity. Increasing innovation in turn is ultimately expected to contribute to headline growth in the economy. One component of the growth is the historic rise in the number of patent-applications in the period, which in part can be ascribed to the basic economic factors that will be reviewed below. Another component involves an increase in the range of applicants, which in part coincide with policy objectives such as those to encourage SME innovativeness[1]or to promote patenting of academic research[2]. A third is a set of changes in the patent-regime itself which may affect the way the enlarged set of economic actors utilize the system. In Norway the move to the regionalized European Patent Office, through accession to the European Patent Convention effective in 2008, represents one such transition which is expected to change patenting behavior among the largely small actors in this small open economy.

Such changes have potentially important implications for the innovation system and the wider economy. The patent system in particular plays a key, but sector specific, role in the institutional environment. It is central and increasingly important non-market element of what Metcalfe (2001) calls, " the extended division of labour in the accumulation and application of knowledge." It can act to focus and to coordinate formal innovation processes both among and between private and public organizations in the economy. But its role can extend further to facilitate the diffusion and the exploitation of new knowledge in the economy more widely, for example by laying the basis for research collaboration.[3]

[1] A focus in chapters 2, 3, and 4.
[2] The focus of chapter 5.
[3] A focus in the chapter 1 and chapter 6.

0.1.1. Changes in the who and why of patent use

Changes in the use and the conditions for use of the intellectual property system can affect the orientation of knowledge accumulation, can condition the ways it is utilization and, thereby, can influence pathways for industrial development. The fact that the patent system is changing implies changing conditions for future patterns of knowledge accumulation. The extra instability this might generate suggests a set of potential challenges for a small open economy that is characterized by a large proportion of small firms. A range of public-policy initiatives have simultaneously been launched to encourage wider use of patents among these groups given they face acknowledged constraints. During the past two decades, changes in law and jurisprudence have led to substantial increases in patenting of software or processes involving genetic material; legal changes have been made in many jurisdictions to encourage increased patenting of university and public research organizations; regional schemes such as the European patent system have expanded to include more countries thus encouraging a greater degree of transnational patenting. In addition, a series of policy initiatives have promoted greater IPR awareness and use among smaller firms and the service sector in particular. The effects of such changes have mixed with other underlying tendencies, contributing together to shift the overall volume of patent applications, its orientation and the range of applicants grows.

In this environment, it is important to understand who is using the patent system, why, and to what effect. In terms of 'why', the literature has tended to assume that patenting addresses the appropriability problem. Most literature in the area has treated patenting overwhelmingly in terms of the 'appropriability problem', which assumes that a firm will not conduct R&D activity if it is unable to fully appropriate returns from this activity.[4] Patenting is regarded as a major if imperfect method to help firms appropriate returns on R&D outlays. But at the same time, firms have been shown to rely much more on other modes of protection, such as lead-time vis-à-vis competitors (Levin et al., 1987, Arundel & Kabla, 1998) while rating other functions of the IPR system higher than pure appropriation of profits. (Cohen et al, 1997)

One implication of the received view is that patenting activity will track R&D expenditure: if one unit of R&D activity leads to a given number of patents in one period, and patents are used to recoup R&D expenditure, then a similar number of patents per R&D dollar can be expected in the following period. And indeed there are other reasons—such as the cost of patenting and what qualifies for patent protection— to expect patenting to trend with R&D expenditure, other things being equal. Recent work however has indicated that the broadening and deepening of patent rights during the

[4] See discussion in chapter 1.

period have tended to outpace R&D spending. (Hall & Ziedonis, 2001) Patenting has in short tended to outpace R&D expenditures. This has raised a variety of questions, including why firms increasingly patent especially if they believe other forms of protection outperform patenting in the first place.

0.1.2. Patent Paradox

This forms the basis of a famous ‘patent paradox’: many surveys have shown that managers do not consider patents as an important mean to secure profits of their innovations, but at the same time firms continue to invest in patents portfolios—and in some cases they increase this activity. Several conjectures have been forwarded to explain this gap. One explanation is that there is no longer a one-to-one relationship between the propensity to patent and its value in recouping R&D outlays. Scherer (2001) posited, from a demand perspective, that patent applications began to take on something of the valor of lottery tickets in the US during in the lead up to the dot-com bubble. Consistent with lottery psychology, the higher the number of patent applications, the greater became the propensity to patent. Such a ‘probabilistic’ dimension of patents tended to be encouraged rather than discouraged by the supply side, i.e. the US patent office and court system. (Lemley & Shapiro, 2005) This coincided with an administrative climate that in attitude and practice reflected a ‘pro-patent era’. (Jaffe, 2000; Jaffe & Lerner, 2004; Merrill et al 2004) This tendency is first and foremost associated with changes in the US system (not least the set-up and the disposition of the court system) but extends to trends in the international IPR system, including WTO rules and the regionalization of the patent system which is expected to affect patent use.

However other factors also came together during the same timeframe to heighten demand for patents. Granstrand (1999) posits a general increase in the propensity to patent due to a range of technological and competitive factors, such as the increasing internationalization of markets. Changes in technological systems have also been associated with the rise in patenting. Kortum and Lerner (1999) find evidence that the rise of patents corresponds with an increase in the volume of patentable technologies. Such a shift is associated with the emergence of new technologies (e.g. biotech and nanotech) and the reputed shift towards a ‘knowledge economy’ in which economic goods (especially ICT related ones) include a higher proportion of knowledge intensive input. Other changes associated with technological markets include shortening product cycles and the increase ease in specific markets (e.g. chemicals and pharmaceuticals and ICT) to imitate innovations also played a role. Torrisi et al. (2006) show that software patents account for a rising share of total patents in European Patents.

The increase in patenting has also been posited to involve changing modes of innovation. A greater focus on patent strategies is expected to be reflected in the rising numbers of patents. A number of more pro-active modes of patenting have emerged (including strategic use of continuations of earlier applications, above) which contribute to the overall rise in the number of applications. (Graham and Mowery, 2004). Changes in the way research is carried out might also impact on changing patterns of patent use. Brouwer & Kleinknecht (1999) show that firms engaged in R&D collaborations tend to patent more.[5] Other factors that are thought to influence patenting include pro-cyclical effects of the buoyant economic conjuncture starting in the 1990s.

In short, the growth and reorientation of patenting during the period is attributed to a comprehensive set of changes in technology, in markets, in strategic factors, and in the administration of the patent system. If patenting continues to rise while R&D managers report that it is not very important in appropriating profits from innovation, this may also be because actors are using the patent system for other reasons (such as collaboration). Another possibility is that a wider set of economic actors (such as the service sector and smaller firms) than those addressed in the surveys and that these have become more active in the patenting: the changing patterns of patenting might reflect the contribution of these actors as sources of invention and innovation more generally.

0.1.3. An empirical shadow

There have thus been changes in use of the patent system and conditions of use that in part have coincided with policy objectives to promote patent use into new areas at the level of what is patented and by whom. In terms of what is patented, the advent of software patents and gene patents constitute significant adaptations of patentability requirements. In terms of who patents, policymakers have as noted encouraged patenting of university research as well as have promoted increase patenting among small and medium-sized enterprises (SMEs) and service sector enterprises.

The combination of changing patterns of IPR use and of public policy initiatives that are designed to adapt conditions of IPR use, serves to raise the question of whether/how IPR use is changing. One way to examine this question would be to look at the way different actors use the patent system and whether the usage changes through time. However, this line of inquiry has been stifled by the general inability to identify important aspects of the patent applicant in the patent-data itself.

There are noted measurement problems associated both with what patent-data reveals (e.g. Basberg, 1984; Griliches, 1990; Archibugi & Pianta, 1992; Iversen, 1998) and with what surveys reveal about patent use (e.g. Levin et al, 1987; Cohen et al., 1987) not least in the face of cross-country differences. (Smith, 2001) Griliches (1990) observes that, 'patent statistics loom as a mirage of wonderful plentitude and objectivity in a desert of data on technical and scientific progress.' This is a

[5] As is corroborated in chapter 6 on collaboration and patenting. See also chapter 1.

mirage in part because of the variable quality of patent-data and in part due to limitations in the information it includes. Limitations in traditional measurements have left a range of theoretical and policy concerns in something of an empirical shadow.

Emerging approaches

In terms of understanding shifts in where innovation takes place, one important limitation is that the patent include only an inkling of who is involved (i.e. the names and addresses of applicants and inventors). The shadow masks what the increase of IPR use says about changing innovation patterns. This makes it difficult to analyze the role of different types of economic actors in the long term relationship between patenting and industrial change; and it makes it difficult to analyze how systemic shocks (e.g. the bursting of the dot-com bubble in 2001, introduction of new legislation or reorientation of the patent system; specific policy measures to encourage research collaboration, patenting among university researchers, etc) may affect these different actors differently.

However, several approaches are now coming into currency that can successfully address some of these limitations. One set of approaches systematically seeks to increase information about the 'who' in the central question 'who patents what and why'. The micro-level technique of individual-linked IPR data serves to link the applicant(s) of a given patent with information from other databases. The link between firm-level data and patent data involves a laborious and mistake-prone procedure. In the interest of some simplification, the early applications of the technique tended to retain some of the same sampling bias of surveys (such as Levin et al, 1987) that it was trying to improve upon: the most painstaking of the early studies based on matched patent-data (Bound et al, 1990) for example found itself constrained to manufacturing firms and 'successful' 'small firms'.

Notwithstanding, it can be used identify the organization's size, industrial activity, as well as performance measures (such as turnover): it can also be used to provide measures of 'market structure' by identifying the total number of companies in a given sector. More recent work has taken advantage of increasingly available patent and company data as well as vastly improved data processing power. The technique however is still laborious and mistake-prone: Magerman et al., 2006 illustrates the difficulty of achieving a certain level of accuracy in such a link. There is currently a set of concerted efforts in the US, Japan and Europe to provide the basis for firm-linked patent data with finance or accountancy data. (e.g. Thoma et al, 2009) In these large datasets, limitations persist. The link with accountancy data provides a very rich basis for analysis. (for one application, see Martinsson, Lööf, Iversen, 2009) However, it constrains the focus to listed and, by implication, established companies. Other companies, such as start-ups, the majority of small firms, and public oriented research institutions are excluded.

This tends to preclude the ability to accurately study the full universe of economic actors. The exclusion of the larger universe of economic agents may serve to increase the signal over the noise of small and inconsequential patents, for example if the object of study is the relationship between R&D and patenting. In other scenarios, censoring the data towards the larger and more established quadrant of the firm-population may be less welcome. One area of study that it makes difficult is the relationship between IPRs and small firms. Approaches have had to compensate in order to include more complete datasets. Webster and Jensen (2004), for example, achieve better coverage in their study of Australian SMEs and patents, trademarks, and design. However they are left to estimate firm-size by the age of the firm, due to data-constraints. The quality of the firm-level data is important to the coverage and to the granularity of the data. A series of studies have emerged from the Nordic countries based on full-count data from government registries. These official data, which are linked to tax registries, are kept up-to-date and provide reliable figures for employment and turnover. Iversen (2003) studied the use of trademarks and patents by Norwegian SMEs during the 1990s. Kaiser and Schneider (2004) constructed a similar database for Denmark that subsequently led to work on outcomes of examination processes. (Schneider, 2007) In a pan-Nordic study, Iversen et al (2009) provided a comparison of SME patenting in these five countries based on the unique database resources. (see also chapter 4 below)

A similar technique—again provided conditions of anonymity are upheld— may also be useful to study certain types of inventors: a chief example here is to study the patenting activity of public research organizations researchers. A third technique can help to improve the explanatory power of surveys is to create panels over successive iterations or waves of a survey. In general, these approaches are able to provide unique new perspectives on how different types of firms approach and use the IPR system differently over time. They can provide a better picture of current sources of invention.

0.2. Summary of thesis

In this light, the research in this thesis explores how different economic actors utilize the patent-system amid these shifts and studies implications for the accumulation of new (technological) knowledge in the innovation system. The question of how IPR regimes are adapting and what this might mean for the integrity of the innovation system is addressed in the context of a small open economy (Norway). In particular, we develop and apply a set of the emerging empirical approaches (introduced above) to shed light on a set of concerns that are important from a theoretical and from a practical (policymaking) point of view.

Focus on the Norwegian innovation system

Several aspects of the Norwegian case recommend it as a good laboratory to study changing IPR usage. In general, the role of institutions such as the IPR system is enhanced in the context of small countries (Johnson, 1988). Furthermore, Norway introduced two changes in the IPR system that reflect major international tendencies during the period under study: the first is that Norway introduced legislative changes (effective in 2003) designed to increase patenting of public research results; and second, and somewhat belatedly, it joined the European Patent Convention (EPC effective in 2008) in order to promote patenting more widely (in Europe). In addition, Norwegian policy concerns tended to track international trends during the same period, especially regarding measures to promote innovation among small firms and in the service sector.

In this sense the Norwegian case represents something of a microcosm of the international policy trends that were designed to influence and reorient IPR use. The policy discussions that have accompanied these changes reveal recurrent concerns about the effect that such changes would have on different parts of the innovation system: in some case (such as becoming part of the formative European patent system), this has involved decades of deliberation and long term concerns. Several concerns emerge from this material: concerns about how to promote country specialization while avoiding the tendency towards technological monoculture (a risk faced by oil and other commodity based economies); concerns about how to adjust to the falling importance of manufacturing in the economy; concerns about how to take advantage of developments in new technological areas; concerns about how to link basic research to the industry structure; as well as the perennial concerns about the ability of the large population of very small firms in this small open economy to adapt to and to take advantage of international developments.

In turn, these practical concerns correspond to a number of theoretical issues as well, notably about the role of small firms, the role of persistent diversity in the economy (service sector), the role of academic industry relations, and the role of research collaborations to take advantage of technological and market opportunities. The finding that IPR-use has loosened itself from underlying fundamentals of innovation raises a number of questions in this context: what role does the patent system plays in knowledge accumulation? Is it changing? Does the increase in IPR usage predominantly involve traditional patent-users (large manufacturing firms in certain sectors) or does it reflect the emergence of other types of IPR users? If there are shifts in who is use the patent system, what differences are observed between IPR use by smaller and larger firms? Is there an equal propensity for small and large firms to patent? Do they differ when it comes to domestic and foreign patenting? What role do researchers at public research organizations (PROs) play in patenting? What is the relationship between patenting and research collaboration?

0.2.1. Thesis structure

These issues place large demands on empirical data as well as on the theoretical framework. In order to address changes in IPR demand and what they mean, the research in this thesis develops a theoretical framework to integrate the role of the IPR system with aspects of technological and industrial change and to discuss implications of the findings. In terms of addressing the empirical challenges introduced above, a set of approaches are used to address particular issues. These allow current IPR usage to be interpreted and changes over time to be assessed, whether they are introduced by policy changes or emerge otherwise.

The thesis is organized into a set of six chapters which focus on different levels of the interrelationship between institutional and industrial dynamics. The following table provides a thematic overview of the chapters or essays. The first chapter is primarily theoretical, although it discusses empirical strategies to focus on the rising importance of patenting in research collaborations which is followed up in the last chapter. Chapters 2-6 are primarily empirical, but build on a theoretical basis that follows on from the first chapter. The chapters may be read in succession or as stand-alone essays.

Table 0-1 Overview of chapters

Theme	Questions
Essay 1: Knowledge formation and patenting	**What role does the patent system play in knowledge accumulation?**
Essay 2: The diversification and specialization of IPR use in a small open economy	**How does use of the IPR system reflect the innovative processes of different agents? What role is played by small firms in specialization and diversification of innovative activity?**
Essay 3: The growing use of patents among small firms: areas of growth and challenges	**If SME patenting is increasing, what technological areas and market dimensions are involved? Do they face greater challenges than larger firms?**
Essay 4: Small firm patenting and the transition to European Patent Office	**How do Norwegian SMEs use the European Patent System? How the effects of this transition be measured?**
Essay 5: Academic patenting and the transition to an institution-based patenting regime	**To what degree do academic researchers already patent and will the introduction in Norway of Bayh-Dole-like legislation improve conditions for academic patenting?**
Essay 6: The impact of patenting on research collaboration	**Does patenting increase the probability for research collaboration? What role do other factors play?**

A systems-based approach is applied throughout as the basis on which to analyze the complement between the individual innovator and the changing institutional environment in which it lives. Systems of innovation approaches are used to orient the discussion of IPR-use to the wider context in which firms interact and innovate. It provides an apt framework in which to understand changing patterns of IPR use within the wider context of institutional change. The national systems of innovation (NSI) framework helps to position the IP-system of the wider Norwegian context which is examined in the empirical chapters. A detailed summary of the individual chapters follows.

Chapter 1. Knowledge formation and patenting: What role does the patent system play in knowledge accumulation?

The first essay introduces a set of issues related to the role and form of the industrial IPR, particularly focusing on the patent system in the formation of technological knowledge. In light of the nature of economically relevant 'knowledge' (Polanyi, 1958; Antonelli & Quére, 2002), the economic role of the patent system is linked to what Hayek (1945) called the 'knowledge problem'. In short, the problem that economies face is, on the one hand, the need to induce inventive activity and, on the other, to coordinate the knowledge that is dispersed among different agents so as to direct it at economic problems.

The review demonstrates that the patent system has during the postwar period largely been focused on the first clause of the problem. It confirms the findings of Mazzoleni & Nelson (1998) that while more comprehensive discussions of the rationale of the patent system go back centuries, modern analysis has tended to limit itself to the 'invention motivation' theory. However, this theoretical fixation has lagged the way the patent system is being used— with its coordination function becoming more important—and has had a limiting affect on policy development as well.

The patent system is an institution that is changing: so too is the way it is dealt with in the literature. In this light, the essay discusses what this means in terms of North (2005) who emphasizes the importance of 'adaptive efficiency' of an innovation system or its ability to adapt its institutional set up to confront emerging problems successfully. North recognizes that the institutional incentive system, of which the patent system is an important part, is inherently imperfect. In short, it is not only that institutions matter. In order for the economy to successfully address emergent challenges and opportunities, what matters is that the institutional set-up continues to evolve and adapt so as to continue to fulfill its role in promoting knowledge accumulation. At the simplest level, this role may be seen in terms of, "whether the prospect ex ante of a patent, together with its ex post presence stimulate or interfere technical advance in a given field." (Mazzoleni & Nelson, 1998)

The patent system is, as indicated above, changing in some fundamental ways. But is it adapting 'efficiently'? The question turns to what affect the expanding number of patents may have on technological change. With reference to the overlooked aspect of the 'knowledge problem', the essay concludes that an important measure of its success in stimulating technical advance is to be found in the patent system's ability to promote research collaborations. This is the issue of multi-actor innovation activities, which are introduced in terms of collaborations or 'industrial networks'. The question, which will be revisited in the final essay, is whether patents may be seen to promote or hinder research collaboration.

0.2.2. Empirical chapters and approaches

The empirical chapters go on to examine aspects of IPR use that are important both to theoretical discourse and to current innovation policy in Norway. In doing so it follows in the tradition of the historic work of Basberg (1984) who provided an early investigation of using patents to track technological change (in Norway from 1840-1980). These chapters extend the empirical focus substantially in order to study IPR usage among different types of entities in this small open economy. In particular, the chapters build on and improve the approach originally developed in Iversen (2003). It extends the Norwegian data in time and scope, it introduces domestic patents and trademarks (chapter 2 and 3); it extends to EU patenting (chapter 4), and it associates inventors with a full-count lists of academic personnel and researchers at public research organizations. (chapter 5) In looking at collaboration, chapter 6 uses a panel of Norwegian respondents from two waves of the Community Innovation Survey (CIS4 and CIS2006).

A set of thematic and empirical filigrees tie these empirical chapters together. One common denominator is that the chapters link up to a set of related policy concerns, including the diversification of innovative activities (especially to the service sector), the extent of small-firm innovation, the new use of the patent system by public research, and the relationship between patenting and collaboration. The first three empirical chapters focus on IPR-usage in terms of firm-demographics in Norway. The prevailing concern with large manufacturing firms with formal R&D activities that is identified in the literature reviewed above is expanded to look at IPR use among all firms in the economy in chapter 2. Small and medium-sized enterprises are shown to be involved in an increasing share of Norwegian patents in the period. In this light, chapters 3 and 4 complement each other as they both focus on small firm patenting: first at home and then abroad. Firm linked domestic IPR data is used in these chapters. In addition, chapter 2 takes into consideration trademark-registrations, whose economic role has been shown to play an increasingly important role especially in the service-sector. The empirical treatment in chapter 4 extends to look at Norwegian patenting in Europe.

Table 0-2 Themes and Approaches in the empirical chapters

Theme	Data	Approach
Essay2: The diversification and specialization of IPR use in a small open economy	Firm-linked domestic patent and trademark data: 1994-2003	In light of Marshall's emphasis on variety, firm-linked IPR data is used to anlayze patterns of diversification among a variety of economic agents in Norway.
Essay 3: The growing use of patents among small firms: areas of growth and challenges	Firm-linked domestic patent data: 1995-1999	In light of the Schumpeterian small-firm conjecture, SME patenting is analyzed in terms of business sector, technology and market concentration
Essay 4: Small firm patenting and the transition to European Patent Office	Firm linked domestic and European patent data: 2000-2005	In light of historical concerns and the approach of essay 3, a growth accounting approach is introduced to follow patenting in Europe by different types of Norwegian firms
Essay 5: Academic patenting and the transition to a new regime	Researcher linked domestic patent data: 1998-2003	In light of the approach in essay 4, a three-step growth accounting approach is developed to identify academic inventors in Norwegian patents. It provides a baseline to measure the effects of legislative change to encourage academic patenting.
Essay 6: The impact of patenting on research collaboration	Norwegian panel of Community Innovation Survey data (two waves): combined observation period from 2002-2006	In light of the potential role for patents in research collaboration in essay1, a set of generalized linear models are used to evaluate how precursor patents affect the probability for collaboration with different types of partners.

Chapters 4 and 5 focus on two structural changes in the Norwegian patent system. In the first case, it is Norway's transition to the European patent system which is intended to promote a greater degree of transnational patenting; in the second it involves the introduction of Bayh-Dole type legislative change that transfers title for patents based on academic research from the researcher to the research institution (e.g. universities): the intention of this legislative change is promote greater exploitation of the science base. From an empirical perspective, these chapters focus on creating growth-accounting baselines against which to assess the effects of these changes over time. While chapter 4 utilizes patent data linked to applicant firms for growth accounting of European patents, chapter 5 links inventors with a registry of all academic personnel at Norwegian public research organizations for growth accounting of academic patents. The final chapter is based on a different type of empirical data which complements the earlier chapters. In chapter 6 a panel of Norwegian responses to two waves of the Community Innovation Survey is used in order to study the relationship between patenting and research collaborations. This approach allows us to lag patent use in relationship to collaboration. A summary of the individual empirical chapters follows.

Chapter 2: The diversification and specialization of IPR use in a small open economy

The first empirical chapter examines patterns of diversification and specialization in Norwegian innovation activity. (1994-2003) Based on a principle of Marshall (1922)—that "the tendency to variation is a chief cause of progress" –the essay investigates the role of heterogeneity of innovative activities in the Norwegian economy. It examines the generation of technological and commercial variety in the Norwegian economy in terms of industrial change, firm-level activities, and the role of IPR systems. The chapter utilizes the complementary lenses of domestic trademark and patent data as each reveals something about the ongoing differentiation of economic activity: the former stresses invention, the latter commercialization; the former tends to emphasize activity in manufacturing, the latter activity in the service sector. The economic role of trademark-registrations (Landes & Posner, 1987) has been shown to play an increasingly important role especially in the service sector (Greenhalgh & Rogers, 2006).

The diversification of this activity is analyzed in terms of firm-size, technology, industry, and region of origin. The essay finds that patent use increased only marginally (5 percent) from the end of the 1990s (1994-1998) to the beginning of the oughties (1999-2003), when factoring in the effect of the dot-com bubble. The trademark data reveals greater fluctuations and a much larger dot-com effect. Following Archibugi & Pianta (1992), a patent-based measure of the technological specialization is conducting across the periods. It reveals specialization in technologies related to ship-building, in consumer goods, as well as machinery and petroleum products (by not fuel itself). Persistent regional patterns are shown, with substantially greater concentration of trademark registrations than patent applications originating in the Oslo region: this confirms the capital as the commercial epicenter of the country, but not necessarily as a source of invention. The share of patent applications from unaffiliated individuals is shown to fall through the period, while that of companies rise. This confirms a pattern remarked on in Schmookler (1957). A half century on, it is SMEs that account for an increasing share of patenting through the period in the Norwegian case. The share of patents from smaller-firms grew most—especially in knowledge intensive services, while that of large manufacturers remained stable. Furthermore, the essay shows that small firms are responsible for much of the fluctuations in trademark registration associated with the dot-com bubble.

Chapter 3: The growing use of patents among small firms: areas of growth and challenges

In this light, the following two chapters focus on SME patenting, at home—in the lead up to the IT bubble: and in Europe—in the lead up to Norwegian membership in the EPC. Essay 3 is a chapter that was published in a book about the modern relevance of Schumpeter and it takes its title from his early conjecture about small-firm innovation: "'The bearer of the mechanism of change': Small-firm inventiveness and patenting in Norway." In line with the Schumpeterian conjecture, the chapter explores the contribution to overall inventive activity of small firms which it argues is especially important in small open economies like Norway where SMEs make up over 95% of all firms. The focus in this and in the following chapter is motivated by the observation that the role these firms play in knowledge generation— and the problems they meet— have implications for the working of the innovation system as a whole and for related policies.

This chapter finds that the share of large patenting firms is as expected higher than that of SMEs. Small firm patenting however extends, as a proportion, quite evenly over technologies. We find that it accounts for between 17 and 22 percent of Norwegian patenting in each of six technological areas: when non-linked firms (expected to be small) are included, the shares rise to a range of 31 to 38 percent. Large firm patenting is most concentrated in the area of chemistry and pharmaceuticals, where Norwegian patenting is relatively unspecialized. (see chapter 2) The chapter goes on to show that the specialization of small-firm patenting varies more substantially in terms the industrial sector of the firm. The essay finds that the proportion of small firm is highest in knowledge intensive services, including business, computer as well as R&D services. These are areas which grew substantially in the period under study.

In terms of market structure, the service sectors—with the exception of R&D services – are the home of many small firms. The intensity of small firm patenting is furthermore investigated in terms of number of applications per applicant and other normalizing measures. The intensity of small firm patenting is highest in R&D services—where patent propensity is generally high— but also in machinery and electrical equipment. All in all, the volume and the share of small firm patenting is shown to be rising. In light of this finding, the essay however goes on to show that the success of patent applications is strongly correlated with the size of the applicant: the smaller the firm, the higher the probability that the application will end in non-grant. If small firms are to be 'bearers of the mechanism of change', it may be important to improve the patenting activity of these firms.

Chapter 4: Small firm patenting and the transition to European Patent Office

This essay pursues the relationship between firm-size and patent use. The focus on domestic patents is updated and extended to a comparison with Norwegian patenting in Europe in the period leading up to Norway's accession to the EPC (2008). In this context, the application of firm-level data is advocated. The approach is introduced as a growth-accounting tool which can gauge the effect this substantial change has on different types of Norwegian firms and other organizations. In this transition, larger firms with markets and patent-portfolios in Europe are expected to benefit since membership would reduce the cost of patenting more widely. Smaller firms, without international markets and thus less interest in European patents, might be expected rather to face a challenge as more European patents come into force in their home market.

The essay first shows that Norway long delayed EPC membership in light of longstanding concerns that it would impose costs on some parts of its industry (mainly smaller firms) that would outweigh any benefits (mainly larger firms). In this historic light, it analyzes patterns of patent use among different categories of Norwegian firms in the run up to joining the European patent system.[6] The analysis shows that most applications filed by Norwegian firms at the EPO involve large firms. However, the next largest group is from the smallest firms. Large firms file on average 1 EPO filing for every 2 domestic applications. Small firms (10-49) file on average 1 EPO application per every 4 domestic applications.

[6] Definitions in the chapter have been adapted slightly in relation to the previous chapter in order to fit in with a Nordic wide analysis. (see Iversen et al., 2009)

The essay follows up on findings in the previous chapter, with some nuances. Patent intensity by number of firms and employment is highest in the chemicals sector, followed by the R&D service sector. These are industries where the proportion of small firms (<50 employees) is lowest. Small firms account for over half the European patenting in roughly half (14) of the industries. The proportion is nearly 90 percent in the case of Computers and Technical Consultancy where small firms dominate the demographics. Certain industries show a preference for domestic and not European patenting, especially technical consultancy where small firms dominate.

The success of patent applications is found to be skewed, as in the last chapter. The highest proportion of non-grant is found among the smallest applicants. The proportion of grants to the smallest 'micro' firms is substantially less (19 percent) than its share of total applications (24 percent). This may suggest that the applications of these firms are less successful than that of the large firms where grant rates are substantially higher than application rates.

Chapter 5: Academic patenting and the transition to an institution-based patenting regime

This chapter follows up the theme of growth accounting methods from essay 4 in light of another substantial change in the Norwegian patent system. The focus of "A baseline for the impact of academic patenting legislation in Norway" (co-authored in Scientometrics) is legislative changes that went into effect in Norway in 2003 to encourage greater commercialization through patenting research results. This policy ambition faces the problem that no record of the patenting activity of academic researchers is available before 2003 when the "professor's privilege" was phased out here as it had been in several other countries.

The essay reviews the relationship between patenting and academic research. The relationship involves important issues from a theoretical and a practical point of view. These are reviewed as is how the relationship has developed in Norway. In light of other efforts (e.g. Balconi et al, 2004), the essay develops and demonstrates a three step methodology to baseline changes in the extent and focus of academic patents. Details of this method are spelled out and choices discussed: in addition, the method is followed up in further paper also involving the co-authors (Gulbrandsen et al, 2009). The assumption that university researchers did not patent and that legislation was therefore needed is disproved. The essay finds that nearly 11 percent of all Norwegian domestic patents in the period 1998-2003 involved at least one inventor from a public-sector research organization (PSR: including universities, colleges, hospitals, and other not-for-profit research organizations). The share is highly technological related. The essay finds that 21 percent of inventors involved in chemical and pharmaceutical patents (most of which are lodged by large firms, see above) were from universities or colleges, while a further eight percent were from the institute sector.

The essay shows that in many cases (especially in chemicals and mechanical engineering), private enterprises own the patent. The findings raise questions about the direction that university-industry relations might take in the wake of the new legislation. Following the legal change, university researchers no longer hold the prerogative to reassign the patent to a commercial actor. One question is whether industries will continue to collaborate as much they did with university researchers if they have to negotiate with universities over the rights.

Essay 6: The innovative entity, cooperation and IPR use

The preceding empirical chapters studied the propensity of different populations of firms and other actors to patent (and register trademarks). The focus was on the individual actor, with the question of collaborations between university and industry emerging in the last chapter. The final chapter pursues this focus on research collaboration, by investigating how patenting affects how different actors collaborate. In doing so, it pursues a research agenda identified in chapter 1. This empirical essay addresses the scope of the patent-system to facilitate coordination of (technological) knowledge production among different actors—either in sequence or in parallel, thus returning the conclusions of the first essay that indicated this function to be of increasing importance

This essay studies this relationship between patenting and research collaboration using a balanced panel of Norwegian responses to two waves of the Community Innovation Survey (4 and 5), with a combined observation period of 2002-2006. One advantage of the CIS itself is that it provides comprehensive about the enterprise and its activities. This provides a broad vantage point to study the interplay between propensities to patent and to cooperate in the context of other factors that might influence each. Another advantage of CIS is that it is periodic, leading to the ability to use panels of responses. This complements the approaches above that have used matched IPR data.

The essay discusses contexts in which research collaborations may involve patenting. In general, patenting may precede collaborative effort, may accompany it, and/or may follow it. The latter scenario is the prominent focus of the (mainly industrial organization) literature. This essay instead focuses on the potential for patenting to lead (simultaneously or subsequently) to research collaboration. The analysis accounts for a range of other factors that might affect the propensity to collaborate. In addition to R&D activity, industry dummies, and firm-size, strategic activity, fiscal constraints, and technological dimensions are accounted for in order to minimize unobserved heterogeneity.

The approach employs standard generalized-linear models (ordered probit and multinomial logit) to evaluate how precursor patents affect the probability of the three ordered outcomes: no collaboration, sporadic collaboration, or continuous collaboration. Collaboration is then differentiated to analyze the effect patenting has on collaborations that involve competitors (horizontal), that involve suppliers and customers (vertical), and that involve involving outside research organizations. A strong and consistently positive effect of patenting is found on the probability that the firm collaborates. Patenting is found to affect the propensity for continuous collaboration most strongly but it also increases the odds of sporadic collaborations significantly. The findings support the position that patenting of own knowledge contributes to the probability that the firm also collaborates with other firms. Patenting is positive and significant in each model, but strongest in relation to the probability that the firm will continue to collaborate; and then, strongest in relationship to continuous collaborations with suppliers and customers.

The essay contributes to a better appreciation of the relationship of patenting and research collaboration, in terms of the persistence of (continuous & intermittent) collaboration as well as in terms of the type of collaboration (horizontal, vertical, and research organizations). Furthermore it provides an understanding of the role that other factors—structural (e.g. size and R&D), strategic activity, fiscal constraints, technological dimensions, and product cycles have on collaboration.

Chapter 1: Patent-regimes and the formation of technological knowledge: a review of issues[7]

The first essay of the thesis links the role of the patent-system to the promotion of knowledge formation in the economy. The prevailing view of this role has been limited to a question of motivating the individual actor to innovate. On this basis, we indicate that theoretical interest has tended to lag the way the patent system is evolving in practice as part of a larger innovation system.

Theme	Questions
Essay 1: Knowledge formation and patenting	**What role does the patent system play in knowledge accumulation?**
Essay 2: The diversification and specialization of IPR use in a small open economy	How does use of the IPR system reflect the innovative processes of different agents? What role is played by small firms in specialization and diversification of innovative activity?
Essay 3: The growing use of patents among small firms: areas of growth and challenges	If SME patenting is increasing (see last essay), what technological areas and market dimensions? Do they face greater challenges than larger firms?
Essay 4: Small firm patenting and the transition to European Patent Office	How do Norwegian SMEs use the European Patent System? How the effects of this transition be measured?
Essay 5: Academic patenting and the transition to an institution-based patenting regime	To what degree do academic researchers already patent and will the introduction in Norway of Bayh-Dole-like legislation improve conditions for academic patenting?
Essay 6: The impact of patenting on research collaboration	Does patenting increase the probability for research collaboration? What role do other factors play?

The patent system is presented here as an institution that is changing. The implication is that these changes can ultimately affect the way knowledge accumulates in the economy. The will allow us in later chapters to consider the significance of specific changes in patent use—such as increase demand among small firms—or of specific changes of the conditions of use—such as the entitling universities to patent. In particular, this chapter indicates that the role the patent-system plays extends beyond that of motivating individual actors to innovate: in particular, it might promote the propensity of more than one actor to engage in research based collaboration. This is a theme that we return to investigate empirically in the final chapter.

[7] An earlier version was submitted as a sub-report for the "Understanding knowledge in the enlarging Europe – U-Know" Project (April 2009) under the 6th EU Framework Program. A modified version was submitted in November 2010 to special issue of a journal.

1. Patent-regimes and the formation of technological knowledge: a review of issues

Eric J. Iversen[8]

0. Introduction

Socio-economic institutions matter for the formation of technological knowledge in the economy. The ability for central institutions to adapt ('adaptive efficiency') has long-run implications for promoting economic growth (North, 2005). The patent-system is an important element of the institutional landscape ('the artifactual structure') whose design is to promote the formation of technological knowledge in the economy. It is also an institution that is changing as are the ways in which knowledge formation takes places. The ability of the patent-system to adapt in this context is expected to have important consequence for the way economic actors generate, disseminate, and use new knowledge. The way it does so can have significant implications for economic growth.

This paper reviews the role of the changing patent-system as an institution in promoting knowledge formation. Its starting point is that the patent-system is changing; that modes of knowledge formation are changing; and that the literature's treatment of the role of the patent system in knowledge formation is also changing. In this setting, it is important to take stock of key aspects of knowledge formation and of the patent-system, reviewing the rationales attributed to the patent system in terms of the nature of knowledge. The growing importance of cooperation in knowledge production is seen as particularly important. The paper focuses on the scope of the patent-system to facilitate coordination of (technological) knowledge production among different actors—either in sequence (cumulative) or in parallel (collaboration). In particular, it links this growing focus to the question of coordination in 'networks of innovators' or 'industrial network settings'. The aim is to contribute to a stronger conceptual basis on which to approach the role of the patent-system while also indicating directions in which to study this important subject empirically.

Section 1 provides a brief background to the review. It takes into account of some of the shortcomings in conventional approaches and highlights the need to consider the role of the patent system in terms of the overall innovation system. The second section reviews some the foundations of knowledge formation in the economy. This brief review highlights the importance of the collective learning processes, which traditional market-failure thinking has failed to capture when appraising

[8] This paper emerged from discussions with Marion Frenz (University of London, Birkbeck) and comments from Nick von Tunzelmann (SPRU).

the role of the patent-system. In this light, the third section turns to the patent-system, which it sees as an institution in the sense of North (2005) that shapes the incentives according to which knowledge is generated and coordinated to address economic activities. The final section discusses the coordinative role of patents in the context of four different types of networks of innovators, indicating some empirical strategies.

1. Background

Patent use—and the conditions that shape patenting behavior— are changing. Policymakers are reviewing the form and function of the patent-system9 as evidence increasingly suggests that the institution has evolved away from its historically based public policy rationale (e.g. Jaffe and Lerner, 2004; Merges & Nelson, 2006; Meurer and Bessen, 2008). Changes in administrative, legal, and institutional norms are in this context expected to affect shifts in how IPRs are used, by whom, and why. There are however mounting questions about what consequences such shifts may have for the way economic actors generate, disseminate, and use new knowledge.

While clearly important, the co-evolution of the patent-regime and the changing innovative behavior of economic actors is comprehensive and hard to study. The literature has instead tended to limit itself to one of the implied concerns, namely the patent-system's role in overcoming the 'appropriability problem' and encouraging economic actors to generate new knowledge. This mode of analysis has increasingly been criticized for its myopic focus on appropriability conditions for the initial discrete innovator (see Mazzoleni & Nelson, 1998) and for its narrow market-failure justification and unsupported assumptions (Dosi et al., 2006). It has been criticized too for its built-in tendency to overlook tradeoffs with collaborative or improving innovators (e.g Gilbert and Shapiro, 1996; Klemperer, 1990; Bessen & Maskin, 2007). Meanwhile an expanding set of literature (e.g. Imai & Baba, 1989; Hagedoorn & Schankenraad, 1990; Debresson &Amesse, 1991) has pointed to the growing importance of cooperation in knowledge production.

A more fundamental concern is the tendency of the literature to collapse the concept of 'knowledge' into a homogenous commodity. This device is doubtlessly useful in focusing on economic efficiency arguments. But in doing so one aspect that the conventional approach oversimplifies is the role of the patent-system. 'Knowledge' is an epistemologically complicated subject that is characteristically abstracted by the mainstream literature if acknowledged at all (the default position of course is that new knowledge is a commodity that spreads uniformly and frictionlessly through the economy as information). Aghion et al. (2008) criticize the 'homogenizing' device used by that section of the

[9] See the Patent Reform hearings in the US, December 2008; see also current patent reform in Germany and in Japan.

literature that actually looks beyond the perfect information assumptions. This critique, rooted in the new economics of science literature, portrays this device in the following terms: (i.) The approach transforms “homogeneous flow of the economy’s investment” into an uncertain flow of “heterogeneous informational novelties” (research output) (ii.) The output information is then added to the stock of generic knowledge, which is seen as, “…malleable in the sense that it can be particularized as an array of specific technological capabilities that, under the right economic conditions, can generate innovations yielding lower cost or higher quality new goods and services, or possibly both.” (Aghion et al. 2008, 2) The implication is that this conventional approach collapses several aspects of knowledge and knowledge procedures, suggesting that its results thus may be unreliable.

In light of imperfect information, pervasive self-reinforcing externalities, and barriers to competitive entry, there is a noted need to appreciate the historical and systemic aspects to technological change and innovation. This means taking into account the interrelationships between technological change, scientific advances and “the setup of socio-economic institutions operating in a given context”. (Aghion et al. 2008, 3) Quéré (2008) likewise advocates the ‘need for innovation systems approach’ to understand the governance of technological knowledge, while Granstrand (2006) highlights the role of IPR in ‘governance in and of innovation systems’.

The idea of a collective learning process has important implications for the functioning of the patent system. It becomes important to better understand the role of the patent system in terms of the wider systemic interrelationships that shape ‘decision architectures’ of individual firms (Wu, 2006). Section 4 returns to this aspect especially as it relates to the role of the patent-system in coordinating networks of innovators and ‘industrial networks’. Before doing so, it is necessary to review the economic attributes of knowledge aspects and, in this light, to survey the role that has been attributed to the patent system down the years.

2. Economic attributes of technological knowledge

Conventional analysis tends to conflate how technological knowledge comes to be, on the one hand, and how it spreads to areas of application on the other. An initial tendency underlying much analysis is to reduce the complexity of knowledge into information as noted above: this transformation downplays the distribution process while focusing on the creation process. This tendency has contributed to the overall preoccupation with knowledge production in the literature, which has overshadowed concerns with the distribution and coordination of new knowledge. A brief review highlights these two interrelated aspects as they are relevant to the role of the patent-system.

As a starting point, Arrow's (1962) influential welfare-analysis homogenizes knowledge into information as an economic commodity. This device, which is carried through much of the conventional literature, lends itself to a discussion of failure in the market for information. Arrow's analysis is associated most often with its identification of market-failures in the appropriability conditions that influence knowledge (information) production. But this analysis also served to identify some "peculiar attributes" of information not only in terms of its supply but also in terms of its demand. These attributes[10] include, the indivisibility of information, the ineffectiveness of monopoly due to cost of diffusion (even with IPR there is incomplete appropriability), non-exclusivity of use, inherently different values of information for different actors, and a fundamental paradox in the determination of demand (how to buy something that is unknown).

Arrow' analysis demonstrates not only that the supply of information will be suboptimal due to the demonstrated shortcomings in appropriability conditions but also that demand for knowledge will be suboptimal at any price due to a strong tendency to underestimate its value11. This situation affects the diffusion of knowledge and challenges the idea of market for knowledge (see Troy & Werle, 2008). A remarkable aspect of the Arrowian analysis is that it recognizes that the 'interdependence of inventive activity' aggravates these problems even more. This recognition points to the important fact that knowledge is quite distinct from information as a 'peculiar' commodity. In this vein, Machlup (1962) distinguishes between knowledge as product and knowledge as an intermediate good, which involves such an interdependence of knowledge producers and users. A modern streak of Machlup's book is that it merged the question of production and coordination by introducing the case of 'knowledge receiving as knowledge production'12.

A wide literature has meanwhile considered the special epistemological questions about knowledge as an economic good13. In general its starting point is that knowledge implies some relationship between the thing (what is known) and the person who acquires it (the knower who 'learns'). The value—and indeed the ability to conclude a transaction of the 'thing' in any real sense— is not a question solely about price but also about characteristics both of the thing and its 'owner' (the original knower or the learner). Polanyi (1958) focuses on this action of knowing. In this and later works, he introduces the distinction between tacit and explicit modes of knowledge, finding that all knowledge to a degree involves a tacit (even ineffable) component. This distinction entails that

10 See the development of this influential discussion of informational attributes for example Romer (1990) who develops the non-rival quality of knowledge in use or Dasgupta and David, 1994; Aghion and Howitt, 1998) on the possibility of "inter-temporal knowledge spillovers".

11 North calls this, "A specific kind of transaction cost—that of ascertaining the (measurement and performance) characteristics of goods and services acquired which are alien to one's specialized knowledge." (North, 2005: 66)

12 This is a precedent for what Bresnahan and Greenstein (1997) later dubbed 'co-invention'.

13 See e.g. Gibons et al, 1994; Faulkner & Senker, 1995.

knowing is contextual and requires a multi-sided effort in order to transfer what is known.14 Knowledge production and its transfer are interrelated to a certain degree, with the latter aspect involving some translation process.

The reflexive nature of knowledge in turn entails a relationship between the firm and the availability of new technological knowledge outside it. Firms can be seen as dependent on their environment to secure information and to access knowledge as well as other strategic resources. The role that external sources of (scientific, technical and market) information play in successful innovation by business firms has been recognized for decades (cf. Freeman, 1991). How this is accessed and integrated is not cut-and-dried. In general, firms, "(combine) new generic knowledge with the specific idiosyncratic product, market and technical conditions of application into which each agent operates. The generation of new technological knowledge by each agent relies systematically upon its ability to access, retrieve, understand and use external knowledge." (Antonelli & Quéré, 2002: 5) The ability of the firm to do this is dependent on how it organizes its internal resources in relation to external knowledge and how it interacts with other organizations in technology based collaborations. In turn these dimensions involve how the access and the interaction are mediated, for example, using patents.

2.1. Dimensions of knowledge: localized yet distributed

There are several characteristics of knowledge that influence the localized character of knowledge and that affect the relationship between its production and its diffusion. The way knowledge is organized affects the way firms cooperate, largely by influencing the coordination costs implied by an extended division of labor. Quéré (2008) identifies a range of the attributes of knowledge which vary from case to case:

- fungibility or its scope for potential applications; complexity, variety of complementary units of knowledge that are used to generate a new unit;
- cumulability, the degree to which new knowledge is based on complementary knowledge which is current or previous ('vertical and diachronic complementary character'); stickiness,
- the embeddedness of knowledge in human capital and routines;
- and finally tradability, the extent to which knowledge can be traded as a disembodied good in the marketplace. (Quéré, 2008: 147)

These aspects –especially tradability and fungibility— influence whether and how organizations interact with one another in the development and diffusion of the new knowledge in question. Antonelli & Quéré (2002) point out several observed aspects about how knowledge behaves in the

[14] See also Howell & Boies (2004) in the management literature on the importance of 'relational knowledge'. See also Nonaka and Takeuchi, 1991 for adaptation in the management literature.

real world: technological knowledge involves learning which will tend to follow along the learning strategy of the firm[15].

- technological knowledge tends to agglomerate or bundle, reinforced by complementarities, spillovers (e.g. Jaffe et al, 1993) and increasing returns. This promotes regional concentration (see e.g. Hoekman et al, 2008 for a recent account of the geography of collaborative knowledge production in Europe).
- a firm's ability to absorb external knowledge is affected by communication (e.g. Griliches, 1992) or interaction costs (Langlois, 1992), by absorptive capacity (Cohen & Levinthal 1989, 1990), as well as by dynamic capabilities of the firm (e.g. Teece et al, 1997).

Some degree of interaction between the firm and the source of knowledge is therefore necessary. The reflexive nature of knowledge formation is important when considering the role of the patent system (section 3). An important vehicle to promote the creation as well as the distribution of new knowledge is inter-firm collaboration. The tendency for competitive firms to collaborate together in the development of new technologies is an established characteristic of innovation. However formal technology-based co-operation agreements have increased and changed radically during the past several decades, especially in high-tech fields like ICT. (e.g. Imai & Baba, 1992; DeBresson & Amesse, 1991) There has been a quantitative increase in the number of formal technology-based agreements and a qualitative change in the nature of those formal linkages (cf. Mowery, 1989; Hagedoorn & Schankenraad 1990; Freeman, 1991).

In this context, organizations engage with one another in networks of different configurations in order to experiment with new alternatives (exploration) and to refine or extend knowledge bases (exploitation). Firms manage exchanges with organizations around them to improve their access to new generic knowledge. (DeBresson & Amesse, 1991) Powell et al (1996) indicate that this shifts the 'locus of innovation' to the interaction between different organizations with complementary knowledge; this modes of coordination then function to a certain degree as "networks of learning". The need to coordinate information flows during collaborative technological innovation can overcome the power relationships of contended competitive markets. Robertson & Langlois (1995) indicate that the tendency for various organizations to emerge is contingent on the nature and scope of technological change and on the effects of various product life-cycle patterns. Several technological and non-technological factors are found to affect the tendency for firms to cooperate. These include:

a) Technological complexity (e.g. Singh, 1997) and technological modularity (e.g. Henderson & Clark, 1990; Langlois & Robertson, 1992; Langlois, 2002)

[15] See also Patel & Pavitt (1991) on how knowledge is managed in large firms. See also Suzuki & Kodama, (2004) On the persistence of innovation in large Japanese companies.

b) Technological interrelatedness (e.g. David, 1987; Lundgren, 1995; Antonelli, 2001), building on the need to integrate complementary competencies (Baba & Imai, 1992), the need to facilitate the codification of tacit knowledge (e.g. Foray & Lundvall, 1996)

c) The underlying institutional infrastructure (e.g. Carlsson and Stankiewicz (1991)

d) Network externalities (e.g. David, 1987)

Coordinated technology-based co-operations may take a variety of forms. Hagedoorn & Schankenraad (1990) distinguish between six general organizational modes of inter-firm cooperation in high-tech areas[16]. But the list may be adjusted according to different contexts, such as their relevance for innovative activities.[17] A useful distinction in this context involves the nature and scope of technological innovation, where Henderson & Clark (1990) distinguish between innovation at the level of the components or subsets (modular innovation) of a larger technological system and innovation in the configuration of the system itself. In addition to refining the classical dichotomy between incremental and radical innovation in light of a noted change in the complexity of technology, the distinction influences how organizations might collaborate.

The distinction between component and architectural knowledge (Henderson and Clark, 1990) entails knowledge about the core design of the component products as well as about the overall architectural design of the integrated whole. Britto (2004) uses this distinction to analyze the 'modus operandi of cooperative agreements'. Building on Henderson & Clark, he identifies four working types of networks that differ according to several dimensions of the technology (nature and scope), product markets, types of information flows, etc. Britto's four categories are:

1. Technological subcontracting networks,
2. Modular assembly networks,
3. Complex-products networks
4. Technology-based networks.

One critical dimension of this interaction involves how learning takes place in the networks. This dimension will condition whether and how patents may be used in knowledge distribution. Section four will return to these categories to discuss how the patent-system can be directed to address more cumulative forms of innovation. (see also Gallini & Scotchmer, 2002)

[16] Joint ventures, joint R&D, technology exchange agreements, direct investment, customer-supplier relations, one-directional technology flows.

[17] Based on DeBresson & Amesse (1991), Freeman (1991) suggests nine-categories of networks in addition to less formal interrelationships.

3. Institutional incentive systems: the 'knowledge-problem' and the role of the patent-system

The short review above indicates that knowledge formation is not just a question of solving a 'market-failure' in the provision of new information. It involves balancing the localized character of knowledge generation with the distributed character of technological knowledge. This section briefly reviews how the rationale of the patent system has been treated down the years in light of this. It first puts the role of the patent system as part of the institutional setup into context of the innovation system before tracing the twin strands of its role to induce and to coordinate new knowledge. The review reveals that both aspects have been present throughout the discussion but that emphasis of each has varied.

3.1. The 'knowledge problem' and institutions

The review of the attributes of knowledge and associated problems helps to put the role the patent-system into perspective of the overarching innovation system. The patent-system is a central element of the institutional setting in which firms and other economic actors innovate. Institutions define the 'rules of the game' for economic activity. Institutions are needed to shape human interaction and structure the interchanges that promote the creation, exchange, and accumulation of new technological knowledge.

Institutions matter in the formation of economically significant knowledge because markets are not well geared to transacting knowledge. In general, a combination of market and non-market mechanisms promotes the growth of economically important knowledge involves. The institutional setup is instrumental in setting the incentive structures according to which economically important knowledge grows.[18] At the aggregate it aims to address the generic knowledge problem that society faces. According to Hayek (1945), the problem is twofold; it involves, "…finding a method that not only best utilizes the knowledge dispersed among the individual members of society but also best uses their abilities of discovering and exploring new things." (Hayek 1945, 190) Knowledge accumulation involves balancing the localized character of knowledge generation with the distributed character of technological knowledge. The generic implication is that the overall institutional framework—including the patent-system—has a dual focus:

1. to coordinate knowledge dispersed among different agents and to direct it at economic problems and
2. to induce inventive activity in general.

[18] "…it is important to stress that the performance characteristics of any market are a function of the set of constraints imposed by institutions (formal rules—including those by government—informal norms, and the enforcement characteristics) that determine the incentive structure in that market."(North 2005, 66)

There is a distinction between focusing individual activity on creating new knowledge and coordinating the knowledge of different agents. These two elements at base involve address the need to manage uncertainty during the development of the invention. The networks of innovators reflect several sources of uncertainty familiar from basic research. Rosenberg (1995) traces several sources of uncertainty to product design and new product development, which are endemic to the nature of innovation, including that:

- The impact of innovation depends on improvements not only in the invention itself, but also in complementary inventions. (Rosenberg, 1995: 176)
- The impact of invention A will often depend upon invention B—which may not yet exist.
- inventions will frequently give rise to a search for complementary inventions. (Rosenberg, 1995: 177)
- Technological systems may be said to comprise clusters of complementary inventions.
- one of the greatest uncertainties facing new technologies is the invention of yet newer ones. (Rosenberg, 1995: 183)

The question of uncertainty in knowledge production has implications for the tradeability of knowledge using patents. Troy & Werle (2008) provide a discussion of the institutional basis of this role. They point out that this function has implications for how 'markets for patents' might work where, pointing out that a licensing regime may still need to be developed to sufficiently address it (see below).

In this light, "the coordination of knowledge requires more than a set of prices to be effective in solving human problems". (North, 2005: 73) The price system is incapable of completely integrating knowledge (a learning process), which is dispersed. North (2005) links the relationship between knowledge production and coordination to the foundations of the market economy itself, arguing that,

"…because the division of labor produces a division of knowledge and different kinds of knowledge are organized in different ways, the coordination of knowledge requires more than a set of prices to be effective in solving human problems. The implication is that the institutional structure will play a critical role in the degree to which diverse knowledge will be integrated and available to solve problems as economies become more complex." (North, 2005: 73)

The institutional setup is endogenous to knowledge formation. Institutions co-evolve with changing modes of knowledge formation and other factors. Institutions are also imperfect. North emphasizes the inherent fallibility of institutions, arguing that the ability of economies to adapt their 'artifactual structure" according to changing conditions ('adaptive efficiency') is essential to successful economic change.[19] Indeed, "The key to useful institutional analysis is to take into account the imperfect nature of institutional incentive systems and build that understanding into the analytical framework" (North 2005, 66) The ultimate goal of the incentive system is not only a question of efficiency. In this context distributional goals also play an important part in development.

3.2. The patent system as institution: brief literature review

The patent system faces two general challenges if it is to address the 'knowledge problem' sketched above. On the one hand this institution has a role to play in shaping the initial incentives to innovate—ie. its familiar role in inducing economic actors to generate new knowledge. Addressing the 'appropriabilty problem' however does not address the whole 'knowledge problem'. The patent-system also has a role to play in improving the coordination of knowledge production among different actors—either in sequence (cumulative) or in parallel (collaboration). A review of the extensive literature[20] indicates that the importance of these two roles has been central to the debates about the rationale of the patent system throughout its history.

3.2.1. Early foundations

The literature, which is as old as the modern economy itself, has tended to emphasize the one or the other of the effects of the monopoly-protection regime at different points in its development. Summing up the situation during the Depression, Plant (1934) contrasted two historical directions of thinking. The first position, going back to early political economists (Mills) and into the Utilitarians (Bentham) focused on the inducement of invention through the 'Rationale of Reward', which overcomes what later became know the 'appropriability problem'. The second position focused on the role of the patent system in promoting the Diversification of Activity. [21] These authors (e.g. Pigou and Traussig) indicate that inventive activity would take place without the patent-system and that the patent system merely directs this activity into specific types of knowledge creation.[22]

In this early stage one can trace the pendulum swinging away from the strong emphasis on the 'natural rights' of the inventor (to induce invention). Towards the end of the 19th century, one notes

[19] "Put simply the richer the artifactual structure the more likely are we to confront novel problems successfully. That is what is meant by *adaptive efficiency*; creating the necessary artifactual structure is an essential goal of economic policy" (North 2005, 66)

[20] The legacy of review books and articles on the economics of IPR is long, demonstrating somewhat different focuses, e.g., Penrose (1951), Machlup (1958), Basberg (1984), Kaufer (1989), Griliches (1990), David (1993), Besen and Raskind (1991) and Merges and Nelson (1992), Wallerstein et al (eds) (1993); van Dijk (1994), Mazzoleni & Nelson, (1998), Dixon & Greenhalgh, (2002); Gallini & Scotchmer, (2001), Gallini (2002), Andersen (2001); Cantwell (ed)

[21] See also Locke vs Bentham or Diderot versus Condorcet. A variety of authors have reviewed the epistemological debates. Pugatch (ed) 2004. The Intellectual Property Debate for a discussion of the different aspects of the intellectual foundations or justifications of the patent system. See also Plant, 1934; Cantwell 2004; Menell, 1998; Andersen and Konzelmann, 2008.

[22] Plant saw the patent system as affecting inventive activity in two ways. It may affect the total amount of inventive activity or it might divert activity into those fields in which the monopoly grant will be expected to prove most remunerative. He was concerned with the opportunity cost of this effort from existing productive activity.

a greater concern for the cost of the patent system to other actors and greater focus on communalism of inventive activity into the 20th century. This was a period in which the Rationale of Reward had lost sufficient legitimacy that the patent system was in fact revoked in more than one jurisdiction. After an intermediate stage in the western economies, the rationales of the patent-system were actively reviewed after the war[23]. In 1950 Machlup and Penrose distinguished four general types of arguments attributed to the patent-system in promoting knowledge formation, finding only one that addresses the collaborative aspect of the patent-system[24]. Based on these categories, Machlup (1958) later famously found little evidence after more than a century of theoretical argument and available empirical evidence, to support or refute the position that the patent system promotes 'the progress of the technical arts and the productivity of the economy'.[25]

3.2. Current analysis of the patent system

The subsequent fifty years, during which economic research on patents really took off, has certainly nuanced the picture as to the effects of patenting. But it has not provided conclusive evidence about the role of patents in promoting the formation of new technological knowledge. The dominant position in the postwar treatment of the patent system has been to focus on the strength of patent protection (including breadth and duration) in inducing private organizations to invest in risky research development and innovation activities. A recent tendency however has been to return to the concerns about the role in facilitating (or getting in the way) of collaborative knowledge production.

A convenient way to think of the overall role of the patent system in the modern debate, is that, "patents are designed to create a market for knowledge by assigning propriety property rights to innovators which enable them to overcome the problem of non-excludability while, at the same time, encouraging the maximum diffusion of knowledge by making it public." (Geroski, 1995: 97) As a 'market for knowledge', its design is recognized to be faulty in a variety of ways, noting:

- Examples of innovation under weak patent regimes (e.g. Murmann (2003) on the German dye industry versus British). See also MacLeod (1988) who argues that the role of the patent system during the industrial revolution was exaggerated.
- Empirical (survey-based) studies consistently indicate that the prospect of patent protection plays only a subsidiary in research and development decisions in most industries. Drugs, scientific instruments and chemicals are exceptions.[26]

---

23 Note the interesting story of the appropriation of German intellectual property following the wars.

24 (i.) the natural property right in ideas (ii) the just reward for the inventor; (iii) the best incentive to invent; and (iv) the best incentive to disclose secret information.

25 Machlup (1958) "An Economic Review of the Patent System".

26 Scherer (1983), Mansfield (1986), the Yale survey (Levin et al. 1987) the Carnegie Mellon study (Cohen, Nelson, and Walsh 1996):

- A minority of innovations is patented (e.g. Arundel & Kabla, 1998) because firms assess the patent-system as imperfect in appropriating profits (e.g. Mansfield et al., 1981; Levin et al, 1987). Other appropriation strategies are more or less important for different industries: secrecy, lead-time, complementary sales and service: contrast Yale (1983) and Carnegie-Mellon (1994) on rankings.
- The relationship between patents and R&D is unclear, especially in industries where innovation builds on prior innovation (Merges and Nelson, 1992; Green & Scotchmer, 1995). Many patents are registered so as to quickly allow individual firms to negotiate access to important external technologies (Hall and Zeidonis, 2002).[27]
- Patent strategies can contribute to unproductive competition for monopoly profits; see the counter-example of non-disclosure of patents in standardization activities.[28]

Still, a consensus has emerged that patent rights do influence knowledge creation decisions and that they may affect the way knowledge is coordinated. In the modern discussion the primary aim of the patent system is to improve the "allocative efficiency" for the economy's investments in innovative activities. In this view, a principal rationale is to overcome the 'appropriability-problem' or the expectation that society will under-invest in inventive activity on the assumption that knowledge is non-excludability like information. (Arrow, 1962; see above) To address it the patent-system provides the familiar prospect of monopoly rights that is expected to increases private investment (in research, development and innovation costs) in the creation of new technological knowledge. The central trade-off involves balancing the static costs imposed by the system (surplus profits accruing to the inventor because of the monopoly to exercise a given invention) through the dynamic surplus accruing to society through the increased investment in inventive activity in general.

David (1993) sums up the role attributed to the patent-system in terms of how it affects the organization of knowledge production: the prospect of patent protection can promote new R&D, the existence of a patent can provide the basis for further utilization as well as the basis to coordinate the use of new knowledge (especially through licenses), and the patent system can limit the underutilization of inventions, for example if it leads to a license by an organization better positioned to work the invention. The general premise is that the benefits of patents are their ability to influence the production of new knowledge and to influence the utilization of existing knowledge-stocks. But patents are also recognized to impose costs on the production of new knowledge (and to impose opportunity costs as well). Out of this recognition have grown extensive literatures on the conditions under which the benefits are maximized and the costs are minimized, not least in terms of the duration of protection (Nordhaus, 1969) and the breadth of protection (e.g. Beck, 1983). In this

[27] The relationship between patent to R&D dollar suggests that patenting trends reflect more 'harvesting' rather than innovation. (Hall & Ziedonis, 2002).
[28] As in cases such as in Stambler v Diebold, Inc (1988), involving the standards related to ATM cards, an early case of conflict in which a patent holder attempted to assert his patent for what manufacturers believed to be an open and available standard. See Blind & Iversen, 2004.

technical discussion there is an implied balancing act of influencing the access to patent protection in such a way as to avoid waste of resources on premature invention, to avoid duplicative R&D and substitute inventions while at the same time not promoting excessively rapid spending on research and patent races. However Kitch's seminal work (1977, 1980) on the role of patents in controlling different types of innovation 'prospects' links with the more recent focus on patents by arguing that patents encourage the commercialization of existing inventions.

Stepping back, the overall impact of the patent system can be seen as involving, "whether the prospect ex ante of a patent, together with its ex post presence, stimulates or interferes with technical advance in a field." (Mazzoleni & Nelson, 1998)[29] Based on this distinction, Mazzoleni & Nelson (1998) provide an updated survey of the normative role that has been ascribed to the patent-system in recent economics-oriented literature. They note four types of 'theory':

Theory 1—"invention motivation" theory designed to induce R&D investments

Theory 2—Patents Induce Disclosure and Wide Use of Inventions: the focus is on how patenting might extend use, rather than how it enhances incentives for invention in the first place.

Theory 3—Patents Induce the Development and Commercialization of Inventions

Theory 4—Patents Enable Orderly Development of Broad Prospects.

The Mazzoleni & Nelson review from 1998 demonstrates the post-war literature has been strongly preoccupied with Theory 1. It has focused on the role of the patent system to induce individual organizations to pursue inventive activities in a way that primarily links the strength of that effect to the strength of patent protection. (see for example Kortum & Lerner, 1998) This mode of analysis has increasingly been criticized for its myopic focus on appropriability conditions for the initial discrete innovator (see Mazzoleni & Nelson, 1998), for its built-in tendency to overlook tradeoffs with collaborative or improving innovators, and its narrow market-failure justification and unsupported assumptions (Dosi et al., 2006) The focus on strengthening incentives to invent in order to overcome the perceived 'appropriability problem' has systematically overshadowed work oriented around the other three theoretical starting points.

However, there are signs that this preoccupation has lessened in recent years. The literature is now placing more emphasis on the effect of patents to coordinate knowledge production (or its failure to do so) in scenarios involving multiple inventions and/or multiple organizations. A brief synopsis indicates a growing concern for the patent in promoting technology-transfers from one organization to another as well as within more complex interactions during 'cumulative or sequential innovation'.

[29] Contrast the concern of Plant (1932) that the patent system lacked theoretical underpinnings for its provision of monopoly, and that it served to divert resources from existing areas of production to inventive activities, which are inherently risky.

Given the difficulty that the reflexive nature of knowledge places on interaction, the concern with how patents facilitate a necessary level of coordination has grown in importance.

3.3. The coordination function and multi-invention scenarios

A growing literature has looked into the degree to which patents help or hinder the interaction between multiple organizations in cases where efficiency is improved by the involvement of multiple organizations. During the mid 1990s, the idea of knowledge systems emerged emphasizes that the creation of new knowledge is not the only aspect of the innovation system that needs to function to promote knowledge formation. David and Foray (1994) emphasize that a complementary dimension is the 'distribution power' of the system, including the role of the patent system to promote interaction ('connectivities') between organizations in the production and distribution of knowledge in new systems of innovation. The distribution power can be seen in the terms of the patent system's role in disseminating information about inventions. The full disclosure of information in patent applications can allow for dissemination, verification, and application by others engaged in complementary intellectual pursuits.[30] Further, Foray (1995) argues that knowledge-systems are changing in a substantial way, with innovation increasingly involving a routinization and systematic utilization of existing knowledge. This view suggests that the role of IPR as an incentive device to induce individual investment is being reduced. Instead they take on a more important role in the coordination of research and innovation activities beyond the dissemination of information, for example in facilitating tech transfers and technology-oriented collaboration.[31]

The growing emphasis on the coordination function of the patent system builds on the idea that the formation of technological knowledge involves a growing division of labor. Successful technological innovation builds both on the ability of the inventor to generate new knowledge but also on his ability to produce and profit from the innovation. In many cases, the inventor is not the organization that will take the invention to end-product. Different organizations such as public research organizations, small firms and multinational firms clearly have different abilities to utilize an invention even in cases where their ability to invent is similar. Their abilities in the one or the other areas can be complementary.

Specific factors about the technology or the organizations involved or the way their relationships are put together will influence this coordination process and whether it takes place within the organization or across organizations. An instrumental question here is, "whether the multiple steps

---

30 But this effect is rarely realized: Bessen (2004) for example finds that disclosure of inventions is in fact not improved by the patent system.

31 A legacy can be seen to go back to Pigou and Traussig argument (see above) that inventiveness is to a large degree a given. It also links with the more recent focus on patents in encouraging the commercialization of existing inventions from the prospect perspective of Kitch (1977).

in the invention, tend to proceed efficiently within a single organization, or whether efficiency is enhanced if different organizations are involved at different stages of the process”. (Mazzoleni & Nelson, 1998) A recent study among inventors puts what drives patent use into perspective. Gambardella et al (2007) indicates that less one in five patents are used to exclude external competitors, which is roughly in line with the number of patents that are ‘unused’. Roughly half of all patents are essentially sought to ensure the freedom to operate in the company operations.

In terms of coordinating innovative activity, the survey indicates that over 13% of patenting activity involves some form of licensing. (Gambardella et al, 2007) Half of this seems to be in the form of technology transfer to another organization to develop the invention, whereas the other half seems to involve the continued participation of the original inventor. The ability of patents to promote technology transfers between organizations becomes important. But as discussed above, the nature of knowledge introduces a, “…specific kind of transaction cost—that of ascertaining the (measurement and performance) characteristics of goods and services acquired which are alien to one’s specialized knowledge.” (North 2005, 66) The potential for such transactions therefore also involves the difficulty of transferring tacit knowledge, information-asymmetries and the need to align not only the incentives and frameworks to facilitate cooperation.

3.3.1. Licensing configurations and multi-invention contexts

The coordination process can take place as an arm-length through licensing in the form of technology transfer but also in technology based-interaction. In terms of the first, the question of the strength of protection has also been considered in terms of how it affects the transaction costs in licensing an invention (e.g. Arrow, 1962; Merges, 1995; Arora, 1995). Teece (1986) indicates that the existence (or lack) of complementary assets affects the propensity to license while Arora and Gambardella (1994) show that technologies that are more heavily dependent on tacit knowledge are less likely to be licensed than knowledge that is more easily codified. In this context, static ‘transaction costs’ should be distinguished from other dynamic costs of interaction. Langlois, (1992) argues that the need of firms to build up internal capabilities in time to provide requisite ‘absorptive capacity’ lead to a situation of ‘dynamic transaction costs’[32].

These costs have direct effects on the way technologies are licensed. The literature on technology transfer tends to transfer the focus on patent strength to how it affects knowledge exchange from one organization to another. The theoretical model of Arora (1995) demonstrates that stronger patent protection (codified) knowledge facilitates knowledge exchange by increasing the willingness of the licensor to transfer the know-how component (tacit knowledge) affects the success of the

[32] The dynamic question of whether the firm is positioned in terms of its ability to adapt to new opportunities ultimately involves a deeper level of uncertainty in firm strategy. Link to Troy & Werle, 2008.

license to promote technology transfer from one organization to another. Gallini (2002) finds an effect of strong protection (high licensing fees) to preserve the commitment of the licensee firm. Such licensing arrangements might also lead to new firm creation as a way to promote two-way communication between the original inventor and others. Arora and Merges (2004) shows the strong protection can affect firm-creation since it may be more efficient to spin-off specialized groups as a vehicle to develop patented technology. This can lay the basis for the transfer of know-how to the original licensor from user-needs as the invention is customized. This arrangement can in turn promote a division of labor between research (for example in the university setting) and development (by a firm). The need for a substrate for collective learning can even be called for to coordinate distributed R&D activities between different parts of the same firm. (Wilkens & Karaomerlioglu, 1999)

When more than one innovator are involved, the dynamics and the implications for the patent system change. Bessen & Maskin (2007) observe here that, "when discoveries are "sequential" (so that each successive invention builds in an essential way on its predecessors) patent protection is not as useful for encouraging innovation as in a static setting." (Bessen & Maskin 2007,1) Scotchmer (1991) looks into the case of sequential innovators in terms the strength of patent protection, showing that the strength of protection must be balanced between the incentive of the first innovator and the incentive of subsequent waves of innovators. In this case the breadth of the primary invention is instrumental as is the incentive of the secondary innovator. Green & Scotchmer (1995) subsequently show that in addition to the breadth of patent protection for the primary innovator in a sequence of innovation, the ability to strike cooperative agreements is another way to avoid profit erosion by subsequent innovators. These agreements may involve cross-licensing, which according to the Gambardella et al (2007) paper constitute about 4 percent of patenting activity.

The failure to overcome coordination problems can undermine the basis on which collaborations take place. This can for example lead to the underutilization of not only single inventions but of sets of interdependent innovations. In this context, "patent policy not only affects incentives for innovation but also influences the transaction costs, which in turn determine the preferred organizational modes in the industry." (Somaya & Teece 2000, 1) Nor is it only about transaction costs. Addressing coordination problems is not only about focusing on the strength of patent protection to change the cost of using the market to access outside knowledge. It depends as well on addressing 'interaction costs' of the involved firms so that the integrated modes of production can be achieved. To look at these important issues, the last section returns to consider the role of patenting in the context of the four archetypes of organizational modes introduced above (Britto, 2004).

4. Networks of innovation and multi-inventor patenting

The production and application of new technological knowledge involves considerable uncertainty at different points during the innovation process (Troy and Werle, 2008).[33] Such uncertainty may affect the pursuit of an original creative spark. This question of inducing invention despite the uncertainty of would-be innovators about their ability to appropriate profits of the activity has preoccupied the literature for much of the past. But invention is rarely a once-off, single organization event. Invention has a tendency to involve follow-up inventions and improvements, especially in certain technologies. In terms of a single innovator scenario, the uncertainty attached to the innovation process is already formidable. Arrow's analysis points to this in theory (see above), while Georghiou et al (1986) demonstrate that even in single product inventions a form of 'post-innovation' activity is often decisive. Patents may help manage uncertainties about the development of the market, and of the technology during this process.[34]

The plot thickens in more complicated multi-invention scenarios as the tendency is for other organizations to become involved. Given the contextual nature of knowledge, uncertainty may be compounded in such situations, which may undermine the coordination needed to align different organizations with different interests, attributes, positions, and levels of knowledge. In view of changing modes of innovation, some argue that auctions and third party intermediaries will increasingly provide the link between supply and demand of invention based on patents.[35] However, in light of the dimensions of knowledge discussed above and in light of previous experience[36], it is unclear how new intermediaries will overcome the, "(f)undamental and strategic uncertainty related to patent trading– a specific decontextualized institutional form of knowledge property – (that) has prevented functioning markets for patents from emerging." (Troy & Werle, 2008, 20)

4.1. Patents, 'decision architecture', and the network of innovators

In terms of the direction of future research, Rhoten & Powell, 2007 note 'a need to clarify the objectives, operations, and effects of the IP rights system in light of the changing ways in which IP rights govern and are governed'. (Rhoten & Powell, 2007, 20) The changing direction of economic analysis and the mounting call to consider governance aspects (Granstrand, 2006) in approaching the patent system calls for a better understanding of micro-level patenting behavior. Some aspects of

---

33 See their argument that the ongoing discussion of a 'market for patents' be considered in the fundamental context of uncertainty.

34 See Tietze et al 2006 on strategic IP management in biotech.

35 This suggests that more use will be made of 'sleeping patents' that Gambardella (2005) reported to make up some 17% of total patenting. See Chesbrough's (2006) claim that, "Tomorrow a variety of intermediaries will be available to (individual inventors) to help sell their ideas to the highest bidder." (Chesbrough 2006, 139)

36 See the failure of a centrally managed licensing-regime in the UK during the 1930s, referred to in Plant (1934).

how patents affect firm-based decisions will be introduced before the section goes on to argue that industrial or innovation networks provide an apt level of study.

At the level of the firm, for example, Wu (2006) assumes away the key incentive and deadweight loss effects of patents in order to emphasize how the existence of patents shapes the 'decision architecture' of economic organizations. Drawing on Freeman (1987), Coase (1992) and Antonelli (2001, 2002), Quéré (2008) advocates an 'economics of the governance of knowledge' to approach the 'firm as a localized innovation system'. (Quéré 2008, 148) This view casts innovation as a 'collective learning activity' which at the firm level involves pairing the complementary nature (i) of external and internal knowledge and (ii) of the stock of existing knowledge and the flow of new knowledge. Two 'regimes of knowledge accumulation' can result from the 'localized interactions among learning agents': namely firms may embed new knowledge into their production processes in an 'additive' fashion (new knowledge is added to old) or in a 'recombinatory' fashion (where internal knowledge is recombined in new ways by outside knowledge). Additive knowledge creation will tend to correspond with sequential forms of innovation reviewed above, whereas a 'recombinatory' knowledge formation process appears closer to collaborative or cumulative innovation settings. The distinction between these two modes of knowledge accumulation can be useful in considering the scope for patent-use especially in terms of the coordination role.

The networks of innovators introduced above represent formalized interactions of 'learning agents' where the role of patenting may vary considerably. These archetypes provide a promising basis on which to consider the coordinative role of patents in multi-invention and multi-inventor modes of accumulation at the level of networks of innovators, not least in light of the importance of technology-based collaborations discussed. The following sums of Britto's four categories and briefly considers how patents may function within networks of innovators, with reference to some of the arguments in the literature. The categorization builds on the distinction between innovations taking place at the component level and those taking place at the modular level. In this distinction, introduced by Henderson & Clark (1990), innovations at these levels take place in between incremental and radical innovations. They also have implications for the sort of information exchanges that the networks build upon and the way the coordination of learning takes place.

4.1.1. Technological subcontracting networks:

The first category in Britto (2004) taxonomy includes firms in which the dominant mode of interaction is through subcontracts involving central dealers or assembly firms. In these cases an initial shift in the technological module provides relationship between components making up the technological regime. This reconfiguration gives rise to a network of flexible specialization that focuses on reducing production costs and on adapting to changing demand conditions within the bounds of the modular technology regime (e.g. Retail). Information tends to flow in a single direction from the central dealer or assembly firm, promoting Marshallian industrial districts.

In the technological subcontracting network, patents may underlay the basis for the subcontracts with the specialized firms in the form of licensing agreements. The situation may approximate the one described by Arora and Merges (2004) in which vertical specialization is preferred to integration given strong intellectual property rights. In this scenario, there is a general incentive for the subcontracting firms to reduce production costs, which may lead to further innovations within the specialized components. However, this information does not necessarily spill back over to the central dealer or to other specialized component providers. These improvements may form a set of non-sequential innovations that are not coordinated. Over time the combined effect of such incremental changes may provide the basis for more radical shift in the module on which the network is based. Here the knowledge appears to accumulate incrementally on an 'additive' basis.

4.1.2. Modular assembly networks

The second category in Britto (2004) taxonomy involves a production system network based on mass customization and productive flexibility within a given modular architecture (Henderson & Clark, 1990). Innovation involves variation of products based on component improvements within the architecture where firms again make incremental changes in components. In this case however, the coordination of organizations is based on longer-term contracts. This provides the basis for longer-term relationships and encourages co-development with major nodes (main supplier) and with suppliers of complementary components. The interchange of performance and quality information is ongoing and involves a learning-process that is targeted.

The modular assembly network is more collaborative and there is less scope for technology-based competition than in the case of subcontracting networks. These longer-term relationships provide the basis for a greater tendency for collaborators to co-patent where relevant. These relationships may approximate the case of 'general purpose technologies' described by Bresnahan and Gambardella (1998), which tend to lead to the formation of upstream technology specialist firms that license the technology to several manufacturers in different industries. As opposed to the previous case, there will be a greater tendency towards cross-licensing if not co-patenting. Here the knowledge appears to accumulate incrementally on a 'recombinatory' basis.

4.1.3. Complex products networks:

The third category in Britto (2004) taxonomy is a project-based network. These networks involve the production of integrated products that are made up of multiple-components or subsystems (e.g.

telecoms). Seamless interoperability is necessary between the different vendor solutions. Given the core design of the components, different vendors focus on customization and performance improvements within the project collaboration. The network of components and sub-system producers is organized into project-based alliances around a 'systems-integrator'. Interaction with users may also be involved. These alliances build on rich interdependencies between different actors (e.g. to ensure interoperability). The multi-firm alliances may outline a given project and continue across a series of projects. Mission critical knowledge and information are exchanged under conditions of incomplete contracts. This type of network may be dependent on voluntary standardization work or engaged in standards development to facilitate this communication and to increase the take-up of the complex product.

The focus on interdependencies between the complementary parts of the system means that patents take on a non-exclusive function in these networks. There is a tendency to pool relevant know-how and cross-license or even to structure patent behavior in other ways, for example in patents pool arrangements or non-assertion covenants[37]. In this environment of incomplete contracts, another strategy may be to use patents only defensively while keeping things unencumbered by for organizations in the network. Baldwin (2007) argues that collaborative firms may open up 'transaction free zones' within the production system of complex products in order to allow "numerous, complex, interdependent, and interactive transfers to take place economically without the burden of transactions." (Baldwin 2007, 187) Cross-licensing and/or other agreements with non-assertion covenants may be useful here. Here the knowledge appears to accumulate incrementally on an 'additive' as well as a 'recombinatory' basis.

4.1.4. Technology-based networks:

The final category in Britto (2004) taxonomy is the involvement in high-intensity R&D project networks which generate new products on emergent markets (e.g. within biotech) and related services they may generate. These networks engage technology firms across cognitive boundaries in long-term development projects that involve suppliers and/or buyers as well as end-users. The network integrates scientific and technological competencies among participant organizations and involves the codification of tacit knowledge that reflects the division of labor. There is a dynamic inter-change of information back and forth between these 'learning agents'. This rich interchange necessitates a formalization of information streams, including the codification of tacit-knowledge and of agreement on ownership of new knowledge as well as any preexisting proprietary knowledge

[37] See Iversen, Bekkers and Blind (2009) on the question of patent-pools and other modes of cooperation designed to reduce the uncertainty surrounding technological collaboration in multiple rights scenarios, specifically in the generation of voluntary standards.

among partners. Coordination may involve cooperative research programs in which a clear division of labor is drawn up between partners at the outset. This form of coordination points to the wider importance of the 'institutional framework' (including bridge institutions and funding agencies).

Patenting—not least co-patenting— may aid to codify tacit-knowledge in these networks during these learning exchanges, and to square the question of who owns/controls what with regards to new knowledge coming out of the partnerships as well as with regard to the preexisting proprietary knowledge of individual partners. The involvement of funding agencies and other institutional stakeholders in this setting will tend to carry with them guidelines on how to coordinate IPR. In the emergent markets, the propensity to patent will be high, especially in the pharmaceutical area. High patent intensities here are expected to prevail even if 'transaction free zones' (see above) are important to interactions here too. To achieve the necessary depth of interaction these networks are expected to use patent pooling and other agreements to structure IPRs in ways that reduce coordination costs between partners. Here the knowledge appears to accumulate primarily on an 'additive' basis.

These four forms of industrial networks provide a set of archetypes against which the applicability of patents can be analyzed. They provide a promising avenue to consider the coordination potential of the patent system while suggesting a variety of empirical approaches against which to analyze the role of patents. These industrial networks differ in the way learning and knowledge formation takes place. In some cases knowledge may be principally accumulate in an 'additive' way- in the sense that they accrete new knowledge within the frame of the new components. This is more the case in traditional subcontracting networks, in which more efficient and more attractive modes to work within the components are tested to meet end-user demand, or in technology based networks, in which intensive R&D accompany a changing modular technology of an emergent market. The one case is a low and the other a high complexity technological system in Britto's classification (Britto 2004, 32).

In complex product networks and technology-based networks, additions to the knowledge base of the industries are of course also important. In the first case, networks focus on customizing components towards the demand of sophisticated buyers; in the latter the network generate new products and services to go with an emergent market. However in these cases where the complexity of technological regimes is high, a recombinatory mode of knowledge is more pronounced. Knowledge is recombined within the new modular architecture of the system (technology based networks) or within the new components of the systems (complex products networks). This mode of recombining knowledge in interactions with co-developers and/or users entails a co-development based learning-process for the individual agents. In this setting, patents or other IPRs may be more useful to establish contractual arrangements during this process, thus providing a coordinative link. They may play a useful role in the governance of innovation systems (e.g. Granstrand, 2006) at the level of networks. Alternatively the potential to copy-left rapidly changing technologies provides another mode to promote coordination particularly in the software world at minimal transaction costs.

4.2. Some empirical strategies

A series of empirically based strategies may help study the role of patents and other IPRs in the governance of these networks. A list of empirical strategies may draw on the following approaches.

1. Patent-data based studies:
   a. Co-patenting: Empirically, a recent article (Gay et al, 2008) suggests co-invention as a means to study 'collective knowledge', patents, and prolific inventors (other references). Applicable particularly to areas of co-invention such as technology – based networks.
   b. Reassignment of rights (Chesborough, 2006): applicable specifically to cases such as traditional subcontracting arrangements where single organizations dominate interactions.
   c. Patent citation analysis: applicable to all four networks to follow interrelationships between specific knowledge and larger knowledge bases.
2. Use of survey-data
   a. Patval based survey of inventors; Gambardella et al (2007): applicable to analyzing the extent of licensing of patents in different settings and the valuation of the patents involved.
   b. Community Innovation Survey based studies: applicable to study the relationship between patenting behavior and co-operation in general (e.g. Czarnitzki et al, 2007)
   c. R&D survey based studies: applicable to analyze licensing-behavior among R&D intensive fields, especially networks 3 and 4.
3. Case-studies:
   a. Vertical or longitudinal studies of the development of individual networks or industries
   b. Horizontal studies of coordination mechanisms such as patent-pooling.

An approach based on survey data is developed in the Patenting and Collaboration chapter(essay 6), which also reviews this literature in more depth.

5. Concluding discussion

The patent-system has evolved rapidly during the past two decades both due to intentional adjustments (patent reform[38]) as well as to other factors (technological and commercial) affecting the way it is used. This ongoing process of change raises the question of how imperfect the institutional incentive associated with it is and how reforms may help to reform it. There are widespread indications that the imperfection of this particular component of the incentive system may go against its expressed aim to promote the formation of technological knowledge. (e.g. Jaffe and Lerner, 2004; Landes & Posner, 2004; Merges & Nelson, 2006; Meurer and Bessen, 2008).

Modern analysis of the patent system has tended to focus on the "invention motivation" theory or how patents induce the generation of new knowledge. One concern is that patent protection is becoming easier to obtain and that this may contribute to the erection of barriers to innovation for example in the form of patent-thickets. Far from inducing invention, such scenarios point to the possibility that patent-protection may form barriers to entry for involved markets. The focus on strong patent protection has entered the public discourse, resulting in what Peritz (2008) calls an "incentive conundrum". This conundrum involves conflating the public benefit with the interests of private organizations to expand patent protection in a way that confuses public debate and gives policymakers 'rhetorical cover' for advocating stronger patent protection.[39]

In recent years however more attention has turned to the role of patents and patent-based arrangements to facilitate collaborative multi-invention scenarios. There remains a need to better understand the productive potential of intellectual property rights (Andersen & Konzelmann, 2008). This discussion should take into consideration the role of the patent system as part of a larger institutional setup that shapes how the innovation system addresses the perennial 'knowledge problem'. In this context, Granstrand (2006) indicates that IPRs may play a useful role in the governance of and in innovation systems at different levels. Here, there is an evident need to distinguish between cases involving single inventions/single inventor-organizations from cases involving multiple inventions and/or multiple organizations. The importance of patents, and the way they are used, will be different, as the discussion indicates.

This report has reviewed the nature and the role of the patent system in promoting the formation of technological knowledge in the economy. This survey indicates that in the current environment of

---

38 Policymakers are currently reviewing the form and function of the patent-system (cf. the Patent Reform hearings in the US, December 2008) See also a reform process in Germany as well as ongoing discussion of reform at the European Patent Office.

39 Peritz, 2008: "Simply put, the misunderstanding is that the public benefits whenever inventors and their firms benefit from patents. But inventors can be better off, firms more profitable, but society worse off when, for example, the resources applied to invention could have been put to a better use. I call this gap between public benefit and private value, patent's incentive conundrum. The incentive conundrum confuses or provides rhetorical cover for too many policy makers." (Peritz, 2008: 8)

patent reform the coordinative function is reemerging, particularly during the past decade. In a brief look at the expansive patent literature, the review has particularly traced the rise and fall emphasis on the coordination function of the patent system. Another characteristic of recent inquiry is its interest in how patents affect decisions at lower levels of aggregation. This includes the need to better understand two aspects of patent-protection: (i.) how the possibility of patent protection shapes 'decision architectures' in the strategies of firms and (ii.) how the existence of patent affects future innovation by other organizations. One implication is that it the relevant level at which to understand the patent system might not be at the level of individual patent but at the level of bundled knowledge, a portion of which may or may not be patented. In this sense, one should also focus on the effect of agreements other arrangements (e.g. patent pools) to improve the climate for collaborative innovation.

In light of the local nature of knowledge, uncertainty underlies both the generation of new knowledge and its transfer and/or co-development. The report focuses especially on the modes of collaborative innovation to the extent that it is discussed in the literature. The premise is that innovation has long involved collaboration but that the nature and the extent of that technology-based collaboration has changed significantly in recent decades. This development has implications for the coordinative role of patents. The report ahs particularly focused on four types of relational links between organizations that involve some form of knowledge creation and exchange. The categories, based on Britto (2004), have implications for the way patents get used to promote knowledge exchanges in these industrial networks. In terms of future work, the report sketches some empirical strategies to study the use of patents in these networks.

Chapter 2:
IPRs and Norwegian enterprises: diversification of innovative efforts in Norwegian firms

This chapter follows up on the theoretical inquiry of the relationship between patent use in particular and knowledge formation. It is the first of three predominantly empirical chapters that focus on IPR-usage in terms of firm-demographics in Norway. The point of departure is the a principle of Marshall (1922)—that "the tendency to variation is a chief cause of progress". In this light it investigates the role of heterogeneity of innovative activities in the Norwegian economy. It introduces the firm linked domestic IPR data that is used in the first three empirical chapters. The prevailing concern with large manufacturing firms with formal R&D activities that is identified in the literature reviewed above is expanded to look at IPR use among all firms in the economy. In addition, essay 2 takes into consideration trademark-registrations, whose economic role has been shown to play an increasingly important role especially in the service-sector. The chapter also serves to introduce the concern about the role of small and medium-sized enterprises as a source of invention which will be followed up in the next two chapters.

Theme	Questions
Essay 1: Knowledge formation and patenting	What role does the patent system play in knowledge accumulation?
Essay 2: The diversification and specialization of IPR use in a small open economy	**How does use of the IPR system reflect the innovative processes of different agents? What role is played by small firms in specialization and diversification of innovative activity?**
Essay 3: The growing use of patents among small firms: areas of growth and challenges	If SME patenting is increasing (see last essay), what technological areas and market dimensions? Do they face greater challenges than larger firms?
Essay 4: Small firm patenting and the transition to European Patent Office	How do Norwegian SMEs use the European Patent System? How the effects of this transition be measured?
Essay 5: Academic patenting and the transition to an institution-based patenting regime	To what degree do academic researchers already patent and will the introduction in Norway of Bayh-Dole-like legislation improve conditions for academic patenting?
Essay 6: The impact of patenting on research collaboration	Does patenting increase the probability for research collaboration? What role do other factors play?

Publication information : Iversen, EJ (2008) IPRs and Norwegian enterprises: diversification of innovative efforts in Norwegian firms, in Carayannis, EG , Kaloudis A, Mariussen A (eds). Diversity in the Knowledge Economy and Society: Heterogeneity, Innovation and Entrepreneurship. May 2008. 384 pp. Edward Elgar: Cheltenham UK.

Acknolwedgements: The helpful comments of two reviewers on an earlier draft are gratefully acknowledged.

2. IPRs and Norwegian enterprises: diversification of innovative efforts in Norwegian firms

By: Eric J. Iversen

1. Introduction

During the 1990s the volume of patent applications and trademark registrations increased substantially in many countries. In Norway the rate of patent applications grew on the order of 30%; that of trademark registrations even faster. This chapter looks more closely at the generation of technological and commercial variety in the Norwegian economy using the complementary lenses of domestic trademark and patent data. Trademarks, which are increasingly used to understand economic activity, are useful in distinguishing products and services from rivals. They can be linked to the differentiation of commercial activity with an assumed innovative character. Patents on the other hand capture technologically innovative activity with an assumed commercial application. They can be linked to innovation especially in R&D intensive fields such as pharmaceuticals.

Patent and trademark-registration each reveal something about the ongoing differentiation of economic activity: the former stresses invention, the latter commercialization; the former tends to emphasize activity in manufacture, the latter activity in the service sector. There is therefore a significant degree of complementarity in these lenses. This chapter uses the combination to explore the heterogeneity that underlies longer term Norwegian industrial evolution. It first looks at the role of heterogeneity in terms of industrial change, in firm-level activities, and the role of the IPR systems. It then goes on to look at firm-level data illustrating how different Norwegian firms use the two systems.

2. Heterogeneity and innovation

In general terms the innovation process can be understood to involve the sustainable generation, distribution and utilization of new economically-relevant knowledge which continuously accumulates and is recombined in the economy (David & Foray, 1995). The generation of variety is the engine of this evolutionary process and it is recognized to pay clear dividends in economic development. Saviotti (1991) emphasizes the role of variety, suggesting that the increased net variety of goods and services may be more than a result of the evolution of the economic system; it may be considered a key aspect, closely complementing increased productivity efficiency. Trend growth in variety is associated with a build-up of complementary skills as well as new techniques; it is ultimately associated with changes in the competition landscape in the direction of greater choice and lower prices.

2.1. Heterogeneity and industrial evolution

The question of heterogeneity is central to the key question of how industries evolve. A persistent degree of heterogeneity of organizations is assumed to be desirable in terms of the knowledge-bases, the productive behaviour, and the organization of firms. Together such factors help to promote industrial evolution. Indeed, a variety of social science subpopulations have increasingly studied the contribution of variety in organizations and the economy as a whole. A body of more sociologically rooted work has notably grown up to study different aspects of the population ecology of organizations (e.g. Hannan and Freeman, 1977; Carroll, 1985).

Marshall's early assertion that, "the tendency to variation is a chief cause of progress" (Marshall, 8th edition, 1922), has attracted renewed interest in economics.40 Such study has especially had emerged in the Schumpeterian tradition, as the emergence of 'new combinations' which are crucial to Schumpeter's story of economic development may be directly linked to the tendency towards heterogeneity. And interest in this fundamental level of industrial dynamics has indeed evolved along a Schumpeterian vein of inquiry into a variety of areas. These include the sectoral composition of the economy, industrial demography and population ecology, stability of firm-size distributions, persistence differences between organizations and of asymmetric firm-performance, etc.41 During the past couple decades this inquiry has improved what is known about the heterogeneity of firms and its implications for different knowledge, competences and learning processes.

Such efforts to understand industrial evolution in this sense have at a fundamental level been inspired by evolutionary biology. One central link has been recognized (Melcalfe, 1998; Sloth Andersen. 2004) between the extent and effect of changing firms in industrial evolution and the Fisher theorem of natural selection, especially in Price's formalized approach. This link about the mechanism of change provides insight into the basic role of heterogeneity in industrial evolution and its link to innovation. According to Sloth Andersen, the Fisher theorem links the pace of evolutionary change directly to variance in the behaviour of a population, where Fisher, "treats selection in terms of what has later been called replicator dynamics or distance-from-mean dynamics." (Andersen, 1994: 4) Price subsequently (e.g. 1972 and onwards) developed a formalized approach based on measures to trace changes in such population characteristics. The Price equation uses the divergence from the mean in such metrics to partition populations and to trace changes. The equation can be linked to the simple models of Nelson & Winner and in the further efforts to isolate the 'selection effects' from 'innovation effects' as argued by Andersen (1994).

[40] Marshall (1922, 1966) Economic Principles. Cited in Cohen, W.M. and Franco Malerba (2001).
[41] See Malerba (2006) for an overview of this legacy and the field.

Industrial evolution involves transformation in underlying knowledge-bases, in technologies, in actors and actor competences, in organization and relationships (e.g. with users), in products and processes, and in institutions. In this setting, the technological regime literature operates on the assumption that the potential for knowledge growth is conditioned by technological specificities (different technologies have different potentials) and by sector characteristics (the technological environment and the dimensions of demand constrain or otherwise shape development paths). Different technologies have different problem-sets associated with them, and solving these tend to define the 'routines' of the firms in the field. (e.g. Orsenigo et al, 1996; Malerba et al, 2002)

This view emphasizes the importance of interdependencies and complementarities in the economy. The premise is that industrial evolution can be more or less limited by the interaction between knowledge bases, the regime context (including appropriability conditions), and by demand. This dependence on complementarities requires a sufficient heterogeneity in the economy to perpetuate industrial evolution. The concern is getting the creative destructive process to become a 'creative accumulation' process (Schumpeter Mode II cf. Pavitt). The concern is to avoid technological mono-cultures which threaten to reduce the learning dividends of a dynamic system.

2.2. Heterogeneity and the firm[42]

But what are the mechanisms at the firm-level that spur diversification of their activity within a country? Firm level innovation processes are recognized to be shaped by an interaction between factors internal to the firm, such as strategy, physical resources and capabilities, and factors outside its boundaries. Diversity in the contextual aspects for example makes inter-country comparisons difficult (Smith, 2001). A major element of the external factors is the institutional conditions which enable and which restrict certain activities: such factors shape the way firms manage their resources.

In general, the process of differentiation stems from enterprises attempt to distinguish what they sell from rivals in markets that are less than perfect. Schumpeter's emphasis on "technological competition" (Schumpeter, 1942; 1975) indicates that firms develop products and/or services that are new and stand out next to those of rivals: firms develop new processes and new techniques that improve the quality of what they sell: or firms explore new channels of distribution or new ways to influence consumer demand. Instead of focusing purely on efficiency, firms may take risks by investing in distinct and new product/process/service that, if successful, will allow them to charge more for what they sell without direct threat of competition.43

[42] This section is based on Iversen (2003)

[43] In this setting, risk-taking agents compete through an expensive search process to commercialize new technologies on unsaturated markets with correspondingly high profit-margins.

Of course, many markets tend to blend the cost component, the technological component and the taste component. The importance ascribed to each will differ not only according to the main type of market (commodity, product or service) but also, to a certain degree, according to the maturity of the relevant product or service market. Mature markets characterized by little innovation will tend to behave more like commodity markets in which rivals compete principally on price (i.e. price-oriented competition), while the innovative aspect will be more important in emerging markets (technology-oriented competition).

Notwithstanding, three modes of competition can be distinguished. In competitive markets, firms can attract buyers by making what they sell:

- Distinct in terms of price
- Distinct in terms of technological performance
- Distinct in the eyes of the consumer
- Distinct in a variety of ways that overlap the above categories.

In instrumental terms, competitive position depends on the firm’s internal capabilities related to purchasing, finance, production, conducting R&D, marketing, distribution, sales and other functions important to its business. Organizational elements are also important, not least the firm’s competitive strategy. Internal capabilities are necessary but not sufficient to establish and defend a firm’s competitive position. Since competition is essentially a relational phenomenon, there will necessarily be factors outside the firm that will condition its position. Two general types of external factors can be distinguished. First, there are general aspects about the firm’s competitive environment that are important and to which it has to be attuned and responsive. These are aspects that confront the firm but which are difficult to observe. They include aspects of market-structure both on the supply and demand side, aspects such as the dynamics of demand, cost conditions, the existence of economies of scale, the size of capital requirements, etc. A second set of external factors involves potential links the firm can develop with its surroundings. One important element is the role that access to public infrastructure and aspects of the regulatory framework play in shaping the competitive environment. The availability and quality of the ‘economic infrastructure’, regulatory conditions and climate, and the nature and extent of institutional support are some of the external factors that are important (Guerrieri and Tylecote, 1994). Together internal and external factors contribute to the balancing of generation, selection, and accumulation processes of new knowledge.

2.3. Heterogeneity and Institutions

The role of institutions is important here, not least in relation to small firms whose limited resources might nip innovative activities in the bud (c.f. Johnson, 1988). In general, it can be said that institutions hold three basic functions in relation to innovation. They can reduce uncertainty by providing information, they can help to manage conflicts and they can provide incentives for example to promote R&D investment (Edquist and Johnson, 1997). In general, IPRs have a role to play in this 'economic infrastructure' in organizing knowledge production, in promoting new R&D, in promoting further utilization as well as coordinating use of new knowledge, while avoiding underutilization losses. [44]

At the firm level, the assumption is that IPRs can augment the position of a firm by helping it to protect the distinctiveness of its products and/or services both in terms of the underlying technological originality— notably through patents and utility models—and in terms of their distinctiveness in the eyes of the customer —notably through trademarks and industrial designs. The use of relevant types of IP-protection can potentially aid the competitive position of the firm by affording it the room to cultivate its distinct qualities without threat from direct competition from imitations. This suggests that IPRs may play important roles in managing IP in cases of technological competition. In terms of the economy as a whole, the way IPRs do this implies both costs and benefits for different actors. On the one hand, IPR-protection brings with it social costs in the form of higher prices (monopoly pricing): on the other, IPRs provide the economy with an incentive to innovate (based exactly on the prospects for the innovative firm for monopoly pricing). The monopoly profits provided by IPRs may have the added advantage for the economy as a whole if it is ploughed back into higher levels of production and innovation.

3. Empirical evidence of Trademark and Patent use

These traces of novelty provide two complementary lenses on the differentiation of economic activity. This section builds on Iversen (2003) to take stock of this effort in the Norwegian case as viewed through these lenses. This section empirically explores the extent of heterogeneity of Norwegian innovation and commercialization processes as viewed through domestic patenting and trademark data.

First, some further aspects of the lenses should be noted. Patenting, commonly associated with the role of an appropriation-mechanism, emphasizes the diversification of technological ideas that the resulting focus on R&D activities promotes. This focus on the role of patents, however, tends to overlook or downplay the contribution of important areas of economic activity. The emerging prominence of the service-sector is one area whose importance, while not ignored, is reduced by the

[44] For a short presentation of the role of IPRs in the innovation process, see e.g. Iversen (2003) on which this section draws.

patent-lens while other technological areas tend to be magnified.[45] The patent-lens for example underplays such major shifts as the ascendancy of the service industries in the economy.

The widespread use of patents as an indicator of innovation has therefore rightly been accused of missing the sectoral change in the economy. (See Saviotti, 1991) The trademark lens provides a substantially different look at firm-level differentiation, especially in terms of making products and services distinct in the eyes of the costumers. A trademark can be registered for 'signs' that differentiate products and services from rivals. The applicant can apply to have a proprietary name trademark for a defined product-class. A registered trademark keeps competitors from mimicking the identity of the product on the market. In this way the mark becomes associated with the quality of a distinct product or a service which the consumer has come to recognize. It becomes a signal to consumers and provides a basis for marketing which cultivates the product's distinctiveness in the mind of the consumer. (see Landes & Posner (1987) which focuses on the impact of trademarks on 'search costs'. The trademark is particularly relevant to the increasingly important role played by the service sector. (cf. Greenhalgh & Rogers, 2006) Trademarks thus complement nicely the traditional use of the patent-lens with its recognized sector-bias.

3.1. the Approach and data

This section focuses on the domestic use of these instruments in the ten-year period from 1994-2003. It uses a unique data-set of domestic patents and trademarks (provided by the Norwegian Patent Office) which has been associated with full-count registry data of Norwegian enterprises. The datasets and approach was developed for a Wipo report on IPR use of small and medium-sized enterprises in Norway (Iversen, 2003). The enterprise-level information includes information about firm-size, industrial activity, number of companies, annual turnover etc. It comes from a unique, publicly assembled registry covering all active Norwegian companies. The registry is put together by Statistics Norway on the bases of firm-level information from the Brønnøysund Register Centre (http://www.brreg.no/english/) register of Norwegian enterprises and companies and the National Insurance Service's (Rikstrygdeverket) registry of active employees and employers. This database gives us a picture of all enterprises (and subsidiary companies) that formally pay wages to at least one person (a registered workforce of about 2 million). Further information is found in the Annex.

In this presentation, counts of applicants are normalized for Norwegian applications.[46] The introduction of normalized counts presents a more accurate picture of Norwegian patenting and trademark activity, although makes comparison with previous work more difficult.

[45] The sector-specificity of the patent-system is widely noted.

3.2. Patenting

Three aspects of Norwegian patenting activity are of interest in terms of heterogeneity: the general tendency of Norwegian patenting (temporal and spatial), the participation of different size-classes, and the relative technical spread of Norwegian patenting in terms of foreign patenting in Norway.

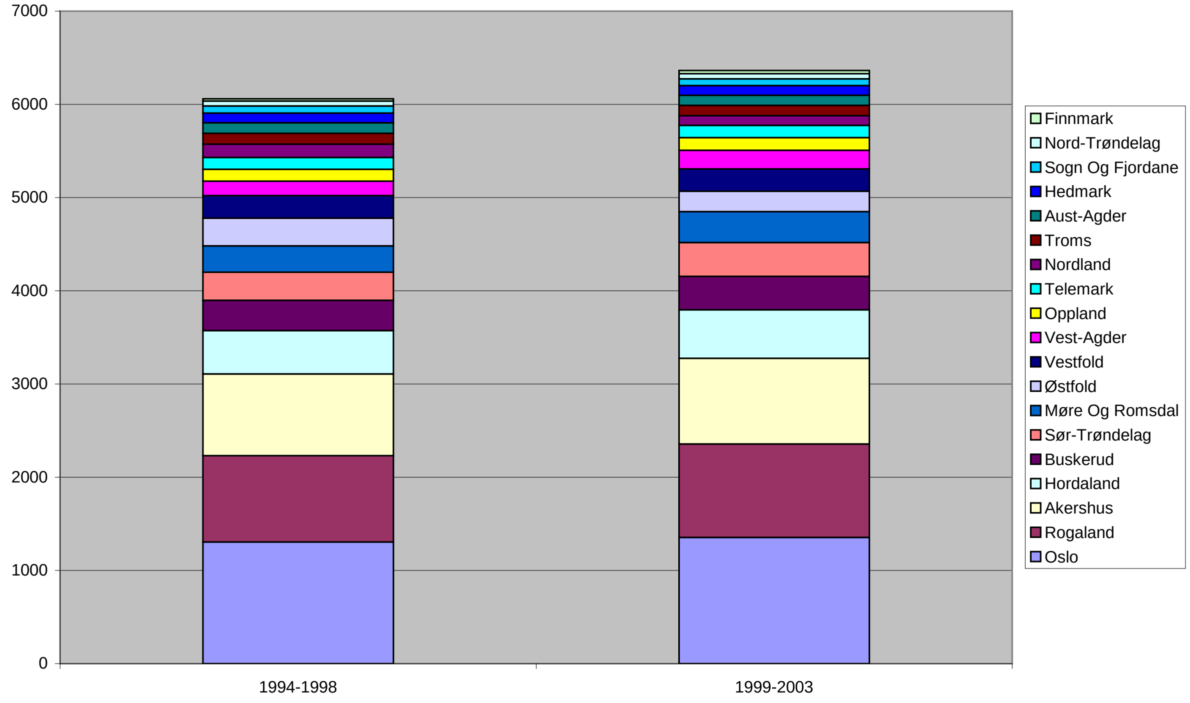
3.2.1. Regional profile

The overall volume of 'Norwegian patent applications'[47] expanded by 5 % from 1994-1998 to the next five-year period 1999-2003. A total of 12,628 patents were applied for involving 15,094 applicants (an average of 1.2 applicants per application). Based on the Norwegian Patent Office's internal number, 7290 separate entities were involved. The 17 Norwegian counties or 'fylker' are represented throughout the period. The overall ranking of counties remains largely the same across the periods, with the majority of applicants concentrated in a few of the more urban counties.

[46] Normalized counts are used for applications. This is to say that each application is counted as one: the number of applicants is normalized to sum to one for each application (thus, three applicants involved in a single application will each be counted as 1/3). This is particularly important for patent applications where multiple applicants are common. Trademarks tend to involve single applicants to a much larger degree.

[47] those involving at least one applicant with a Norwegian address

Figure 2-1 Primary assignees (12,628*) in Norwegian patent applications (normalized counts) by district of origin (=Fylker): 1994-2003



Source: NIFU STEP patentdatabase built on Norwegian Patent Office data. Note*: Normalized counts of applicants. 160 foreign applicants collaborating in patents with Norwegian applicants are not presented. A further 47 Norwegian applicants could not be linked to county.

The six most patent intensive counties account for 70% of Norwegian applicants. Oslo and the adjoining county of Akershus together account for more than a third (35%) of the total volume of applications. This profile however corresponds to underlying features, particularly distributions of employment and relative R&D intensities. Oslo and Akershus make up the most R&D intensive area at the county level, with a combined average R&D expenditure per capita which is over twice the national average of 5,400 NOK in 2001, with Oslo at 13,300 NOK and Akershus at 9000 (Indicator Report, 2003: 23).

The patenting share of Rogaland, which is the seat of the oil industry, increased 8 per cent across the two periods, while that of Sør Trøndelag, the home of the technical college and of Sintef, grew 21%. The figure indicates that while the participation of applicants expanded in Oslo during the period, its overall share decreased, from 22 to 21% of the total. The patent-lens thus indicates that inventiveness is concentrated in several counties associated with high overall levels of R&D but that it is also spread throughout the country. The overall expansion of patenting activity, which rose by a third through the period, is relatively evenly spread across the country. Applicants in urban areas however clearly dominate.

3.2.2. Technological specialization

The proportion of domestic patenting, i.e. at least one applicant with a Norwegian address, has remained stable for more than a decade at around 20 percent of the total annual volume of applications registered by the Norwegian Patent Office. This minority situation is familiar for many small countries and is especially associated with the aggressive patent-strategies of large pharmaceutical companies. As a group domestic applications differ technologically from those filed from abroad. Figure 1 breaks down the 60 350 patent applications the Norwegian Patent Office received in the period 1994–2003 by technical area using a recently developed correspondence between patent IPC classes and industrial (NACE) classes (Schmoch et al., 2003).

Table 2-1 Patents applied for in Norway by technical area in NACE equivalents: 1994-2003.

Sectors	Norwegian	Foreign	Total	Nace Industries
Consumer goods	1064	1573	2637	15,16,17,18,19,36
Motor vehicles and equipment	1507	1343	2850	34, 35
Material and process engineering	2195	5773	7968	20,21,25,26,27,28
Chemicals and petroleum products	852	8553	9405	23, 24 not 24.4)
Machinery and Equipment	3713	8112	11825	29
ICT, electrical equipment, instruments	2718	9681	12399	30,31,32,33
Pharmaceuticals	375	12774	13149	24.4
Unknown	117	1	118	Missing IPC
TOTAL	12541	47810	60351	

Source: NIFU STEP patentdatabase built on Norwegian Patent Office data.

The largest concentration of domestic filings is found in machinery and equipment, while relatively few are filed in the areas of chemicals and pharmaceuticals. In contrast, foreign filings were most active in pharmaceuticals followed by chemicals and petroleum products. This is particularly due to the fact that the chemical and pharmaceutical industries rely heavily on patenting to protect their products, which are expensive to develop but relatively inexpensive to imitate. The globalization of markets means that patent-protection is sought globally. Patenting in this field is dominated by large multinational companies with large patent portfolios. This raises the concentration of foreign applications, which becomes especially pronounced among the small volumes of domestic patents in small countries.

The asymmetry between domestic and foreign filings in the country provides a basis on which to gauge domestic technological specialization. Technological specialization is typically expected to be more pronounced (cf. Andersson & Ejermo, 2006) but also stable in small countries (see Dosi, 1988*). The following table uses the established index developed by Grupp to study Revealed Patent Advantage, based on a Revealed Patent Advantage approach (Archibugi & Pianta, 1992). This specialization index uses a band of +/- 100 which is symmetric around 0 (corresponding to no specialization). In it, larger positives (such as 72 for Textiles etc) correspond to greater degrees of specialization of domestic filings while larger negatives (such as -95 for Pharmaceuticals) correspond to higher specialization among foreign filings.

Table 2-2 'Revealed Patent Advantage' in Norwegian domestic patenting by industry*: two periods 1994-2003

Industries	NACE REV 1.1.	1994-1998	1999-2003
Food, beverages, & tobacco products	15,16	-2,8	2,2
Textiles, clothes, furniture	17, 18,19, 36	69,4	72
Paper and wood-products	20,21	-35,1	-18,4
Petroleum products & nuclear fuel	23	-42,6	-71,5
Chemical (excl Pharmaceuticals)	24 (not 24.4)	-75,3	-66,9
Pharmaceuticals	24.4.	-97,7	-95,6
Rubber, plastics, and non-metallic products	25, 26	20,8	23,3
Metals and metal products	27,28	41,1	36,1
Machinery	29	39,6	33,6
Office machinery & computers	30	20,8	31,6
Electrical equipment	31	29,4	6
Television, radio, and electronics	32	-49	-22,6
Instruments	33	15	9,5
Vehicles, vessels and parts	34, 35	73,1	70,2
Unknown	NA	90,6	91

Source: NIFU STEP patentdatabase built on Norwegian Patent Office data. * Patent IPC classes are translated to NACE 1.1. equivalents. This version of RTA is based on Hariolf Grupp.

Dividing the period 1994-2003 into two periods, this approach illustrates the degree of specialization and tendencies towards change in what can be called the 'market for technology' in Norway. Two general dimensions emerge: there is some evidence of shifts in the balance across the two periods but otherwise a general persistence in Norwegian patent specialization, and there is a high degree of domestic specialization in two areas across the periods. A similar approach is used in Kaloudis (in this volume), where EPO-data are used instead of domestic patent data.

The index indicates a relative stability in the spread of specialization. The negative and positive indexes generally retain the same sign across periods (with the exception of food and beverages). There is some fluctuation in individual indexes, including a drop in the specialization level for electrical equipment and a rise in office machinery. Paper and wood products mark a reduction in the dominance of foreign filings as does inventive activity linked to television and related products.

A high degree of specialization is found in two areas. The first involving consumer goods such as textiles and furniture, meaning that the inventive activities of Norwegian firms tend to be more focused on the Norwegian home market for consumer goods. The second area of high specialization of inventive activities around vehicles and vessels, primarily shipping related. The considerable patenting activity from major oil exploration and exploitation companies is however divided between several areas of this index, such as machinery (including energy machinery) and chemicals (especially under the subclass of rubber and plastic products). The index is not necessarily a good indicator of the industrial activity of the applicant.

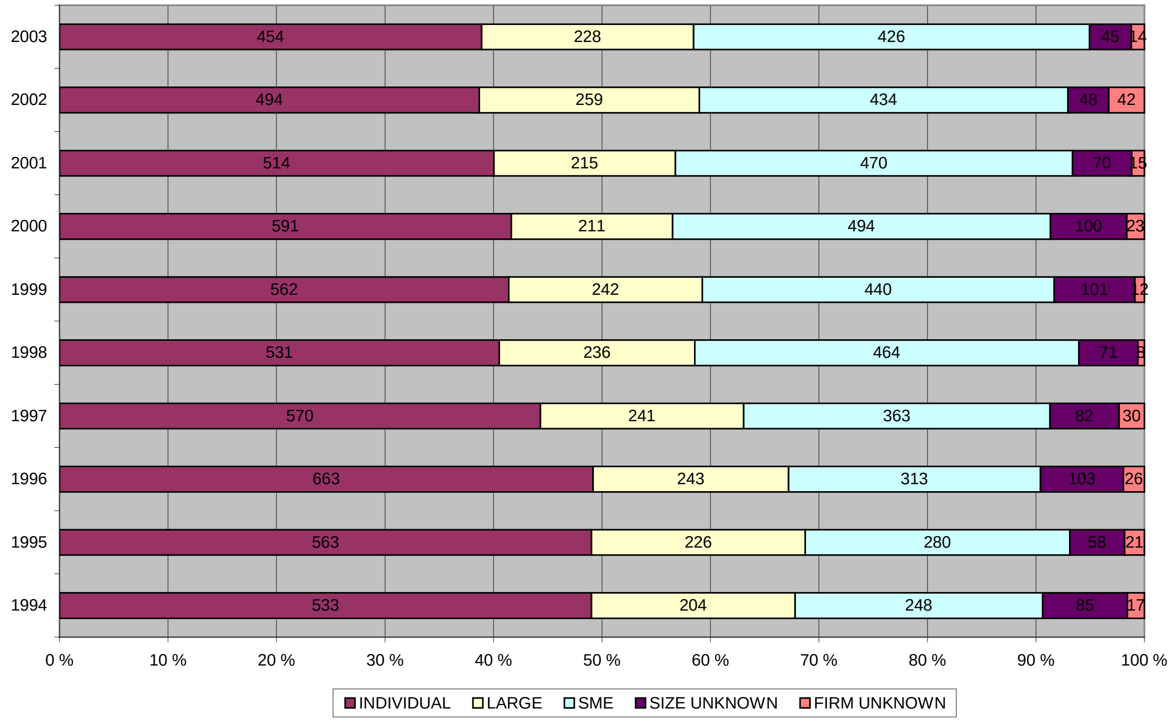
3.2.3. Applicant type

The patenting activities of large firms form a popular focal point for innovation. The Yale surveys for example focus on the R&D units of relatively large firms, while the Community Innovation Survey in Europe, which includes questions about patenting, excludes firms under ten-employees and uses a stratified sample among the firms up 100 employees (in Norway). However, the majority of firms in many countries consist of small firms, which can form an important but often invisible or overlooked source of innovations in the industrial dynamics of a country. (see also Nås et al., this volume) At the same time, many patent applications—especially at the domestic level—are sought by individuals without obvious commercial affiliation.

It is therefore worthwhile to link the volume of academic patent applications by the type of patent applicant in order to get an idea of the contribution of different segments of the economy to overall inventive activity. This type of population accounting provides an idea of where the inventive activity is coming from. What is the mix? Does one type of firm dominate; large firms for example, with dedicated R&D activities and resources to follow up in the bid to turn inventions into innovations?

This figure illustrates the breakdown of Norwegian patent applications by size-classes through the period. It shows that although unaffiliated individuals accounted for 43 percent of Norwegian domestic patenting in the period, there is a clear downward trend in their participation. Large firm patenting is remarkably stable across the period, accounting for roughly 18 percent of the total.

Figure 2-2 Norwegian patent applicants by type and size-class : 1994-2003: normalized counts[48]



Source: NIFU STEP patent-database built on Norwegian Patent Office data.

The patenting activity of SMEs, on the other hand, grew strongly during the period, and fluctuated more. It accounted for at least 31 percent of the total. The size-classes of two other categories of enterprises could not be established for different reasons (see annex). The categories of size- and firm unknown, which account for a further 7.6 percent, are likely to be small firms without formal employment. If so, small firms are involved in nearly 40% of Norwegian domestic patenting. SMEs were most significantly involved in mechanical engineering, instruments, rubber and plastics, and television and electronics.

3.3. Trademarks

Trademarks provide a substantially different look at heterogeneity in the Norwegian economy. Whereas the patent-lens provides a look at differentiation in terms of technically-oriented invention, the trademark-lens provides a look at commercialization activities minted on making what the applicant sells distinct in the eyes of the consumer. The use of trademarks involves a substantially different part of the population of Norwegian firms. There are much fewer manufacturing firms, and many more firms in the tertiary sector, not least in retail and wholesale. The overlap of seems to be on the order of 5-10 percent.

48 An earlier table was based on gross counts of applicants. This table normalized is the applicants for applications.

The basis and the approach is much the same as for the patent database[49]. There are however differences to be noted. First, trademarks do not have technical fields that we can translate to technical areas. Instead it has 45 fields of application that are not immediately helpful in analysis. Second, the status is less fine-grained. These are ignored for present purposes. The underlying industrial activity relies solely on the link to the applicant's industry where available. We know only whether the trademark has been registered or has not (yet) been registered. Finally, the incidence of multiple applicants is much smaller than in the case of patenting.

3.3.1. Trademark applications and registrations

There were 2,900 Norwegian trademark applications in 2003, as against 2550 in 1996. In the period 1994-2003 the annual number of Norwegian applications fluctuated from a low of 1,828 in 1994 to a high of 3,800 in 2000. Smoothing these fluctuations, Norwegian applications grew 32 percent from 1994-1998 to the subsequent five-year period 1999-2003. Foreign applications expanded 54 percent across the two periods, while the Norwegian share dropped from 35 percent to 30 percent. The corresponding share of trademarks registered for Norwegian applicants fell from 25 to 21 percent.

Table 2-3 Trademarks applications and registrations per year for domestic and foreign applicants: 1994-1998 and 1999-2003.

Trademarks	Applicant	1994-1998	1999-2003
Applications	Domestic	12295	16172
	Foreign	34966	53766
	Domestic in percent	35	30
Registered	Domestic	7937	10531
	Foreign	31725	50989
	Domestic in percent	25	21

Source: NIFU STEP trademark-database built on Norwegian Patent Office data.

3.3.2. Regional comparison of patent and trademark applications

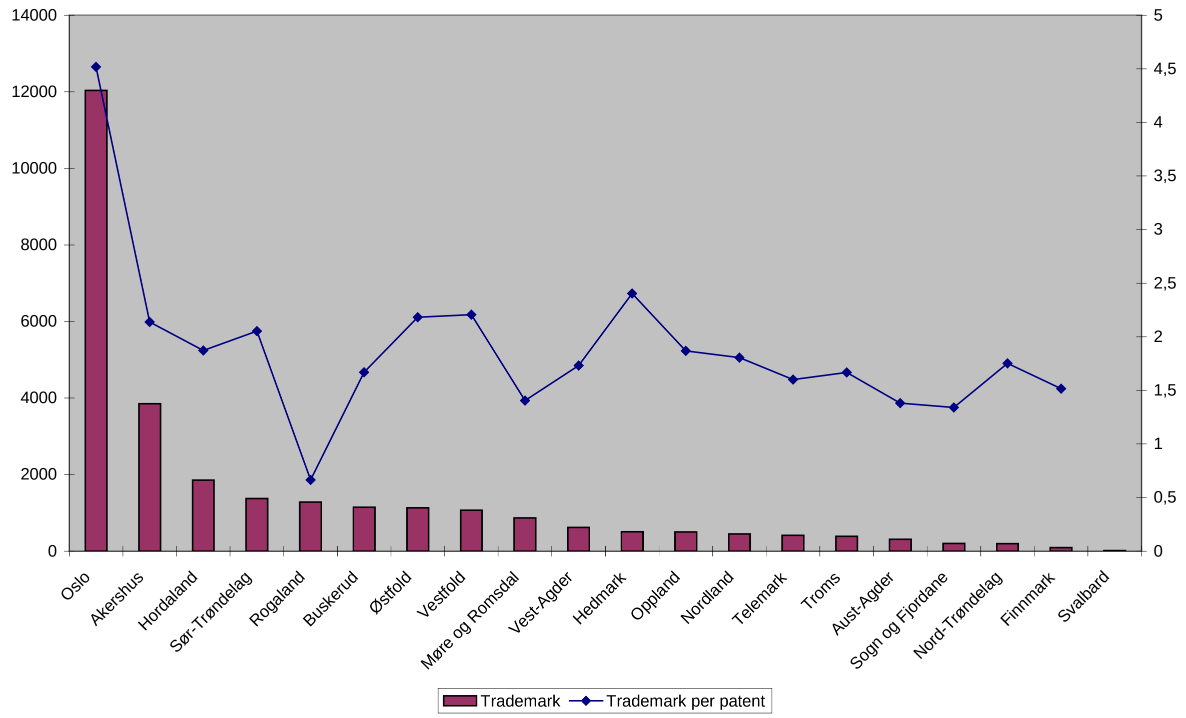
The degree of commercialization activity represented by trademarks can be seen in relation to the inventive activity behind patenting. Trademark applications are an indicator of market competition and are therefore to be expected in conjunction with markets. Oslo and environs, Trondheim, and Bergen account for nearly three-quarters of the total number of Norwegian applications.

Figure 2 demonstrates the regional distribution of Norwegian trademark applicants. The dominance of the area around the capital, Oslo and Akershus, is even more striking than with patent

[49] It is based on the updated data from the Norwegian Patent Office database covering all domestic trademarks applied for and/or registered since 1990, which NIFU STEP has linked against the national registry of Norwegian enterprises.

applications. Trademark applications generally outnumber patent applications two-to-one for the period. The relative levels however vary considerably down at the regional level, indicating that these activities reflect something about economic activity beyond scale in a given region. The two-handed figure illustrates the regional variations between patent and trademark levels. The line indicates the proportion of trademarks to patent applications (the right-handed axis). Oslo sets itself out as the commercial center, where trade-marking leads patenting four-to-one. In Rogaland, a moderate sized Norwegian city where the seat of the oil-industry is, there are a disproportionate number of patent-applications in relation to trademark applications.

Figure 2-3 Patenting and trademark applications by district of origin: 1993-2004. Two-handed axes: the right shows fractional counts for trademark applications (normalized counts); the right for proportion of trademark per patent applications.



Source: NIFU STEP trademark-database built on Norwegian Patent Office data.

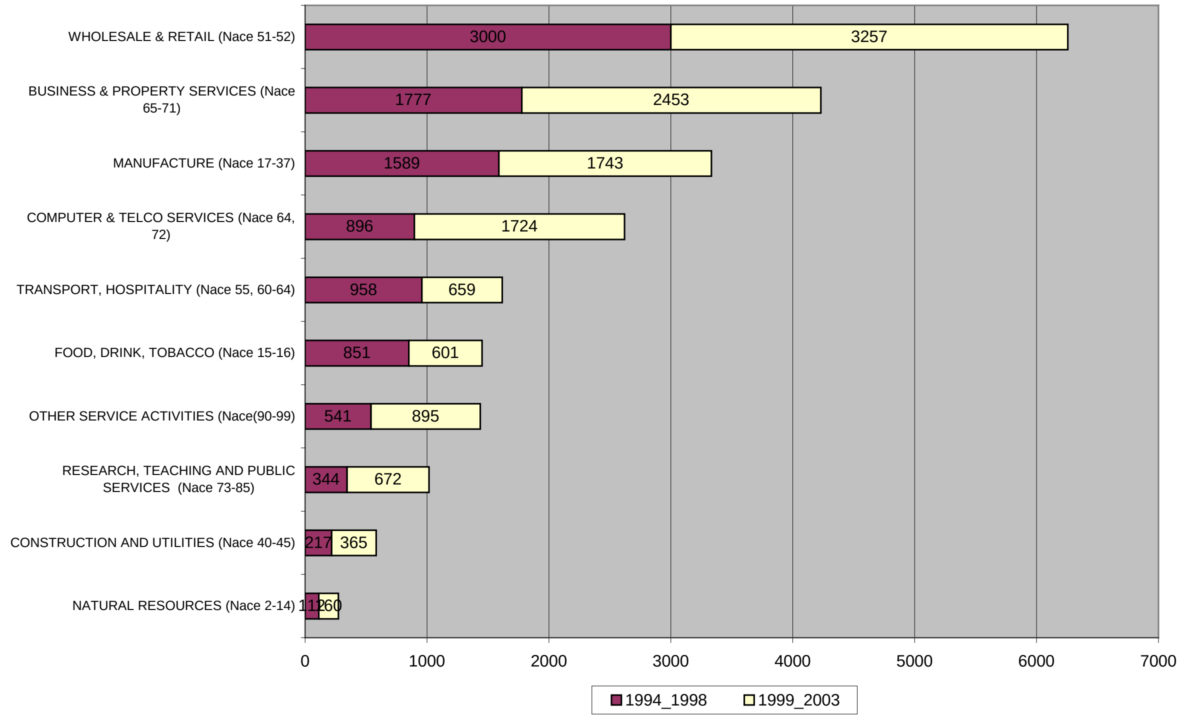
* the patent applications included 160 foreign applicants. These are excluded together with a total of 90 applicants whose geographic location could not be established (42 for trademark and 47 for patent applicants)

3.3.3. Norwegian trademark applications by field of applicant

The business areas of trademark applicants overlap to a modest degree with patent applicants. The degree of overlap is of the order 5 to 10 percent, indicating that the populations involved are quite distinct. Organizations involved in diversification in the eyes of the market are thus substantially different from those involved in technological differentiation involving patenting. Larger more diversified firms more likely to apply both for patents and trademarks.

Trademark users are predominantly service sector firms. The number of trademark applicants who are individuals with no evident affiliation makes up around 14 percent of the overall volume of trademark applications (in contrast to over 40 percent in the case of patent applications). Figure 3 presents the breakdown of enterprise applicants by industry for the two five-year periods.

Figure 2-4 Norwegian trademark applicants by industry, (N=28,482): 1994-2003[50]



Source: NIFU STEP trademark-database built on Norwegian Patent Office data.

The use of trademarks in Norway has increased by about a third (32 percent by normalized Norwegian applications) from the mid 1990s to the first part of the new century. Manufacturing enterprise accounted for a substantial 3300 applications or 11 percent of the trademark applicants identified here. This group, which is more readily identified with patenting activity, grew by 10 percent across the ten year period. The largest applicant group is that of retailers and wholesalers who generally market the wares of foreign producers.

The more knowledge intensive service enterprises are actually more intensive users. The combination of business, computer/telcom, and research and teaching services (which includes research institutes, educational institutes, as well as some public sector services) out-number retail and wholesale industries, accounting for over 27 percent of all domestic trademark applications. In addition, trademark use in these sectors grew much faster than the average for the period. Both

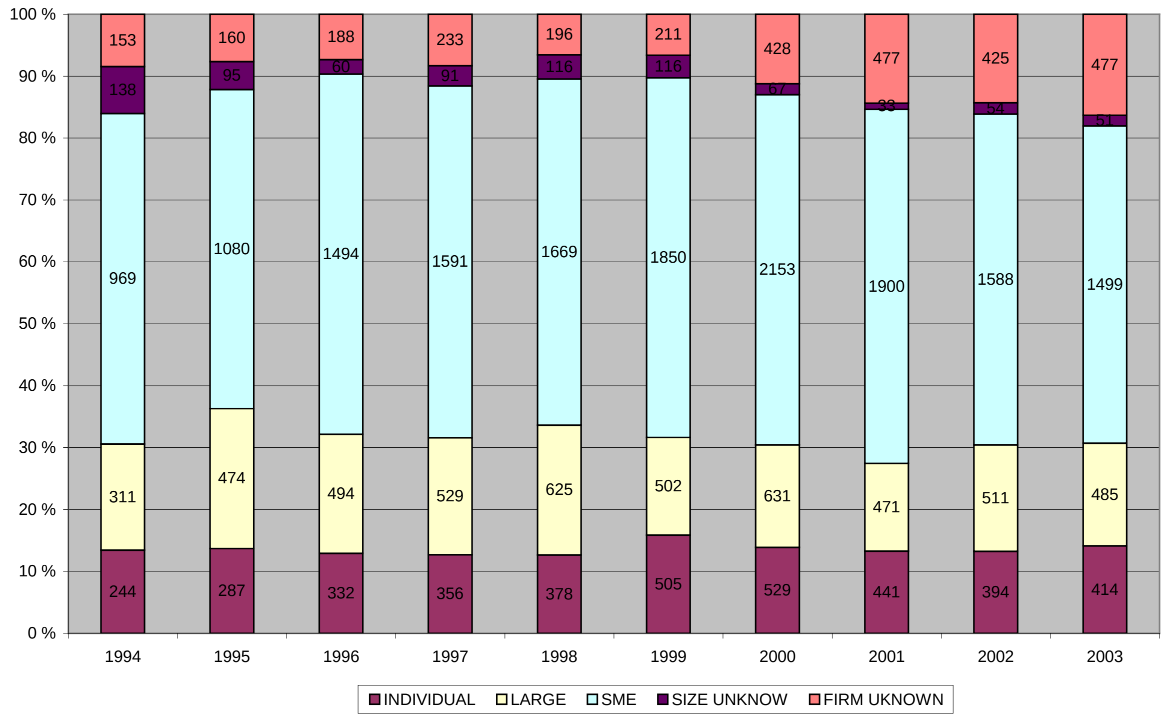
50 The 3530 applications from individuals are excluded. A further 2138 enterprise-applications of unknown industry are also excluded.

computer and telecom services and research and teaching services more than doubled during the period, the latter in part a testimony to effects of the Norwegian dot-com era.

3.3.4. Norwegian trademark applications by size of applicant

Small firms dominate domestic trademark applications, accounting for over 55 percent of domestic trademark applications in the ten year period. As above, the actual proportion is likely to be higher, given that enterprises whose size could not be identified in this exercise, are likely to be small firms. Application levels among small firms fluctuated the most, especially during the economic boom from 1998-2001. At the height of the boom (2000), small firm applications numbered 2150 or 140 percent above its level four years before and four years after.

Figure 2-5 Trademark applicants by size-class[51] (N= 28,475) normalized counts



Source: NIFU STEP trademark-database built on Norwegian Patent Office data.

Trademark applications among large firms on the other hand remain relatively stable through the period, at about 18 percent of the total. A major difference with patenting is the much lower proportion of individuals involved in trademark activities. Their proportion was however more stable here than with patenting, strengthening suspicions that a substantial number are of these actually single-person enterprises.

---

51 The contribution of 3,200 other firms whose size is unknown is not included here. These firms however are assumedly small firms. See table

4. Conclusions and discussion

The importance of the role of diversification processes in the economy has been recognized at least since Marshall classed it as 'a chief cause of progress' in the 1920s. (Marshall, 1962: 355, cited in Cohen and Malerba, 2001: 587). The relationship 'the tendency to variation' in innovative activities and economic progress is however harder to show. This chapter has explored at the diversification of innovative activities through the complementary lenses of the patent and trademark activity. These lenses allowed us to focus on how different firm-types (size-groups, geographical locations, and industries) contribute differently to the differentiation of inventive activity (the patent lens) and the differentiation of commercialization activity (the trademark lens).

This exploration stands a novel approach to the question, which helps discover some patterns both in these aspects of the important diversification process as well as in the contribution of different firm-types to it. We note the general escalation in the overall levels of inventive and commercialization activity. Comparing the late 1990s with the early 2000s, the chapter illustrates the regional diversification of inventive and commercialization activity. Five areas where patenting intensity is high were identified. But we do not find signs of centralization activity: Oslo's share domestic patenting fell slightly for example. The pattern is largely the same for firms involved in trademark activity.

The chapter took particular pains to look at changes in technological specialization of Norwegian patent applicants. The pattern here was relatively stable. We noted the relative emphasis among domestic applicants to patent in the field of machinery and equipment and consumer goods, while the level of patenting of pharmaceuticals was very low. We also looked at the industrial activities of different size-classes that are involved in inventive activity. This revealed the relatively broad spread of the majority of small firm patenting in areas such as instruments, ships, and electronics. A disproportionate percentage of small patentees however were found in the field of machines and machinery

Trademark-activity provides a different look at the diversification of economically important activity across firm-classes. The major difference is that it affords a look at the tendency of service based firms to diversify themselves in the eyes of the consumer. Trademark activity, like domestic patenting, increased through the period. Small firms are more prominent in the profile of Norwegian firms that apply for trademarks than in the profile for patenting firms in Norway. The chapter notes the large contingent of firms in wholesale and retail industries that use the trademark system. The level among other services, not least among 'knowledge intensive firms' in the area of financial services and consultancies, witnesses to a large degree of commercial diversification of small and large firms across the country. But the activity is not isolated to the service sector, just as patenting extended beyond the manufacturing firms. This overall exploration thus indicates the extent of these two aspects of diversification for different sets of Norwegian firms.

Chapter 3:

'The bearer of the mechanism of change': Small-firm inventiveness and patenting in Norway.*

In the preceding chapter, small and medium-sized enterprises are shown to be involved in an increasing share of Norwegian patents in the period. In this light, chapters 3 and 4 complement each other as they both focus on small firm patenting: first at home and then abroad. The focus in this and in the following chapter is motivated by the observation that the role these firms play in knowledge generation— and the problems they meet— have implications for the working of the innovation system as a whole and for related policies. This harkens back to shift that Schmookler found in patenting in the 1950s in favor of larger manufacturing enterprises. The shift that is investigated here is in favor of smaller firms, not least in the knowledge intensive business sector.

Theme	Questions
Essay 1: Knowledge formation and patenting	What role does the patent system play in knowledge accumulation?
Essay 2: The diversification and specialization of IPR use in a small open economy	How does use of the IPR system reflect the innovative processes of different agents? What role is played by small firms in specialization and diversification of innovative activity?
Essay 3: The growing use of patents among small firms: areas of growth and challenges	**If SME patenting is increasing (see last essay), what technological areas and market dimensions? Do they face greater challenges than larger firms?**
Essay 4: Small firm patenting and the transition to European Patent Office	How do Norwegian SMEs use the European Patent System? How the effects of this transition be measured?
Essay 5: Academic patenting and the transition to an institution-based patenting regime	To what degree do academic researchers already patent and will the introduction in Norway of Bayh-Dole-like legislation improve conditions for academic patenting?
Essay 6: The impact of patenting on research collaboration	Does patenting increase the probability for research collaboration? What role do other factors play?

This chapter was published in a book* about the modern relevance of Schumpeter and it takes its title from his early conjecture about small-firm innovation: "'The bearer of the mechanism of change': Small-firm inventiveness and patenting in Norway." In line with the Schumpeterian conjecture, the chapter explores the contribution to overall inventive activity of small firms which it argues is especially important in small open economies like Norway where SMEs make up over 95% of all firms.

*Publication Information: Iversen, EJ (2007) 'The bearer of the mechanism of change': Small-firm inventiveness and patenting in Norway. In E Carayannis & Ziemnowicz (eds), Rediscovering Schumpeter : creative destruction evolving into Mode 3. Palgrave Macmillan, 2007. - XXV, 500. Acknowledgements: I especially appreciate the comments from William Lazonick and from Olav Spilling on an earlier version. The usual disclaimer pertains.

3. 'The bearer of the mechanism of change': Small-firm inventiveness and patenting in Norway

Eric J. Iversen

1. Introduction

Firm-size is one of several variables within a larger system where technology, institutions, demand, strategic decisions and random processes play central roles in shaping overall economic outcomes. (Sutton, 1998) This chapter starts from the premise that the participation of small and medium-sized enterprises (SMEs)— and the conditions for their participation—is especially important for small open economies like the Norwegian case where firm demographics are dominated by relatively small companies. The role these firms play in knowledge generation and the problems they meet have implications for the working of the innovation system as a whole and for policies that address these.

The chapter draws on some aspects the unresolved (-able?) small versus big debate which traces back to disparate positions taken by Schumpeter. In this controversy, we are not primarily interested in the headline issue of which size-classes may or may not contribute most to technological progress. The purpose is to explore the role that different size classes play and to consider some implications to the working of the innovation system as a whole. We explore the contribution of the small firm to inventive activity in line with the Schumpeter's early conjecture (Schumpeter, 1912; 1989), and consider problems this set of firms seem to face in managing their intellectual property in the growing 'market for technology'. (Arora, Fosuri, Gambardella, 2000)

2. Small firms and Schumpeterian entrepreneurs

In the 1940s, Schumpeter (1942) made the familiar conjecture that the activities of dominant large and diversified firms drive technological change in the economic system. In doing so, these firms generate large knowledge spillovers that make their way into the economy in the form of lower costs and a widening range of goods. This conjecture, later championed by Galbraith, is generally contrasted to the somewhat contrary position in which a younger Schumpeter (1912; 1989) suggested that small enterprises might play a substantially more significant role to 'spur growth'.

This suggestion derives from the role given to entrepreneurship in the theory of economic development. In it, economic development is linked to 'new combinations of productive means' where the source of such novelty comes from outside the existing industrial establishment. Observing that it was not the owners of stagecoaches that built the railways, Schumpeter looks to 'new firms' as the source of novelty. (Schumpeter, 1989: 64ff) This novelty reaches beyond the run of the mill, 'circular flow' of economic activities to provide a driver of economic development. In the absence of a theory of the firm, the younger Schumpeter emphasized the role of the entrepreneur. His conception of entrepreneurship is instrumental. For Schumpeter, the role is about realizing new combinations and exploiting them in a process that leads to creative destruction. Langlois points out that this conception contrasts to 'Kirzner for whom the role is about discovery and for Knight (1924) for whom the role is about the faculty of judgment in economic organization' (Langlois, 2005: 4). Below, we will look at the discovery dimension of entrepreneurship in terms of inventiveness, indicated by patent applications, and the exploitation dimension in terms of, indicated by the success rates of patents for different size-classes of enterprises. First we take a look a closer look at the relationship between firm-size and innovation.

2.1. Size-Effects and empirical limitations

This focus on the entrepreneur in new firms as 'the bearer of the mechanism of change' (Schumpeter, 1989: 61) in economic development has served to focus attention on the innovative activities of small firms. A whole literature has grown up to address size-effects in innovation, ranging from the more management to the more econometric-oriented literature. The evolution of Schumpeter's thinking is particularly reflected in the distinction between Schumpeter Mark 1 and Mark 2 models which build on the concept of the technological regime (Winter, 1984): the first features small firms in competitive markets characterized by high turnovers in firm populations while the latter features large firms in stable oligopolistic competitive arrangements.

Although the literature has identified a set of factors which indicate that innovation increases more than proportionately with firm-size[52], the empirical evidence however has not been able to corroborate the size-effect in unequivocal terms. In fact the large number of empirical analyses has, by and large, been inconclusive, and some of the results even contradictory.[53] Moreover, it has been shown that the measures to study size-effects involve serious difficulties which tend to lead to unreliable results. For example, R&D expenditure data is inherently problematic, especially dubious for smaller firms or populations for whom less formal innovative activities are important. (Albaladejo & Romijn, 2000) The need to rely on reported employment numbers also tends to engender problems, while industry-effects are difficult to control for (Cohen, 1995). In terms of output indicators, use of patents has a set of familiar limitations. One is that it is a one-size-fits all indicator (or one value regardless of the invention in question), leading to various yet ultimately incomplete

52 See Acs & Audretsch (1990, 39-40)

53 For surveys, Kamien and Schwartz, 1982; Cohen, Levin, and Mowery, 1987; Cohen, 1995; Symeonides, 1996; and Dixon and Greenhalgh (2002).

attempts to gauge relative values of innovations. Other factors beg the whole question. What is 'firm-size' after all? One factor that calls this into question is the set of scale economies related to technology make up what Penrose (1959) calls 'Technological economies'. Technologies that allow the production of larger numbers at lower unit cost may permit more efficient division of labor, economies of large-scale production and/or economies of (activity) expansion. Technological economies may therefore distort what 'size' means in terms of innovation.

A more general concern is that innovative activities are subject to the interaction of a large number of unobservable factors beyond size-related issues. Firmlevel factors, especially those involving 'strategy, organization and finance' (cf Lazonick, 2004 for a discussion) affect the firm's attempts at realizing the 'new combinations' and exploiting them in the Schumpeterian sense. In addition to factors internal to the firm, there are also factors outside the boundary of the firm that, while unobservable, form the 'extended division of labour in the accumulation and application of knowledge' (Metcalfe, 2001). They are important—perhaps increasingly so—in light of 'the institutionally contingent nature of the knowledge accumulation process, in which imperfectly perceived opportunities are pursued, producing rival and conflicting conjectures"(Metcalfe, 2001: 562). This set of factors includes "market supporting institutions" which have been emphasized by Langlois & Robertson (1995) as facilitating organizational change and development. Institutions in the support-structure which are designed to influence the innovativeness of different types of firms include funding agencies, public research organizations, as well as a layer of insitutions including patent-offices, standards development organizations etc. Such components link up with firm-level capabilities and provide the basis for an important type of interaction.

It is therefore important to the innovation and size debate to recognize that the, "firm propensity and capacity of innovation depends on the systems of linkages in which it is embedded, the institutions regulating the distribution and access to knowledge, the organization of different competencies and technologies combination" (Poti & Basile, 2000: 3). Although external to the firm, the contribution of these factors are not necessarily exogenous to the firm-level innovation processes. Yet, these factors are not usually taken into account when considering the relationship between firm-size and innovation.

2.2. Innovative activity and the patent system

The patent system forms one element of the institutional environment that, to a certain degree, conditions firm-level innovation. It can act to focus and to coordinate formal innovation processes both among and between private and public organizations in the economy. If its role constitutes a sector-specific 'market for technology', this entails that the patent system helps shape knowledge accumulation over time. The literature indicates that there are many factors, including firm-size, that condition the firm's choice when it comes to patenting. A review that could do justice to this vast and varied literature is obviously beyond the scope of this chapter.[54] The role suggested and the role played are not necessarily the same. In terms of technological appropriability, it is worth observing that patents are not considered by business respondents to be the most important mechanism for protecting intellectual property (Levin et al., 1987)[55]. Secrecy is also considered a better appropriation-mechanism for manufacturing firms, than patents for process innovations. An update of this seminal study indicates that the importance of patents has decreased even more, although it might have increased for the largest firms (Cohen et al, 1997).

From the above, the implication is that the quality of the way these internal and external factors inter-work is arguably most important to the smaller enterprises, which may be most susceptible to the negative effects of a badly working system. This observation will become important when considering the withdrawal rate of particularly the smallest patent applicants, and what implications improving the system as a part of the division of labor may improve the contribution this population makes to increased variety.

3. Firm-level aspects and patenting behavior

In light of the hunch that larger firms hold certain advantages in innovative activity, of the uncertainty surrounding the actual correlation between larger firm and innovation, and of the recognition that the surrounding system plays an important in the innovation process, presumably more so in the case of small firms because of their resource problems, it makes sense to assume the importance of small firm innovation in the economy (i.e. Schumpeter in Business Cycles). The argument is not to regenerate the policy hype surrounding the little guy from the 1980s. Quite the opposite. The point is to create a more reliable picture of the contribution of small firms to generating new knowledge and the problems they face there. This might have implications for improving the system to support their innovativeness. That is the contribution we want to make in the following, in which we look into inventive activity through the lens of patenting activity.

3.1. Business sector demographics

There are approximately 130,000 enterprises with salaried employees in Norway (1998) according to the employment register-data used here (see Annex). The demographics provide a first look at the question of diversity in the Norwegian economy. The principal characteristic is the extent to which

---

[54] See Griliches (1990), Takalo, (1999); Ernst (2001); Dixon and Greenhalgh (2002).

[55] The results of the Community Innovation Survey reported below are consistent with this finding.

SMEs absolutely dominate the Norwegian onshore economy in number. Over 96% are small and middle-sized enterprises according to the definition used here. A mere 3,700 Norwegian enterprises are large, meaning they employ over 100 employees or fulfill one of the other criteria.[56] The bulk is to be found in the smallest size-classes, where over 60% are micro (1-4 employees) while 90% are small in the Norwegian classification.[57]

Table 1 illustrates how these enterprises break down according to industrial activity and size-class in a given year. The principal product or service of the largest company in the enterprise is used to assign an industrial activity. The breakdown of the Norwegian economy in this way indicates that a large majority of Norwegian enterprises operate in the Services sector (including Wholesale and Retail), while less than 10% are found in Manufacturing. Public administration, defense, and other services such as health and education (but not R&D services) account for a further 10% of Norwegian enterprises registered by NACE in this database. The ratio of larger firms is highest in four sectors: Offshore Oil & Gas, Public Services, R&D Services, and Electrical Equipment.

[56] The basis definition is based on a total of 100 employees. In addition, smaller enterprises are considered "large" if: they have more than 99 million NOK in annual turnover (an average of one million/employee); they include more than 15 establishments; and/or they are registered holding companies (NACE 74150) with at least 30 employees (most will also qualify according criterion 1) Our definition means that an extra 1000 enterprises are considered large compared to if we had used the 100 employee cut-off.

[57] A sizable, additional population (over 30% according to Spilling, 1999**) register no employees and are not included here. An additional 1 percent could not be associated with industrial activity.

Table 3-1 Number of Norwegian enterprises by size-class and field, 1998.

MAIN INDUSTRIES	ENTERPRISES			
	Large	SMEs	Total	RPA(large)
BASIC SERVICES	1 201	57 546	58 747	0,7
BUSINESS SERVICES	277	18 395	18 672	0,5
ELECTRICAL EQUIPMENT	58	770	828	2,4
ICT AND POSTAL SERVICES	84	1 923	2 007	1,4
MACHINERY & EQUIPMENT	55	1 202	1 257	1,5
MANUFACTURE	503	8 734	9 237	1,9
NATURAL RESOURCES	77	8 514	8 591	0,3
OFFSHORE OIL AND GAS	45	81	126	12,3
PUBLIC & UIH SERVICES	1 095	12 062	13 157	2,9
R&D SERVICES	28	119	147	6,5
UNKNOWN	295	14 538	14 833	0,7
Grand Total	3 718	123 884	127 602	1,0
Percent	2,9	96,0		

Source: Author compiled on data from the Norwegian AA Register

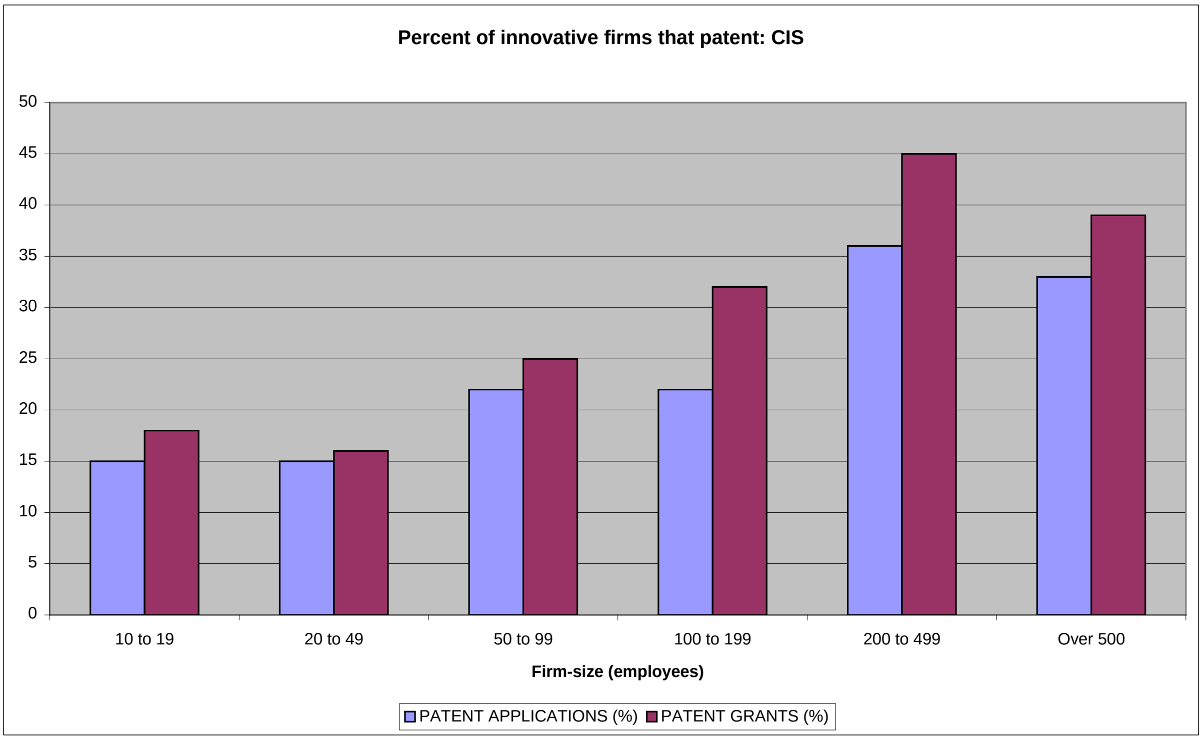
3.2. Firm-size and innovation

According to the most recent the Community Innovation Survey, only about 20% of Norwegian innovative firms[58] use the patenting system while 30% indicate they rely on trade-secrets. There is an apparent correspondence between firm-size and patenting, with between 35-40% of the larger firms reporting applying for or receiving at least one patent in the 1999-2001 period. Patent intensity is highest in industries dominated by large firms in which there are relatively few small companies: the oil extraction sector (67% reporting applications, 73% reporting grants), the R&D services sector (67%, 33% respectively), and the chemical production sector (50%, 56%).

The survey is based on a sample of 3,400 enterprises which attempts to be representative both in terms of industry and geographical location. It however leaves out the smallest size-classes and relies on weighted averages for the smaller size classes. It is also selective in including sectors that are not expected to innovate or patent (e.g. restaurants and hotels). The survey results serve to indicate that the level of patenting in Norway is relatively low, that patenting may be size-dependent, and that largest firms are not those that patent most.

[58] Those who have introduced new products or processes in the past three years.

Figure 3-1 Patenting among innovative enterprise by firm-size (employees) in the Community Innovation Survey: 1999-2001. (N=3416)



Source: Statistics Norway and NFR: http://www.forskningsradet.no/bibliotek/statistikk/indikator_2003/kap5.html

3.3. Patenting enterprises in the period 1995-1999

There is some question whether the survey is successful in representing the patenting behaviour of innovative firms in Norway. The major concern is what the smallest firms, i.e. most Norwegian firms, are contributing to the production of new knowledge in the country. Based on Iversen (2004) this section takes a unique look at the contribution of the economic sector to Norwegian patenting.

In the period 1995-1999 some 3,670 entities were involved in a total of 7360 domestic patent applications in Norway. The majority of these assignees were individuals with no apparent affiliation (2039).[59] A further five hundred companies in the patent record cannot yet be linked to number of employees.[60] In a given year (1998), 490 enterprises were involved in 890 Norwegian patents, while the remaining 580 involved 458 individuals with no visible affiliation. For the five year period 1995-1999, we can identify a population of 1096 firms involved in patent applications. In addition to the 534 unidentified companies, 361 patenting enterprises are micro (1 to 4 employees), 259 are small (4-49), 181 are medium (50-99), and the remaining 295 are large. The next table indicates the

[59] This set will include the contribution of researchers at universities, who until 2003 were entitled to patent their own research results.
[60] Since we are looking at enterprises with taxable employees, these 500 include single-entrepreneur companies. Better correspondence is expected when we link more years of the employer registry. Pending that, it is fair to assume that these firms are most like not to be large enterprises.

proportion of firms in these size-classes that patent (assignee on at least one patent), by business sector.

This full-count exercise indicates that around 3% of all Norwegian enterprises patent. Around 8% of large firms applied for at least one patent in the period, while less than one percent of the SMEs did so. These gross figures reflect the fact that the activities of many firms are not relevant for patenting (or patenting is not relevant for their activities). The right hand columns reflect the industry effects. The patenting of large firms varies between 2.5% of Basic Services enterprises with patent applications, to 75% for Machinery and Equipment. The most patent intensive of the SME classes is the category of R&D Services.

Table 3-2 Number and percentage of Norwegian enterprises involved in Norwegian patent applications by size-class and business sector: 1995-1999.

BUSINESS SECTOR	PATENTING FIRMS			% patenting enterprises		
	LARGE	SMES	TOTAL	LARGE	SMES	TOTAL
BASIC SERVICES	30	132	162	2,5	0,2	0,3
BUSINESS SERVICES	29	199	228	10,5	1,1	1,2
ELECTRICAL EQUIPMENT	25	44	69	43,1	5,7	8,3
ICT AND POSTAL SERVICES	4	21	25	4,8	1,1	1,2
MACHINERY & EQUIPMENT	41	77	118	74,5	6,4	9,3
MANUFACTURE	100	156	256	19,9	1,8	2,8
NATURAL RESOURCES	1	25	26	1,3	0,3	0,3
OFFSHORE OIL AND GAS	16	4	20	35,6	4,9	11,0
PUBLIC & UIH SERVICES	3	16	19	0,3	0,1	0,1
R&D SERVICES	13	20	33	46,4	16,8	22,4
UNKNOWN	33	107	2713*	11,2	0,7	17,7
Grand Total	295	801	3669	7,9	0,6	2,8

* includes: unaffiliated individuals (2039), unregistered (463), unknown (71)

On the other hand, it is interesting to note the spread among patentees in nominal terms: for example, it is worth noting that a substantial number of small Basic Service companies are patenting. We want to focus on the contribution of the small companies in this setting. This breakdown leaves us with the observation that the smallest enterprises provide most of the identifiable (and probably the as yet unidentified) population of patent assignees in nominal terms. The fact that the number of patenting micro enterprises overshadows large ones is no surprise from the perspective that they represent over 60% of the 130,000 Norwegian enterprises: only 0.44% of the micro firms are involved in patenting. However, for some sectors, the contribution is substantial in relative terms as well. Patent intensity among the smallest enterprises is relatively high especially the case of the R&D

Service sector, but also in the electrical equipment and the machinery & equipment sectors. These are sectors with more than the average number of large firms (see concentration values above).

3.3.1. Patent Applications by economic sectors, market structure, and size

The diversity of small firms in Norway has grown quickly surpassing large firms in gross patenting during the late 1990s (Iversen, 2003). The 801 identifiable SMEs were involved during the last half of the decade in a total of 1597 patent applications, a hundred more (1498) than the Large. We need not assume that the 360 Micro-Firms are all potential Cisco Systems to argue that small firms can contribute significantly to knowledge-production. They can represent early pushes in industry life cycles and may in this way contribute to industrial rejuvenation. Nor should one romanticize about this contribution. However, it seems appropriate to make the point that although only 0.6% of Norwegian small and medium-sized enterprises (as against 8% of the larger ones) patented in the late 1990s, the 800 firms contribute to the variation of the knowledge stock on a general basis.

Table 3 introduces the number of applications, indicating also the intensity of patenting in terms of the average number of applications per applicant for the 1995-1999 period. The greatest number of applications is in Business Services followed by Manufacture.[61] The average number of applications per applicant is on the other hand highest for the small sectors in which large enterprises seem dominant (offshore oil and gass and R&D services). On the face of it, SME patenting shows greatest relative strength in the small sectors as defined here. SMEs are more active than their relative patenting intensity would indicate, for example in the R&D services sector, where the average number of applications per applicant is higher than the average. Small and medium-sized enterprises show relative strength in categories where there are both low numbers of enterprises and number of patents.

Table 3-3 Number and percentage of Norwegian patent applications by size-class and business sector.

	applicants		applications		appl per applicant		CHI*2
	total	smes	total	smes	total	smes	sme patents
BASIC SERVICES	162	132	303	222	1,9	1,7	1,4
BUSINESS SERVICES	228	199	706	507	3,1	2,5	1,4
ELECTRICAL EQUIPMENT	69	44	159	63	2,3	1,4	0,8
ICT AND POSTAL SERVICES	25	21	60	47	2,4	2,2	1,5
MACHINERY & EQUIPMENT	118	77	274	135	2,3	1,8	1,0
MANUFACTURE	256	156	697	250	2,7	1,6	0,7
NATURAL RESOURCES	26	25	34	33	1,3	1,3	1,9
OFFSHORE OIL AND GAS	20	4	109	7	5,5	1,8	0,1

[61] Business services include holding companies for large corporations.

PUBLIC & UIH SERVICES	**19**	**16**	**29**	**25**	**1,5**	**1,6**	**1,7**
R&D SERVICES	**33**	**20**	**177**	**131**	**5,4**	**6,6**	**1,4**
UNKNOWN	**140**	**107**	**4810****	**177**	**34,4**	**1,7**	**0,1**
Grand Total	**1096***	**801**	**3095****	**1597**	**2,8**	**2,0**	**1,0**

* excluding: individual (2039), unregistered (463), unknown (71) ***excluding: individual (3182), unregistered (985), unknown (96)*

A closer look reveals that size and sector do condition patent activity in fundamental ways, when the number of applications is compared to total numbers of enterprises. Table 4 presents a composite picture which indicates in descriptive terms how the propensity to patent varies according to market structure, economic sectors, and firm-size. A central aspect of the table is the presentation of the average number of applications per 100 firms for the different industrial sectors. Here the distribution of all Norwegian enterprises in these size and activities (1998) is compared with the number of applications for a five-year period (1995-1999).

This measure reveals that for the period an average of three patents were applied per 100 Norwegian firms. The greatest propensity to patent is among R&D services with an average of 1.2 applications per enterprise (over 5 years). This is followed by the Offshore sector, at 0.6 patents per enterprise, and Machinery & Equipment at 0.2 applications per enterprise. Those areas with the lowest patent propensity is, not unexpectedly, the primary and tertiary sectors, including the public sector.

3.3.2. Size and industrial sector

The table also indicates to what degree the propensity to patent is size related. Large firms are the most intensive applicants.[62] The average propensity is 40 patents per 100 enterprises for the five year period. This is eight times that of medium firms, 20 times that of small firms and 40 times that of Micro firms. Its strength is particularly demonstrated in Machinery & Equipment (12 times the industrial average), Business Services (13 times the average for the industry), Manufacture (11 times the industrial average) and Electrical Equipment (9 times the industrial average).

Breaking up the comprehensive SME category reveals that the intensity of patent applications is lowest among micro-enterprises. This size-class applies on average for 1 patent per 100 enterprises in the five year period. This rate is strongly influenced by which field the enterprise is in. Micro enterprises (1-4) that work in the R&D Activities Sector, applied for 121 patents per100 enterprises, which is above the average for that sector. The patenting activity is also near to the industry average in the ICT services sector. The patenting intensity of small firms is on average twice as high. If we

[62] This changes fundamentally when we compare applications per employee, but that is for another study.

remove the unknowns, its 2 /100 enterprise average is on par with the total population. It is however half the intensity of micro-enterprises in R&D activities, and considerably higher in Business Sectors, where it is on par with the industry as a whole. Medium-sized enterprises demonstrate a considerably higher propensity to patent, at 5 applications per 100 enterprises, or one per year. The relative strength of medium-sized firms is shown particularly in R&D Activities, Machinery & Equipment, and Electrical Equipment.

Table 3-4 Sector and size-specificities of Norwegian patenting: Number of Applications (1995-1999) per 100 Norwegian Enterprises, by size and industrial activity and market dimensions

	applications		Applications per applicant		applications per 100 firms			market dimensions	
	total	smes	total	smes	total	large	smes	market size**	ratio large firms***
OFFSHORE OIL AND GAS	109	7	5.5	1.8	60	227	9	small	high
ELECTRICAL EQUIPMENT	159	63	2.3	1.4	19	166	8	small	medium
R&D SERVICES	177	131	5.4	6.6	120	164	110	small	high
NATURAL RESOURCES	34	33	1.3	1.3	0	1	0	medium	low
ICT AND POSTAL SERVICES	60	47	2.4	2.2	3	15	2	medium	low
MACHINERY & EQUIPMENT	274	135	2.3	1.8	22	253	11	medium	low
MANUFACTURE	697	250	2.7	1.6	8	89	3	medium	medium
PUBLIC & UIH SERVICES	29	25	1.5	1.6	0	0	0	large	medium
BASIC SERVICES	303	222	1.9	1.7	1	7	0	large	low
BUSINESS SERVICES	706	507	3.1	2.5	4	72	3	large	low
UNKNOWN*	4176*	177	34.4	1.7	11	125	1	large	low
Grand Total	3095	1597	2.8	2.0	3	40	1		

*excludes individual patents (3812), includes unregistered (985) and unknown firms (96) **small=under 1000 entities, medium= 1000<x<10000, large>10000 ***low=< 5 percent, medium= 5<x<10%, high=>10%.

3.3.3. market structure

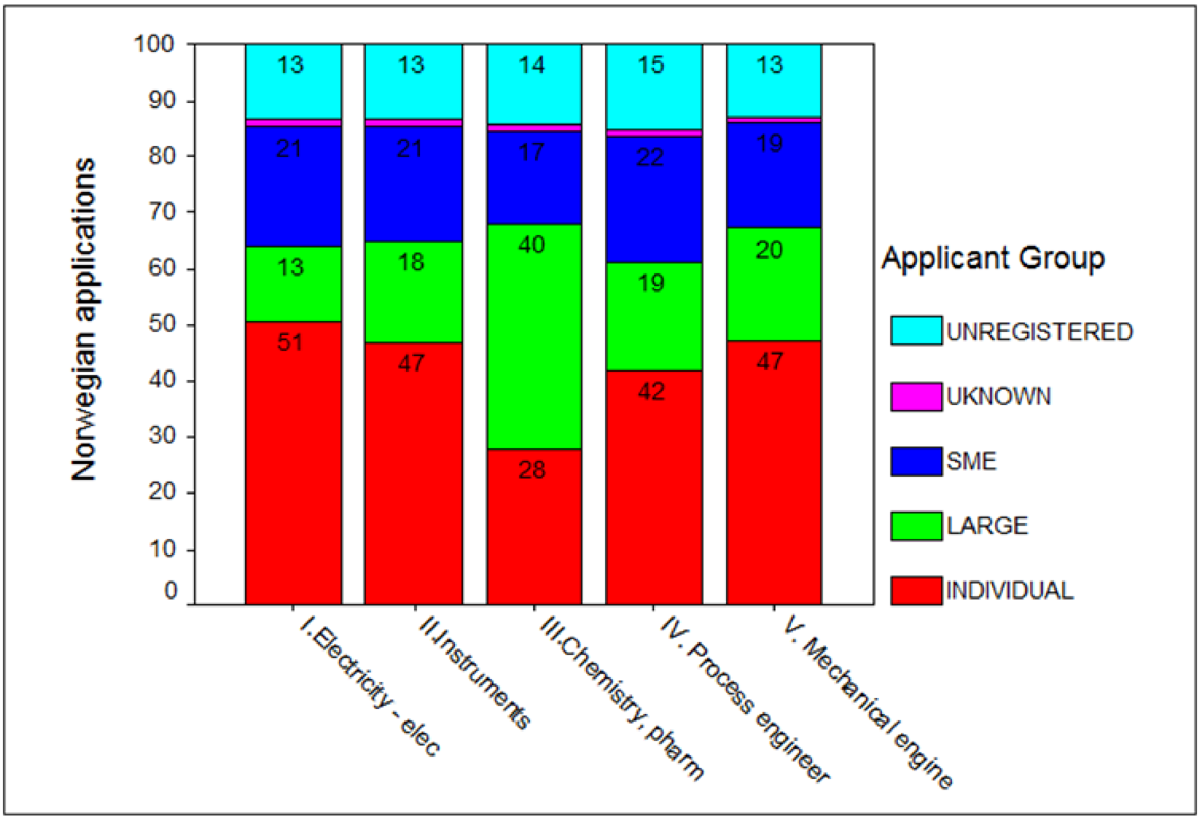
In terms of ‘Market structure’,[63] the gross number of enterprises in a given industry provides a measure of market concentration. The number of patent applications for 1995-1999 can thus be seen in terms of whether the industrial sector of the applicants is small (under 1000 entities), medium-sized (between 1000 and 10,000) or large (more than 10,000 enterprises). A similar descriptive idea of market dominance is provided by looking at the ratio of large firms in the different industries. The ratio of large companies are divided into low (less than 5 percent of the enterprises are large), medium (between 5 and 10 %), and high (greater than 10%).

63 See Nielsen et al (1998) for elements of this approach.

The table ranks the industries based on the size of the market (where the Schumpeterian conjecture would suggest a correlation) and then by the total number of applications in ascending order. In descriptive terms, there seems to be some connection between small market size, higher than average concentrations of large firms, and patent intensities (number of applications and average number of applications per active enterprise). Noting Machinery & Equipment and Manufacture, the correlation does not seem completely clear. Further analysis is needed.

Given the large number of independent individuals and the difficulties in classifying some of the enterprises by industry, we look at some characteristics of the patent applications in order to find out more about the applicants. Here we briefly compare the technical areas of the patents (according to patent classes) with the size-classification of 12,894 Norwegian applicants from 1990-1999. This gives us a full-tally on which to discuss the distribution of applicants by size and activity.

Figure 3-2 Percentage of Size-classes applying by Technical area of applications, % (N=12,984)



Source: Iversen (2003)

The fact that large firms patent differently than SMEs comes more strongly to the foreground in this figure.[64] Large firms are in relative terms most active in the Chemical applications, and least in

64 For full counts for the different areas, see above. It is otherwise reassuring to see that the Unregistered and the Unknown categories are spread evenly across these technical areas

Electricity, which includes ICT patents. SMEs are represented strongest among the many applications that go under the heading of Mechanical Engineering and Consumer goods. They are also reasonably evenly spread. The patenting behavior of the large population of independent applicants is most variable and stands in opposition to that of large enterprises. Individuals are most highly concentrated in Electricity and Electrical Engineering, and least in the Chemicals and Chemistry field.

4. Firm-size and the success of the applications65

The successful conversion of knowledge production into new products and services is contingent on a multitude of factors in competitive markets, as discussed above. Many of these factors may be external to the firm. In light of the above discussion, this final section explores Norwegian patenting behavior for indications as to how the knowledge market functions in Norway. As with the previous two figures, this section is based on the 6,303 Norwegian entities who, together, were involved in 14,319 'active' domestic Norwegian patents during the 1990s.[66] This data allows us to observe how different size-classes of firms not only enjoy higher levels of success in terms of grants: more to the point, it clearly makes the point that the smaller the firm, the higher the probability that it will itself withdraw the application. Withdrawal rates reveal something about the way individual firms evaluate the worth of their invention and their ability to realize it.

The question of withdrawal as opposed to application brings us back to the point that, for Schumpeter, the role of the small-firm entrepreneur substantially involves exploiting the novelty it generates. This conception, as Langlois (2004) observed, contrasts particularly to Kirzner's (1973) where the emphasis was more on the entrepreneur's ability to discover new opportunities. In terms of patenting, the fact that a firm applies for a patent can be associated to this discovery dimension. It indicates that the firm has accumulated novel knowledge for which it had considered at the time of application at least to represent some commercial potential.

Whether the firm is able to exploit the potential of the application in the sense emphasized in Schumpeter is another question. The tendency for patent applicants to withdraw their applications indicates the inability of the firm, for whatever reason, to realize the potential indicated by the application. There may be many practical considerations at work here. On the one hand, it can indicate that the application was poorly framed and the applicant had reason to believe that it would not be granted in an acceptable form. An equally likely reason for why an applicant does not follow up the application (following a fee schedule) is that it has run out of the funding necessary to bring

---

65 This section draws on Iversen & A. Kaloudis (2006). IP-Valuation as a Tool to Sustain Innovation. In Bosworth & Webster (eds) The Management of IPRs. Edward Elgar.

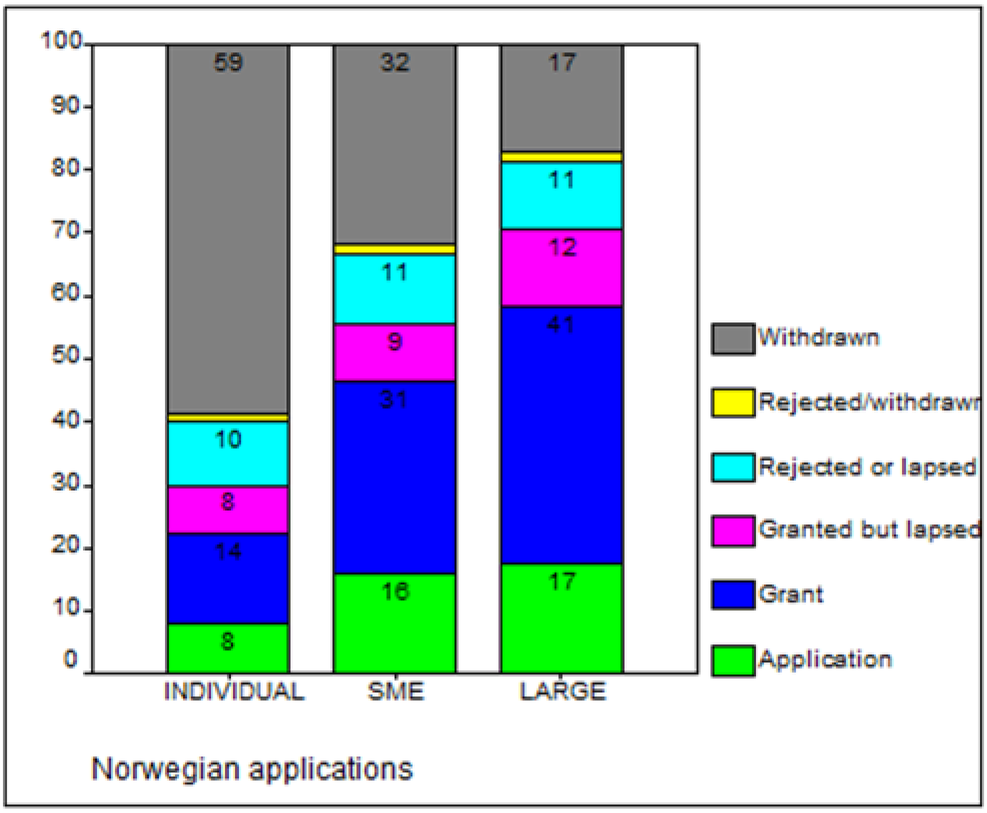
66 By "Active", we mean any patent that was applied for and/or granted during the 1990s AND any patent applied for before then but granted during the nineties.

the idea to market (cf. the capitalization process) and/or that it has lost faith in the idea's ultimate success seen in relation to costs. We can therefore interpret withdrawal to mean, in one way or another, that the initial value expectations by the applicant became disappointed.

4.1. Size-dependent patent-withdrawal

A major difference between smaller and larger applicants involves the 'success' of their patent applications. The level of non-grant—especially cases in which the applicant withdraws his application— is dependent upon size. More than 40% of the Norwegian applications are withdrawn by the applicant. In the population of active patents during the 1990s (which has been widened to include granted patents), about a third (34%) have been granted, 12% remain in examination, and the rest have terminated with a non-grant. Forty percent of the SME applications are granted. Large enterprises as a group enjoy a success rate of over 50% and a withdrawal rate that is half that of SMEs and a third of that of independent applicants. There may be many factors behind the differences in success rates, where "success" is measured in patent grants. At least part of the explanation, however, is probably a better working understanding of the IPR-System, and the fact that it is more comprehensively built into the enterprise's business strategy. In principle, a national IPR-System should aim to reduce the number of withdrawal that result from misconceptions of the system or in poor competences in dealing with it.

Figure 3-3 Norwegian applications [67] by size-class and status.(N=12,277)

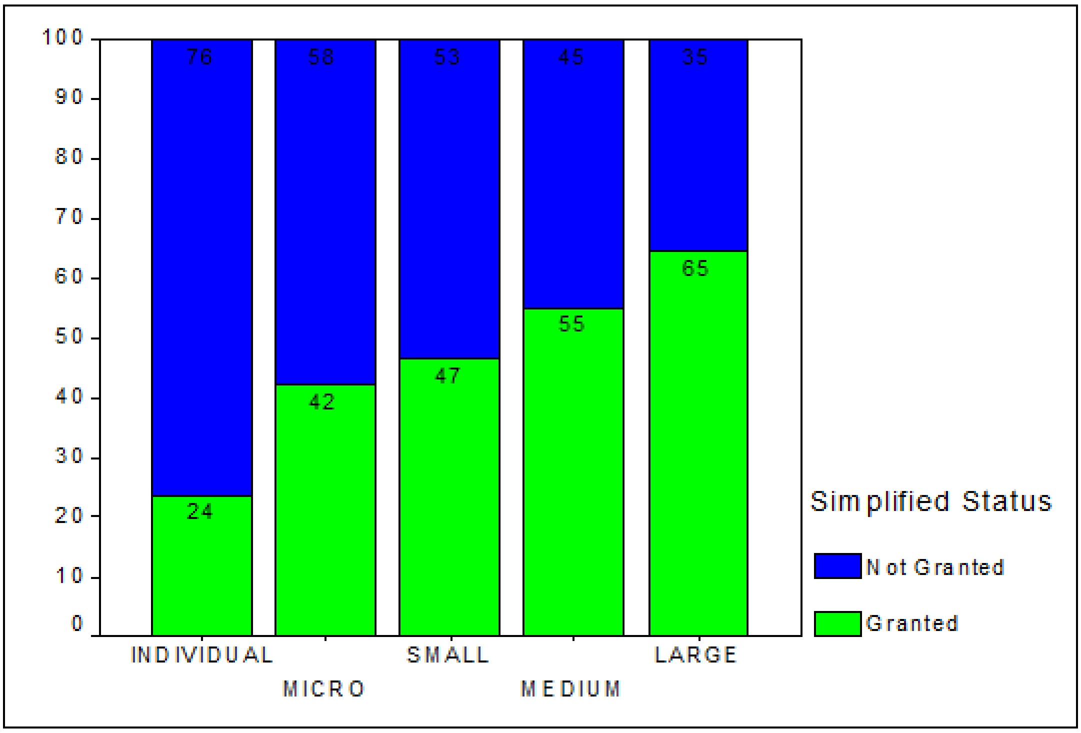


Source: Iversen (2003)

The following figure breaks down the SME definition to see if indeed the level of non-grant (especially because of withdrawal) is dependent on size. Those applications that are still in application are removed as are the Unknown and Unregistered enterprises. In this way, the size-based trend becomes more clear. Patent Grants climb with size, from 24% in the case of Individuals, to 65% for Large Enterprises.

[67] 2,042 Unknowns and Unregistered applications are removed.

Figure 3-4 Norwegian applications according to Size-Group and simplified status. Percentages of processed applications (N=5,751)



Source: Iversen (2003)

The fact that SME patents are more often withdrawn than those of large entities raises suspicions that smaller entities find it more difficult than larger ones to follow through on their attempts to innovate. In this vein, the figure shows that 'success' among Norwegian patenting is indeed dependent on firm size. There may be many factors behind the differences in success rates, where "success" is measured as non-withdrawal. Part of the explanation is probably to be found at the firm level: larger firms have a better working understanding of the IPR-System, they have internal resources (and thus staying power and fighting power in litigation), and that they have a more conscious and better informed policy about intangible assets built into the enterprise's business strategy. Another reason may involve the quality of the patents. Those of small firms might in general be of less potential value, making the pursuit of a patent more costly than benefits expected to accrue during its commercialization. A last possibility is that signals from the Patent Office indicate that the idea may not in its current form fulfill one or more of the criteria for patenting.

The reason that a much larger proportion of SME applications is withdrawn (1/3) than large enterprise applications (1/6) has to do with such factors. However, it presumably also involves factors that are external to the firm, especially access to funding at critical stages in the development process. In general, the variable withdrawal rates suggest that several types of factors that might be at play, including: (i.) that smaller actors, especially independent inventors, tend to overestimate the value of their intangible assets going into a formalization process; and (ii.) that smaller applicants are forced to cut losses during the long development process because of difficulties accessing complementary assets—especially funding. This suggests that many, perhaps good ideas, are not developed. (capitalization problem and the functioning of investment markets)and that smaller applicants have a poorer working understanding of the patent system and could use a greater degree of assistance when approaching it.

A better understanding of what leads to this disproportionate withdrawal of patent applications by smaller enterprises is needed. As it is, the substantial rate of miscarried patent applications represent a loss of resources (both time and money) for a population who assumedly can ill-afford it. Given that small firms are understood to be more dependent on outside factors, one question this raises—pending a study into the underlying causes— is thus whether the inability of small-firms to follow through on their patent applications is size-related and structural. If so, the question then turns to whether there is a case to improve the support structure in order to help firms to overcome these problems including making better decisions about patenting.

5. Conclusions

Economic development is closely connected to knowledge creation, dissemination, and utilization in its economic agents. In the theory of economic development, Schumpeter emphasized the role on the entrepreneur in new firms as 'the bearer of the mechanism of change' (Schumpeter, 1934: 61). This chapter has looked at the inventiveness of small firms in general, indicating that patenting among Norwegian small firms increased substantially during the 1990s. It presented an explorative set of data which shed light on how the propensity to patent varies by firm-size, industrial sector, market characteristics, and other aspects of firm populations. The chapter underlined the correlation between firm-size and the success of patent applications, revealing a size-related tendency to withdraw patent applications emphasizes the importance of improving firm-internal processes. The role these firms play in knowledge generation and the problems they meet have implications for the working of the innovation system as a whole and for policies that address these.

Chapter 4: A baseline for the impact of EPC membership on Norwegian small and large firms

This chapter pursues the focus on the relationship between firm-size and patent usage from the last essay. The focus on domestic patents is updated and extended to a comparison with Norwegian patenting in Europe in the period leading up to Norway's accession to the EPC (2008). In this context, the application of firm-level data is advocated at a more instrumental level. The approach is introduced as a growth-accounting tool which can gauge the effect this substantial change has on different types of Norwegian firms and other organizations. This foreshadows the approach in the next chapter which adapts a similar approach to follow trends in academic patenting.

Theme	Questions
Essay 1: Knowledge formation and patenting	What role does the patent system play in knowledge accumulation?
Essay 2: The diversification and specialization of IPR use in a small open economy	How does use of the IPR system reflect the innovative processes of different agents? What role is played by small firms in specialization and diversification of innovative activity?
Essay 3: The growing use of patents among small firms: areas of growth and challenges	If SME patenting is increasing (see last essay), what technological areas and market dimensions? Do they face greater challenges than larger firms?
Essay 4: Small firm patenting and the transition to European Patent Office	**How do Norwegian SMEs use the European Patent System? How the effects of this transition be measured?**
Essay 5: Academic patenting and the transition to an institution-based patenting regime	To what degree do academic researchers already patent and will the introduction in Norway of Bayh-Dole-like legislation improve conditions for academic patenting?
Essay 6: The impact of patenting on research collaboration	Does patenting increase the probability for research collaboration? What role do other factors play?

Acknowledgements: This chapter is based on Norwegian input to a Nordic report for the Nordic innovation Centre. That project developed a common dataset and approach. See Iversen et al 2009. (http://www.nordicinnovation.net/prosjekt.cfm?id=1-4415-312). In addition, ETLA provided Patstat verification files for the five Nordic countries. Tore Sandven, Senior Researcher (NIFU STEP Studies in Innovation, Research and Education) provided help with the unified registry data.

4. A baseline for the impact of EPC membership on Norwegian small and large firms

1. Introduction

In 2008, Norway became the 33rd European country to join the European Patent Convention. (EPC) The move means Norway adopts the regional patent office (EPO) as a home office, thus changing the conditions to patent in and from the country. Since first assessing the possibility more than 40 years earlier, Norway remained outside active EPC membership because its thorough and repeated evaluations indicated that net benefits would not in sum outweigh advantages for the Norwegian innovation system as a whole.

This chapter investigates the role firm-size played in Norwegian use of the European patent system in the lead up to EPC accession. The transition to the EPC poses a shock for the national innovation system which is expected to affect different actors differently. Larger firms with markets and patent-portfolios in Europe might be expected to benefit since membership would reduce the cost of patenting more widely. Smaller firms, without international markets and thus less interest in European patents, might be expected rather to face a challenge as more European patents come into force in their home market. Norway chose to delay EPC membership in part due to fears that it would impose costs on some parts of its industry (mainly smaller firms) that would outweigh other benefits (mainly accruing to larger firms).

In light of these initial concerns, it becomes important to monitor how EPC membership plays out for different Norwegian firms. Although it remains too early to evaluate this question, it is clear that it is not possible to address it without knowing to what degree smaller firms patented in Europe before membership. The chapter follows up on the evaluation of the role that firm-size plays in Norwegian domestic patenting in the previous chapter. Based on a Nordic effort to associate firm-information to EPO patents from 2000-2005, it shows that the largest firms as well as the smallest Norwegian firms both patented actively in Europe in front of the transition and that small firm patents do not fare worse than larger firms (measured in terms of lapsing and opposition).

The chapter proceeds as follows. To set the scene it first introduces Norwegian concerns about joining the EPC. Aspects of firm-size are discussed, before we present the data and methods used to link patents with Norwegian firms. The following sections then size up the total population of Norwegian enterprises by industry and by size-class, before presenting a breakdown of Norwegian patenting according to firm-size, industry and other characteristics based on firm-level information identified by the linking procedure. This presentation combines firm-level characteristics with characteristics of patenting, such as where different types of Norwegian firms file for patents (the

EPO/Euro-PCT or domestically), in what technical fields, and when. Some indications of what happens after application are also sketched. Questions that emerge here include: are small firm patents granted as frequently as large, are they withdrawn, how long do they live, and are they opposed.

2. Norwegian industry concerns in front of EPC membership

In order to position the question of small firm patenting as Norway moved to the EPO, it is helpful to take a brief historic look at Norwegian patent policy. The first thing to note is that while Norway was among the last European countries to join the EPC, it was an early adopter of a patent system. Bruland & Smith (2010) argue that in the early stages the nationally based patent systems in the Nordic countries were notably used as a way to facilitate technology transfer from abroad. Nordic countries were –and remain—very small economies next to established economic powers like Germany, the UK and the Netherlands. A primary concern was to help domestic industry to accumulate technological knowledge from abroad. The question of how to capitalize on home-grown technology in foreign markets remained much less pressing—although still occasionally important—concern. (see Basberg, 1984 below)

In this setting, the patent system created a gradient for the inflow of technological capabilities while also helping to capitalize on domestic inventiveness on international markets. Since patents helped control technological flows of technological knowledge going in and out of these small jurisdictions, it had something of a gatekeeper function. This role was aided by the fact that the patent systems in these countries were closely patterned on international exemplars and were related to each other. Adapting national rules to international conventions while controlling the enlargement of the jurisdiction through collaborations between different patent offices has been one way Nordic countries have influenced the balance between inflows of foreign technologies and commercialization of Nordic inventions internationally. Basberg (1984) shows how patenting tracked technological change in Norway from 1840-1980 while domestic specializations emerged. As technological capabilities accumulated and promising domestically based inventions emerged, patenting could then be used in the dissemination of domestic inventions on international markets. The commercialization of the Søderberg electrode from Norway in the early 20th century, which was accompanied by hundreds of patents, is a prominent example of this. (Basberg, 1980; 1984: 245ff) Søderberg was Swedish.

In this setting, Norway has for over a century debated the introduction of different forms of patent collaboration and how they might affect different parts of the Norwegian innovation system[68]. The collaboration between different national offices however first came to the fore after World War 2, when plans for a Nordic patent collaboration slowly took shape. The rationale was to reduce the workload of the patent offices in the respective countries as well as to make the application process more efficient for Nordic applicants. This led to a formal proposal for a Nordic patent system (1963) which Norway approved in principle in 1967.

The Nordic effort was never actually launched. Events overtook it and in 1970 the international Patent Cooperation Treaty (PCT) was launched to provide some simplification of international patent applications. This was followed in 1973 by the introduction of the European Patent Convention (EPC) a year after Norway decided not to join the European Community. The EPC was in overall design was closer to the Nordic plan. In the aftermath of Norway's no to the EC, a select committee endorsed in 1976 the ratification of PCT (which took place in 1978) but decided to postpone a decision about joining the EPC, not least in light of the fact that the EPC was—and still is—a transitional agreement on the way towards a 'Community Patent.'[69] (Guellec and van Pottelsberghe, 2007)

Moreover Norway's reluctance to join the EPC as a fully fledged member in the 1970s (and again in the 1980s and 1990s) cited potential problems both for Norwegian businesses and for the patent office and the related parts of the country's IPR system.[70] One the one hand, full ratification of the EPC was expected to benefit a minority of Norwegian patent applicants in the form of less expensive applications for the enlarged jurisdiction: they forecast 100 applications per year at the time involving. This benefit would mostly to accrue to mostly large firms who had markets in Europe. At the same time, accession to the EPC might represent a set of problems for Norwegian industry more generally, which is made up mostly of small firms. A negative consequence that was forecast was that greater numbers of European patents would come into force in Norway[71], which would lead to a larger burden in terms of monitoring and potentially of litigation costs.

---

68 This section is based on Iversen, & Aanstad, 2010. Internasjonalt patentsamarbeid: nøkkelen til norsk patentpolitikk. Nifustep Arbiedsnotat.
69 "Initially, the EPC of 1973, instituting a 'European patent', was conceived as a transitory agreement until the implementation of the 'Community Patent' (CP) (the Luxemburg convention) was set in place. All EPO member states have tried to remedy this lack of integration at Community level by promoting EPC-based intergovernmental projects: the London protocol (which would reduce the translation requirements in signatory states) and the European Patent Litigation Agreement (EPLA) (which would set up an integrated judicial system for patents in Europe)". (Guellec and van Pottelsberghe, 2007)
70 NOU 1976:49 Internasjonalt patentsamarbeid, p 89.
71 NOU 1976:49 Internasjonalt patentsamarbeid, pp 85-86.

This increased activity would tend to affect smaller firms more, as small firms are more sensitive to such costs.[72] Norway's deliberation about EPC membership coincides with growing concerns about the innovativeness of small and medium-sized enterprises both in Norway (e.g. Isaksen & Smith, 1997; Iversen, 2003) and in Europe. This concern is grounded in the large share of small firms in this small open economy (as demonstrated in the chapter above and substantiated below). Despite general and specific concerns, there is relatively little systematized and comprehensive information about how IPR use among different SMEs to substantiate these concerns and to inform policymakers of areas for potential improvement. The lack of reliable and comparative empirically-based information obscures the small-firm patenting and arguably prevents better policy development on this front.

Thus, when Norway finally acceded to the European Patent Convention (EPC) in January 2008, it revitalized the question of how Norway's large proportion of small firms would be affected.[73] Are Norwegian small and medium-sized enterprises now in the position to take advantage of the transition? Or will it create new challenges for them, as the committee recommendations anticipated down the years? The following sections apply a baseline of European patenting by Norwegian economic actors at the threshold of the transition. This baseline, which was developed together with researchers in other Nordic countries based on a common design and execution, provides the basis on which to track how different economic actors in Norway adapt to the transition to EPO. In this way, it becomes possible to assess the effect of the transition in light of policy interest here and to adapt policy measures if problems emerge.

3. Differentiation of small and medium-sized enterprises

The fact that small and medium-sized enterprises dominate the Norwegian onshore economy in number means that the SME category is a highly heterogeneous group. This heterogeneity might mask other factors that affect the propensity of the firm to patent in the first place, let alone to extend its protection to outside jurisdictions. At the firm-level, the patenting decision is likely to be based on a combination of firm-level strategy and firm-level resources. We introduce some aspects of the small and medium-sized enterprises as they may condition whether patenting is relevant.[74]

The OECD typology of small and medium-sized enterprises features nine types of small and medium-sized enterprises.[75] It distinguishes recognizable firm types while suggesting the potential relevance

---

[72] see Dodgson & Rothwell,1992 as well as the issues introduced in the previous chapter

[73] At the same time, the Norwegian government focused on IPRs as an important part of innovation policy, emphasizing the accession to the EPC. See the Innovation Green Paper. (St.meld 7 (2008-2009)

[74] This section draws on Iversen, 2003 which discusses motives for IPR use in detail.

[75] In OECD DSTI/STP/TIP(98)6: Originally from JCL, OPTEM and Helsinki University of Technology , report of EIMS protect, European Commission (1997).

of patenting. The types span differences in age (new to mature), differences in development strategies (niche developers, collaborators, market-leaders, subcontractors) as well as differences in what might be called business-culture (reactive versus passive). It is clear patenting may be more relevant for some types of firms depending on its overall strategy and where it is in terms of its overall development.

Rizzoni's (1994) typography pits 6 generic types of SMEs against eight types of firm-level factors important to innovation and competition more broadly. In general, the importance of patents may be expected to increase from left to right across the matrix. On the left, SMEs are likely to see patents purely in terms of costs: the benefits of the domestic—let alone the European patent system—are likely to be unclear to and largely irrelevant to "static small firms" in the matrix. Firms that live from hand to mouth in commodity and small-scale markets and that have limited strategic and innovative activities are unlikely to draw much benefit from an active patent strategy.

Table 4-1 Small firms and technological innovation: Rizzoni (1994) taxonomy

	1. "Static" small firms	2. "Traditional" small firms	3. "Dominated" small firms	4. "Imitative" small firms	5. "Technology-based" small firms	6. "New technology-based" small firms
A. Factors of success	Low manufacturing costs.	Flexibility and product Differentiation.	Specialisation economies.	Flexibility and product personalisation, within market niches.	High distinctive competence ; skilled human capital.	Scientific entrepreneurship ; general and abstract knowledge.
B. Sectoral patterns	Mature sectors ; local markets.	Mature and Fragmented sectors.	Mature or growing sectors, dominated by large firms.	Stabilised sectors ; co-existence between large and small firms (in market niches).	Rapid-growth sectors ; not standardised consumer demand.	New sectors science-based, with high technological opportunities.
C. Type of technology	Old, or new but simple, unskilled-labour intensive technologies	Low capital intensive, simple technologies	Low or medium capital-intensive technologies.	Sophisticated, sufficiently stabilised technologies.	Advanced technologies, skilled-labour intensive.	New "soft" technologies, skilled-labour and knowledge intensive.
D. Types and sources of innovation	Only innovations contained in machinery.	Design modifications, incremental and "imported" innovations	Incremental innovations machinery procurement and agreements with large firms.	Incremental product innovations. Acquisition of patents or know-how.	New products (still, no radical innovations) ; various sources of innovation.	Radical innovations. In-house R&D ; intensive relations with universities and large firms.
E. Innovative strategy	Absent.	"Traditional" strategies. Technical change conies from outside.	"Dependent" strategies. Upstream-led or downstream-led innovation.	"Imitative" strategies. Crucial role in diffusion process.	"Defensive" or "offensive" strategies.	"Offensive" strategies. External monitoring ; high specialised "core" competence.
F. Corporate strategy	Targets : survival in the short-term; non-growth	Like Static SFs ; inter-firm productive relations.	Short-term objectives ; more autonomy.	Medium-term objectives. Search for interaction and co-operation.	Development of Distinctive competence. Inter-firm agreements.	Focus on innovation and networking activities. Growth call be a strategic goal.
G. Organisational structure	"Elementary"' organisation ; central figure : owner-entrepreneur	like Static SFs ; occasional resort to consultants	Technical entrepreneurship.	Entrepreneur is still important, but organisational structure is expanding.	Good balance between technical entrepreneur-ship and managerial skills.	High and diffused iechnical-scientific skills ; dynamic management and "organic" system.
H. factors of weakness	Weak entrepreneurship and Management ; limited financial and human resources	Like Static SF's.	Lack of Internal resources and limited skills.	In-house R&D is short lack of financial resources.	Unplanned innovative activity ; lack of financial resources.	Planning deficiency in Product development and in growth

Source: Rizzoni. Revue d'economie industrielle, 67. 1994.

Patent propensity increases for firms in the right-hand columns. Firms involved in knowledge-based content are more likely to patent domestically and abroad, especially in cases where this content is expensive to produce but relatively cheap to copy, such as in software, biotech and pharmaceuticals more generally. This is expected in cases of entrant firms in emergent technologies (i.e. "New

Technology-Based Companies") where firms not only consider whether to patent but also how and where. Still, costs associated with patenting may remain a real concern.

Firms in the middle ground of the table are expected to have more varied needs, attitudes, and actual practices. The so-called 'dominated' small firm may need to define and perhaps protect their intangible rights in their relationships with their partners, even where contracting is the major mode for defining their interrelationship. Imitative companies may need to monitor the markets in which they operate. They will also have to make sure that their strategies do not bring them into conflict with existing actors. Furthermore, a firm will not necessarily remain in the same niche throughout its lifetime. They may move from one category to another as they mature.

This matrix illustrates that not all small and medium-sized enterprises alike and not all will utilize the patent system. It is important to keep this in mind as we move to consider what sort of Norwegian firms patent in Europe. First we present the approach that allows us to analyze the patenting records of these firms.

3. Data and approach

To study Norwegian patenting in Europe we link EPO patent data to the national registries of all enterprises. This extends the approach used in the previous chapter in time and in scope, as it includes European patents through 2005. The firm-linked patent approach represents a marked improvement on existing approaches, as discussed above. It is useful in constructing a baseline as the approach:

- can identify the size and industry of the patenting firms: patent-counts only provide aggregate counts;
- includes a full-count of all enterprises: the Community Innovation Survey (CIS 4) excludes firms with under 10 employees, i.e. the majority of Nordic firms;
- provides a global picture in which particular populations can be focused on and compared; case-studies and other small-scale surveys provide limited evidence about the situation of individual firms.

The approach used here is slightly different than in the previous chapters. Here we build on a common approach that was employed for all Nordic countries in what is the first concerted cross-country collaboration to link administration-data and IPR data.[76] The definitions used to build the common Nordic approach are slightly different from that used in the previous chapters. In this chapter, the presentation of firm-size for example relies on the EU definition (2003); the

[76] In 2008 OECD initiated work on patent name harmonization to which the author and his Nordic colleagues have contributed. See http://www.oecd.org/document/10/0,3343,en_2649_34451_1901066_1_1_1_1,00.html. The approach used in this chapter builds on the Nordic effort, which was the first time that national teams collaborated to consistently match and analyze patent-data. See Iversen et al. 2009.

correspondence between International Patent Classes (IPC) utilizes a common key first developed for the OECD Patent Manual (1994); the name-harmonization process relies on existing studies (WIPO, 2003; Eurostat, 2006).

Small and medium-size enterprises: For the sake of comparison, the study employs the EU definition of SMEs (EU, 2003). This definition is pegged to the number of employees, but recognizes that size involves overall resources. Therefore a measure for turnover or balance-sheet total is included which overrides the purely employment based division.

The four categories are:

1. Micro (0-9 employees and less than €2 million in turnover)
2. Small (10-49 employees and less than €10 million in turnover)
3. Medium-sized (50-250 employees and €50 million in turnover)
4. Large (firms with more than 250 employees or greater than €50 million in turnover).

This definition entails that a SME is an enterprise with fewer than 250 employees and/or €50 million in turnover. [77] Because of the relatively small scale of Norway and its economy only about 0.6% of Norwegian firms qualify as large according to this definition. Therefore, the chapter breaks down results according to the smaller classes as well.

Applications: The study looks at European Patent Office (EPO) and domestic patent applications (Norwegian Patent Office) involving at least one Norwegian applicant received. Focus is placed on the EPO applications. Since membership affects the propensity to patent through the EPO office, a greater proportion of Norwegian patenting is found at the domestic office in the timeframe than in other Nordic countries.

The contribution of the Norwegian applicant(s) to patent applications that involve more than one applicant is computed as a fraction of that application (i.e. fractional counts are used). EPO applications include patents that arrive at the EPO either through the Patent Cooperation Treaty (PCT) route or directly.

Time-span: In the case of the European patents, this is the date of publication at the EPO. For the domestic data the date of application is when it was received by the office.

Enterprises (foretak) versus Establishments (bedrift): the enterprise-level was used and all values (number of employees and turnover) were aggregated up to this level.

---

[77] The definition is slightly different from the one developed in the preceding chapter.

Industrial activity: The enterprise's industry is defined via the EU's NACE classificaiton (Nomenclature générale des Activités économices dans les Communautés Européennes). The most up-to-data classification is used if this had changed over time. Zip-codes were associated to county and district-levels via the Norwegian Post's database, thus allowing us an additional criterion on which to check the identity of the applicants.

Technological Areas: The primary IPC classes of the patent applications were associated to Technological Areas by a widely-used Correspondence Key: the INPI/OST/ISI Key, Version 3. This correspondence key was first suggested in the OECD Patent Manual (1994; 2008).

3.1. IPR data

The backbone of the patent data comes from the EPO Worldwide Patent Statistical Database (Patstat, see the Annex). The EPO currently includes 34 countries, with Norway among its latest members. The Patstat database however documents the patent record of more than 80 countries. The extraction is from the October 2007 edition of the Patstat. The intent of Patstat is to provide researchers with raw-data. As a result the quality of the data, specifically that of the instrumental name and address fields, are lower than that found in the providing offices (see comments in Iversen et al, 2009). Therefore, the Patstat data is complemented by two sets of patent data:

1. The Norwegian Patent Office (NPO) data: the Norwegian Patent Office data extracted in December 2007 and includes more specific information about the status of the applications in addition to the cleaned applicant fields. Note that the data also includes patent applications even if they were withdrawn before the statutory date. These applications, which largely involve smaller applicants, are usually not reported. They can be used here to compare difficulties that emerge during the application process among small firms as against larger firms (see preceding chapters).

2. Questel Orbit Data was also used to supplement the Patstat coverage of EPO and Euro-PCT applications involving Norwegian applicants. In addition to cleaned name files, this data include opposition data and data on lapsed applications which can be useful in gauging differences in patenting behavior among the different populations.

3.2. Business register data

These enterprises are linked by enterprise name with concurrent years of the Employment database for all Norwegian enterprises (hereafter "National Registry")[78]. This registry is put together by Statistics Norway on the bases of firm-level information from the Brønnøysund Register Centre (http://www.brreg.no/english/) for all Norwegian enterprises and companies and the National Insurance Service's (Rikstrygdeverket www.nav.no) registry of active employees and employers. This database is a registry that contains all enterprises (and subsidiary companies) that formally pay wages to at least one person. (a registered workforce of about 2 million) The enterprise-level information used here includes information about firm-size, industrial activity, number of companies, annual turnover etc. This type of registry is only found in a limited number of countries, especially the Nordic countries.

Box 1 The National Registry data

Source: NAV Aa-register (Employer-Employee database) and Enhetsregisteret (ER) SSB

Time-span: 2000-2005

Key-dimensions: All economic entities including public organizations

Special Conditions: Number of entities expanded in 2001-2002 as the minimum number of employment was lowered. Presentation of the Industry structure relies on the Employer-Employee database (excluding many sleeping entities). Merging procedure involves the wider ER to include links with entities without employment.

These matches were further tested against the full-count of all firms registered in Norway (Bof Enhetsregister). There are approximately twice the number of firms in the BoF database, as it includes all firms registered in the country, though not necessarily active. Many firms do not record employment and/or industrial activity. Such firms may be used as vehicles for patent applications, especially among private individuals and very small firms who are just making a start. A link here is therefore relevant to the study, although it may not necessarily yield information about the employment or even the industrial activity of the registered firm. Absent employment information, the enterprise will be listed as a firm without employment ("Other Firm"). It is in all probability a Micro-firm.

---

78 Based on the firms in the Employer-Employee database (AA database or "Arbeidstaker-Arbeidsgiver"). See Furseth & Haglund (2008) Arbeidsdeling mellom Brønnøysundregistrene (BR), NAV Aa-registeret og Statistisk Sentralbyrå (SSB). Statistics Norway, 2008/18. The presentation of the Industry structure relies on the Employer-Employee database (excluding many sleeping entities). Merging procedure involves the wider ER to include links with entities without employment

3.3. Merging patent data with business register data

The database analysis conducted in the study is based on coupling the identity of Norwegian applicants in the patent-applications with firm-level information available from the business registries. The name-matching procedure relies on the official Organization Number used in Norway (foretaksorganisasjonsnummer), which is associated to applicants name. The procedure itself is adapted from standard procedures that have been developed here (Iversen, 2003; Magermann et al, 2007). The details of the approach are presented in Annex[79]. In brief it involves an approximate string strategy using matches in name-fields in conjunction with other information, instrumentally zip-codes. The challenge is to reduce the number of false-positives while also limiting false-negatives.

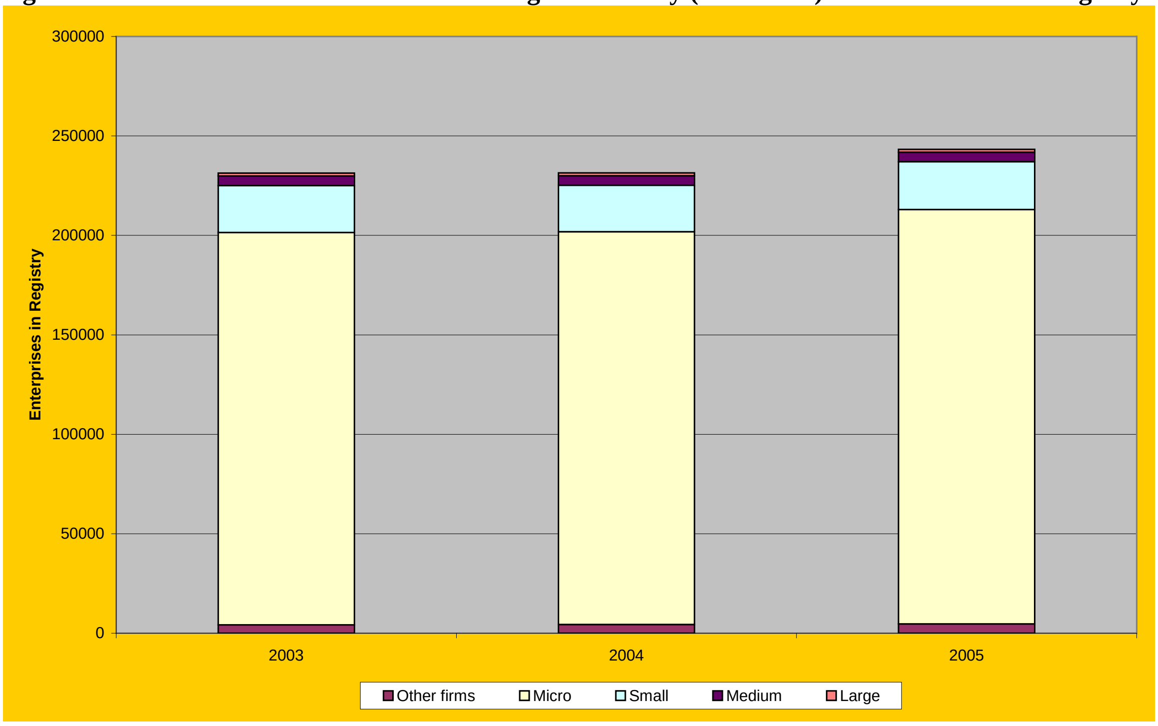
3. Overview of economic and patenting activity in Norway

Small entities dominate the demographics of economic entities in Norway. Over 97 percent of Norwegian entities are small according to the EU definition. In fact most (88 percent) Norwegian enterprises are micro firms according to the EU definition. Internationally these are very small firms. This majority of firms are furthermore not covered by the Community Innovation Survey (CIS) and other surveys which may be used to gauge IPR use among SMEs. These surveys also tend to stratify their samples of small-firms, which constitute a further 10 percent of Norwegian firms (ca 24,000 in 2005).

Figure 1 illustrates the extent of the small-firm bias in the Norwegian economy for the period 2003-2005. Micro firms dominate the population, even more so if the category of 'other firms' (or firms without reported employment) are included. The proportion of the smallest firms rise slightly in the period, while that of the medium-sized and large firms fall back correspondingly.

[79] See also Iversen et al, 2009.

Figure 4-1 Firm-size distribution in the Norwegian economy (2003-2005): National Business Registry



Source: National Business Registry, 2005. Statistics Norway.

Table 2 presents a general snapshot (2005) of some basic aspects of Norwegian economic entities which are expected to influence patenting. The table indicates that with the exception of the aggregate areas of mining and utilities, Norwegian industry is dominated by SMEs (according to the EU definition). The 225 patent applications (fractional counts) published at the EPO in 2005 can here be compared to R&D expenditure (million Euros), turnover (million Euros) and the gross number of employees. Turnover and the size of the firm lay the basis for the definition of small and medium-size enterprises used here.

Many large Norwegian entities (such as hospitals) are found in the community and government sectors, which are strictly speaking outside the business enterprise. Almost half of the large entities in the Norwegian population of economic entities are found in these sectors (Community, Social… and Other categories in the Table). However, these are included in industrial breakdowns since patenting from universities and hospitals are substantial and growing.[80]

[80] The reader should however be aware that these entities are included in the gross counts here, but are dropped in cross-country comparison with other Nordic countries in Iversen et al. 2009.

Table 4-2 SME* share of economic activity in total population 2005

	Other	Micro	Small	Medium	Large	total firms	total employm	Turnover M€*	Percent Small
TITLE	*number of enterprises by size-class 2005*								
AGRICULTURE, HUNTING, FORESTRY AND FISHING	570	38232	473	95	7	**39377**	**63 453**	**5 409**	**99,7**
MINING AND QUARRYING	8	482	117	35	29	**671**	**39 621**	**8 661**	**90,5**
MANUFACTURING	312	11665	2915	815	222	**15929**	**257 330**	**60 704**	**93,5**
ELECTRICITY, GAS AND WATER SUPPLY	11	180	139	94	29	**453**	**14 305**	**7 408**	**72,8**
CONSTRUCTION	478	26839	2863	274	33	**30487**	**154 555**	**19 261**	**99,0**
WHOLESALE AND RETAIL TRADE; RESTAURANTS AND HOTELS	1387	39140	8843	1264	267	**50901**	**412 869**	**105 263**	**97,0**
TRANSPORT AND STORAGE AND COMMUNICATION	262	16259	1373	324	115	**18333**	**157 192**	**28 503**	**97,6**
FINANCE, INSURANCE, REAL ESTATE AND BUSINESS SERVICES	1410	38433	3298	599	146	**43886**	**281 287**	**24 167**	**98,3**
COMMUNITY SOCIAL AND PERSONAL SERVICES **	0	18384	2682	1076	585	**22727**	**775 573**	**161**	**92,7**
OTHER**	181	17961	1381	183	27	**19733**	**87 583**	**6 128**	**98,9**
Uknown	20	744	1	0	0	**765**	**861**	**8**	**100,0**
TOTAL	4639	208319	24085	4759	1460	**243262**	**2 244 629**	**265 673**	**97,4**

Source: National Business Registry, 2005/ Statistics Norway. Aggregate Business Enterprise R&D figures from Statistics Norway. Patents from European Patent Office data: Patstat and Questel Orbit * According to EU definition of SME. For classification by employment only see Annex table 1b.

This high level of aggregation confirms the expectation that the manufacturing sector accounts for most firm-level patenting. Patenting however is not confined to manufacturing, but extends to the service sectors in a significant way[81]. It becomes clear that a greater level of detail is needed to appreciate the level and orientation of small firm patenting. This chapter (and annexes) extends the analysis of patenting by considering different levels of aggregation of industrial activity as well as finer breakdowns of firm-size. [82]

3.1. Innovation Activity

The first step is to review some evidence of the question of patenting currently available. The Community Innovation Survey (CIS) is one of the most used sources of information in Europe on the relationship between innovation and intellectual property rights use in firms. The advantages of the survey include that it is repeated periodically, that it comparable across countries, and that it provides insight into relationships between firm organization, innovative activities and outputs, such as patents. It also provides the basis to study patterns involving firm-size.

There are at least two major disadvantages however. The first is that sensitivity to sampling, which especially affects small firms (see above). The Norwegian sample for CIS4 includes about 4650 firms (enterprises) or about 2 percent of the total population of active firms in 2004. Firms with 10 employees or fewer tend not to be included in the survey at all, which again excludes the growing majority of Norwegian firms.

There are other considerations when interpreting survey data here. It should be noted for example that the CIS sample is designed to pick innovative firms. While these certainly overlap with IPR users, they are not interchangeable. As a result, the stratified sample of the sample among smaller firms

[81] Note that the Unknown category for patenting includes here both patents filed by private persons and firms which could not be categorized.

[82] A corresponding table is also found in the annex at a more disaggregated level (Annex Table 1).

does not necessarily present a representative presentation of IPR users. In addition there is little information in (the Norwegian CIS4) survey on IPRs beside that the firm has applied or not. Countries where information on numbers of patents is requested are prone to substantial reporting errors.

Still, the CIS does provide valuable light in the empirical shadow covering the use of intellectual property rights, for example about the relationship between patenting and research collaboration (see chapter 6). The following descriptive statistics[83] suggest that about 14 percent of Norwegian enterprises either patent or use trademark: the proportion is virtually identical if SMEs in the sample are focused on. Taking this literally for the whole Norwegian population is misleading: it would suggest that over 34,000 Norwegian firms patented in 2004, while the number is closer to 1000 as demonstrated below.

Table 4-3 Survey evidence of IPR use by type of innovators: Norway CIS4

	All firms	Product Innovators			Process Innovators	Marketing Innovators	Product and Marketing Innovators
		All	New to Market	New to firm only			
Patent users	7.7	21.3	24.7	17.2	18.1	14.6	19.7
Trademark Users	10.1	23.2	28.1	17.8	21.4	25.3	28.9
Patent or TM	14.2	34.4	40.8	27.3	30.8	31.8	37.4
Patent and TM	3.6	10.1	12	7.7	8.7	8.1	11.1
Patent only	4.1	11.2	12.7	9.4	9.4	6.5	8.6
TM only	6.5	13.1	16.1	10	12.7	17.2	17.7
No IPR	85.8	65.6	59.2	72.7	69.2	68.2	62.6
Firms*	6210	1714	873	794	1329	1011	692

Source: Compiled by author based on CIS4 data (Statistics Norway) for OECD Microdata Project reported in OECD(2009). Note* these descriptive statistics are weighted using standard weights

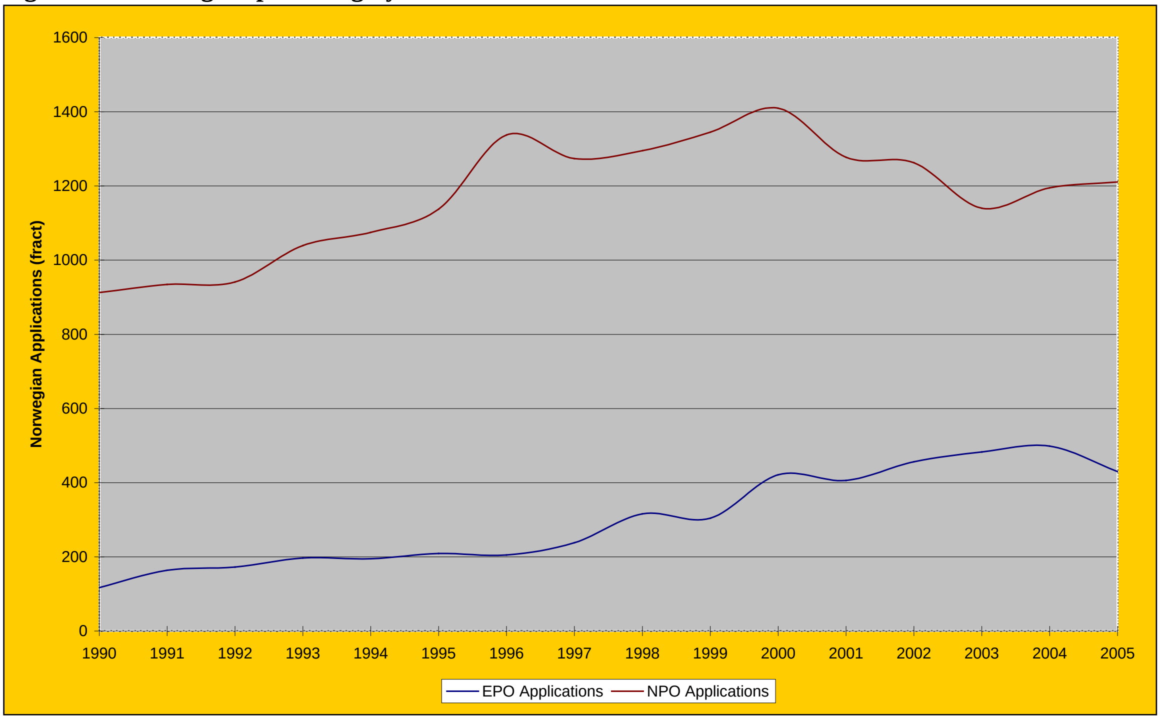
The survey is more useful when considering what type of innovative firms use different IPR types. It indicates that 41 percent of product innovators in Norway who introduced a new product to market within the three-year timeframe of the survey, using either patents or trademarks.

3.2. Patenting activity

Norwegian firms have faced a different proposition than their Nordic neighbors before acceding to the European Patenting Convention in 2008. There are two general affects to note. The first is that the majority of patenting activity has tended to go to the domestic office. Figure 1 demonstrates that for every European application there were between four and five domestic applications (which also generally provide the priority application).

[83] Compiled for the OECD Microdata Project (2007) Topic 5 to study incentive effects of IPRs in the context of the survey. These descriptive statistics were compiled by the author based on the common templates. See Oecd 2009.

Figure 4-2 Norwegian patenting by Patent Office: 1990-2005



Data Source: Compiled on Norwegian Patent Office data and EPO data: Patstat and Questel Orbit. * Patent counts are fractional. NPO data include withdrawn patents (12.2007)

An additional effect is that foreign applicants had to file directly or indirectly (PCT) with the domestic office for protection in Norway. The proportion of foreign demand for Norwegian patents therefore dwarfs domestic applications. A large proportion of the foreign demand has in this situation originated from large MNC in the chemical and pharmaceutical industries which patent widely (see the proportion of US demand below). This pattern has remained rather consistent from at least 1990 (the see the Norwegian Indicator Report).

In addition, foreigners that co-patent with Norwegian applicants or firms with specific interest in the Norwegian market (for example in the shipping or oil-exploration fields) would also file a Norwegian application. Table 2 demonstrates that demand from the other Nordics has amounted to about 10 percent of application volume in Norway during 2000-2005, while the domestic share is just over 20 percent.

The share of domestic applicants is however significantly higher, since the average number of applications per applicant is higher among foreign patentees. While about a fifth of the applications were (fractionally counted) Norwegian, more than a third of the individual applicants were Norwegian (33.7%).

The transition from the domestically-oriented to the regionally-oriented patent office will have a set of consequences both in terms of where Norwegian enterprises might patent and what sort of patents they are likely to meet in their own markets. These effects have implications for Norwegian small firms. After the accession to the EPC, it will now be cheaper for Norwegian applicants to patent in one or more (up to 33) other European countries. This effect however might not be very large for small firms, whose markets traditionally are more local /national.

Table 4-4 Patent applications to the Norwegian Patent Office by country (filings from 2000-2005): fractional counts

		Applications Share		Applicants 2000-2005	
		2000-2002	2003-2005	Tot	Shares
Domestic	Norway	20.3	20.4	3553	33,7
Nordic Countries		10.1	8.6	1033	9,8
	Sweden	5.7	4.6	535	5,1
	Denmark	1.9	1.8	261	2,5
	Finland	2.5	2.0	208	2,0
	Iceland	0.1	0.1	29	0,3
Other European Countries		34.1	32.8		
	Germany	10.7	9.2	813	7,7
	Great Britian	5.2	4.8	645	6,1
	France	5.3	4.4	405	3,8
	Switzerland	4.0	4.6	241	2,3
	The Netherlands	3.8	4.5	202	1,9
	Other	4.9	5.3		
Other Countries		35.3	38.1		
	USA	26.5	29.1	1877	17,8
	Japan	4.4	4.1	295	2,8
	Other	4.4	5.0		
Applications Total		19 500	17 365	10 550	100.0

Data Source: Compiled on Norwegian Patent Office data (12.2007)

The other effect which may be greater for smaller firms is that a higher number of European applications may become active in Norway than before, since it will be cheaper for these applicants to extend protection here. This prospect makes monitoring patenting behavior more important as domestic firms adapt to the changing scenario.

Domestic and European patenting intensity varies across size-class and industry; the decision to seek patent protection is also conditioned by other factors. The following table puts into perspective the use of patents with other magnitudes of interest, for example the number of firms, number of employees in those firms, and reported turnover. It associates domestic and European patenting for 2000-2005 with the industrial activity of the applicant firms for a baseline year (2005). The aggregate estimates for R&D expenditure which is computed by Statistics Norway at the level of these industries are also supplied to suggest relationships between patent decisions and R&D expenditure which is known to be highly correlated with patenting (although not necessarily innovation).

The relative magnitudes indicate relatively high levels of patenting in Chemicals, Transport Equipment (including ships), Technical Consultancy and Other Business Services, Instruments, and Mining (which includes the important field of oil extraction). With the exception of the Technical consultancy and to a lesser degree Instruments, these are industries where large firms are relatively dominant.

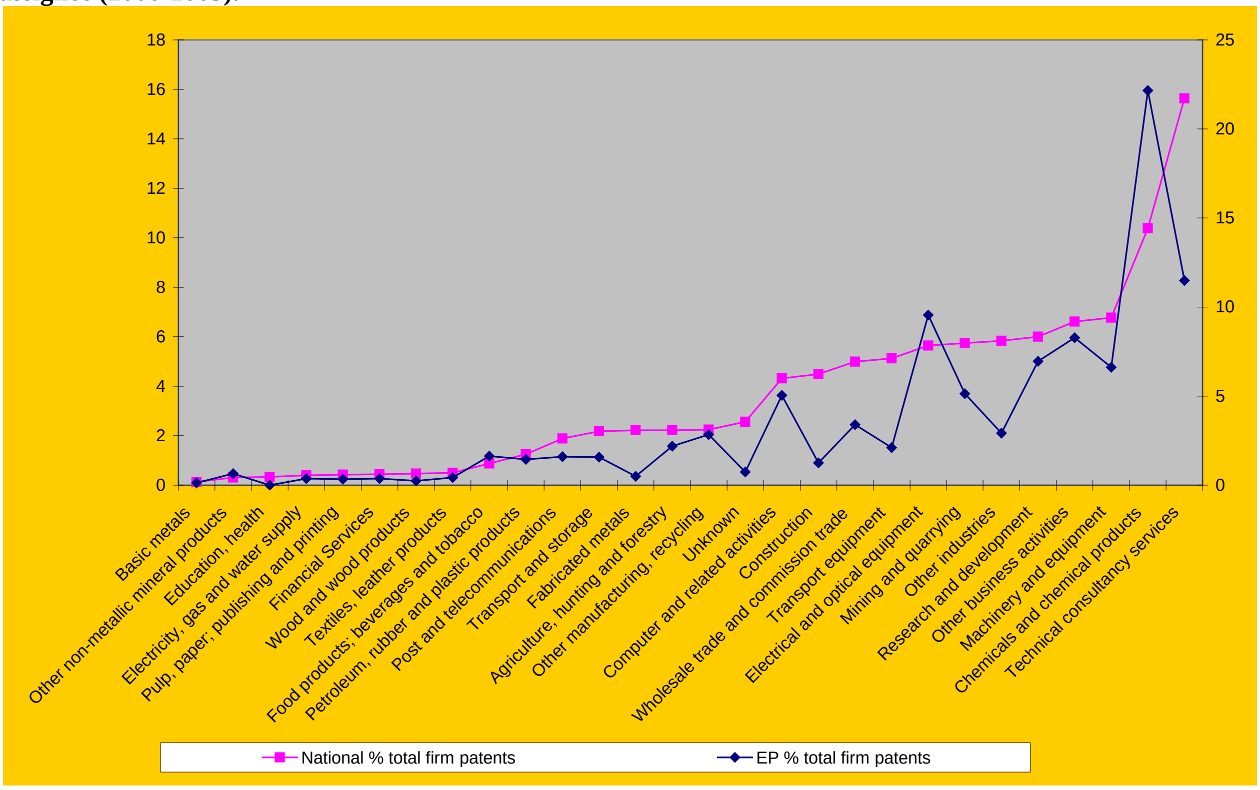
Table 4-5 Selected indicators across economic entities in Norway (2005)

Economic Activity	Enterprises 2005					Patent Applications 2000-05*	
NACE	total firms #	total employ	Turnover Meuros	R&D Meuro	Small firms %	Domestic	EPO
Agriculture, hunting and forestry	39 377	63 453	5 409	5	99,7	100	36
Mining and quarrying	671	39 621	8 661	106	90,5	258	83
Food products; beverages and tobacco	1 683	51 106	16 683	58	86,6	40	27
Textiles, leather products	1 072	5 532	711	8	97,2	23	7
Wood and wood products	1 561	15 607	2 419	7	95,7	21	4
Pulp, paper; publishing and printing	2 536	33 528	6 251	28	94,9	19	6
Petroleum, rubber and plastic products	353	5 317	921	11	93,2	56	24
Chemicals and chemical products	184	13 199	4 960	137	73,9	466	359
Other non-metallic mineral products	671	11 006	1 976	8	93,1	14	11
Basic metals	146	11 172	6 850	45	76,0	6	2
Fabricated metals	1 990	19 495	2 338	21	96,1	100	8
Machinery and equipment	2 031	23 959	5 040	118	95,1	304	107
Electrical and optical equipment	1 066	18 846	3 984	249	92,4	253	155
Transport equipment	1 088	36 486	6 800	69	88,5	230	34
Other manufacturing, recycling	1 548	12 077	1 771	16	96,8	101	46
Electricity, gas and water supply	453	14 305	7 408	6	72,8	18	6
Construction	30 487	154 555	19 261	18	99,0	201	20
Wholesale trade and commission trade	13 270	102 588	52 989	74	94,5	224	55
Transport and storage	17 295	119 788	20 438	11	97,9	98	26
Post and telecommunications	1 038	37 404	8 065	51	93,4	85	26
Financial Services	1 142	45 257	304	88	91,2	20	6
Computer and related activities	5 012	36 014	4 455	274	98,0	194	82
Research and development	264	10 892	613	40	80,3	269	113
Technical consultancy services	6 501	35 531	4 327	122	98,7	701	186
Other business activities	21 186	122 654	8 935	..	98,6	297	134
Education, health**	21 404	648 241	154	..	94,2	15	0
Other Activities**	68 487	556 135	63 942	..	97,8	262	47
Unknown	746	861	6	..	100,0	115	12
TOTAL	243 262	2 244 629	265 673	1 569	97,4	4 485	1 620
Private Individuals						2 930	302
Firms no match						82	66
matched firms no data						See Uknown	52
TOTAL						7 496	2 041

Data Source: Domestic patents compiled on Norwegian Patent Office data (12.2007). EPO data: Patstat and Questel Orbit *Patent counts are fractional. Small firms, less than 50 employees; **including hospitals, goverment bodies and other non-business entities *fractional counts

This composite picture begins to indicate structural factors that account for different patent intensities in the population. Figure 3 and 4 unpack two aspects of the distributions. Figure 3 depicts the general differences in the filing patterns with the respective offices (domestic and EPO). Filing patterns, which involve costs to the applicant (see below) are expected to be sensitive to firm-size. Here they are depicted according to size and industry for purposes of illustration.

Figure 4-3 Comparison of the percentage of domestic and EPO patent applications in given industry by assignee (2000-2005).

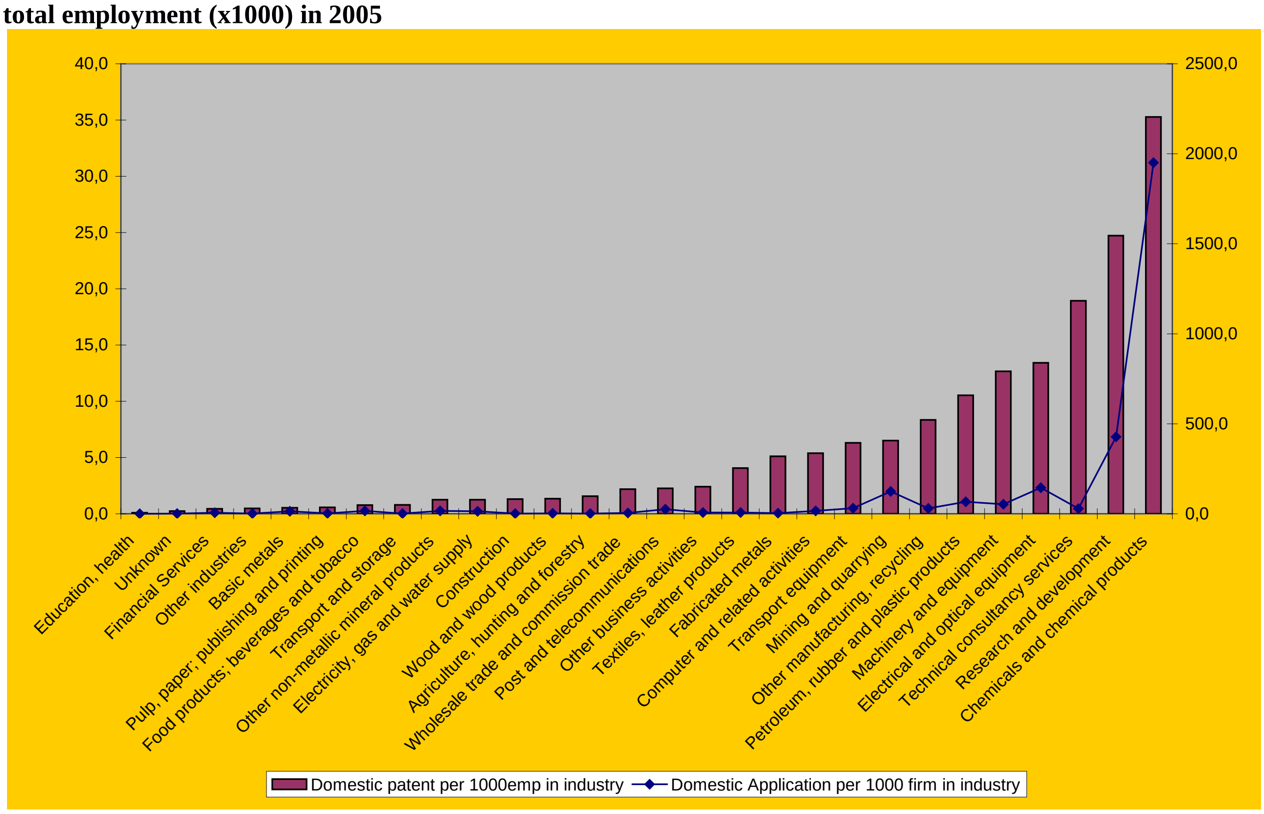


The proportion of NPO and EPO applications for each industry are compared against the total number of applications filed at the respective offices by Norwegian firms. This comparison suggests a broadly similar industrial profile for filings at both offices. However certain industries show a preference for domestic and not European patenting. The discrepancy is most apparent in the case of technical consultancy, but is also evident in Construction, Other industries, and Transport Equipment. With the curious exception of the last case, these are all industries where small firms are dominant (see Table 4 again).

Another of the possibilities that the approach opens up is to compare the number of applications by employment or overall number of firms. Turnover and R&D intensities can also be developed. Figure 4 presents a rough indicator of patent intensity by calculating domestic applications (for 2000-2005) per 1000 employees and by 1000 firms in the respective industry (for the base-year 2005).

This rough picture allows a more instructive look behind patent counts which might be useful to policymakers. Consistent with expectations, patent intensity by number of firms and employment is highest in the Chemicals sectors, followed by the R&D sector. It is worth noting that these are industries where the proportion of small firms (<50 employees) is lowest (see % Small firm column in Table 3 above).

Figure 4-4 Domestic patent applications by industry of assignee (2000-2005) per total firms (x1000) and total employment (x1000) in 2005



Data Source: Domestic patents compiled on Norwegian Patent Office data (12.2007).

In addition, a set of industries also patent moderately in terms of employment. These more mechanical products and services, specifically include technical consultancy services (where computing is important) and electrical and optical instruments, as well as machinery. The patenting activity of the oil industry is partly reflected in these figures but moreover found in the oil –extraction industry (under mining) as well as petroleum products. Note that the average firm size in each industry is reflected in the discrepancy between patenting by firm and patenting by employment.

This picture based on domestic patenting is set to change with the transition to full-EPC membership, which brings Norway in line with its Nordic, and indeed European neighbors. In the timeframe under consideration here, the overwhelming majority of Norwegian applicants have followed the Euro-PCT route when applying to the EPO area (88%). In contrast, about 7 percent of Norwegian applicants have (2004-2006) utilized the PCT route also for applying domestically. These patterns are expected to change with the transition to the EPO. How they will change—and how small firms and large firms will adapt to the new situation—can be followed up on this basis.

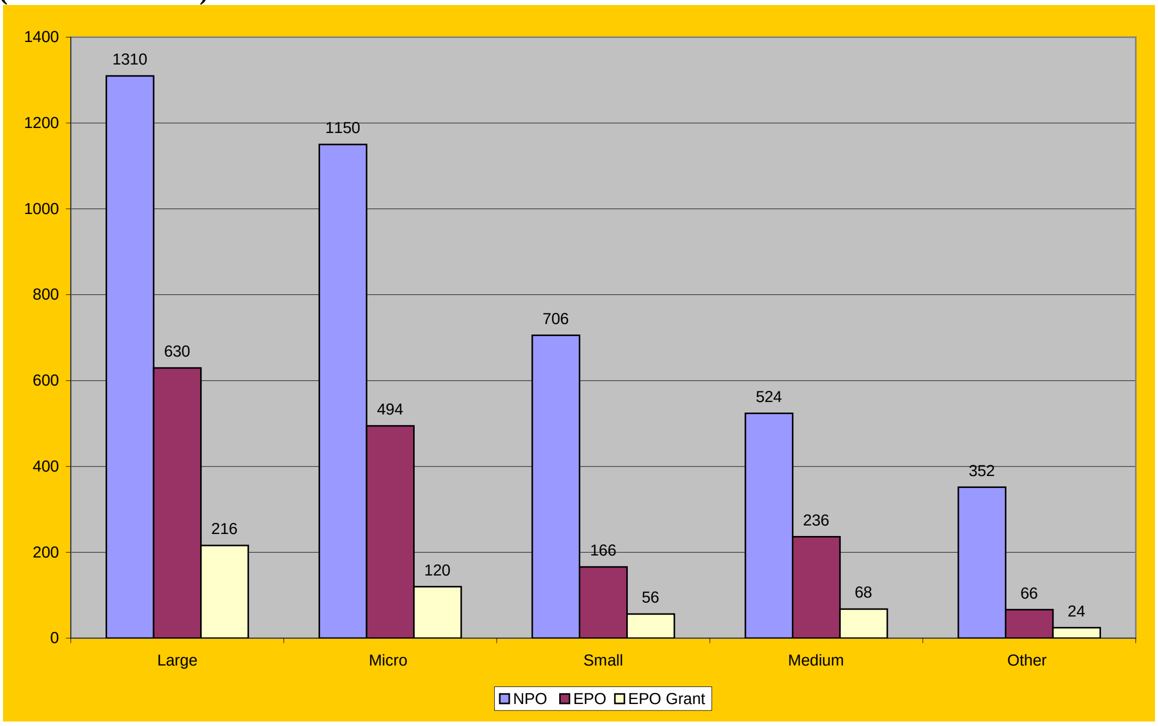
4. Enterprise size and patenting

Firm-size conditions not only the degree to which enterprises use intellectual property rights but the tendency to pursue rights beyond national borders. In light of the transition to full EPC membership, it is important to understand how different size-classes tend to file their applications. This section presents Norwegian applications by size primarily at the European Patent Office. It does this in light of domestic applications since the domestic application lays the basis (as priority) for a subsequent European application in many cases.

The question has not been either to apply for a patent either in Norway or EPO, but both. Before EPC membership, the price of extending a domestic application to one or more EPO countries represented a higher cost (higher than a firm in a member country). An extension to the EPO may thus be seen as an indication of the value of the particular application. In like manner, a patent that is subsequently granted is a subset of the original applications. A grant also is even more of an indication of the value of the underlying invention.

In this light, Figure 5 presents a composite picture of domestic applications, European applications, and European Grants according to firm-size categories for 2000-2005. It is a snapshot. So although European applications during the period will overlap with the domestic applications for the period, the domestic applications are not necessarily the priority for those applications. The same is even truer of the grants during the period, given the time-lag between different stages of the application and examination processes.

Figure 4-5 Breakdown of firm-size by number of patent applications and Patent Office: 2000-2005 (fractional counts)



Data Source: Domestic patents compiled on Norwegian Patent Office data (12.2007). EPO data Questel & Patstat

Yet, a comparison of the relative magnitudes of these stages helpfully introduces differences between small and large firms along a set of other dimensions considered in this section: how much is patented, what is patented, where it is patented, as well as indications of what happens to the applications (i.e. granted, withdrawn, etc). The figure confirms that most Norwegian patents originate in the largest companies patent, both domestically and in Europe. Patents filed by the Micro firms (excluding others which include firms without reported employment) account for 1150 or 90 percent as many domestic applications as the large firms.

On this rough basis, large Norwegian firms applied for about half (48 percent) as many patents in the EPO during the period as they did domestic patents. During the same time period they were granted an equivalent of about one-sixth (17 percent) the number of their domestic applications. Small firms (10-49 employees) filed on average 1 EPO application per every 4 domestic applications. Small firm grants at the EPO were very small when compared against the number of domestic applications during the same period (corresponding to only 8 percent).

4.1. Technological Areas and firm-size

The propensity to patent is recognized to depend on industry and technological area. This bias needs to be addressed when trying to understand the relative patent intensities of small versus larger firms. Table 4 compares the size-distribution of patent applications between 2000-2005 with the overall population of firms by industry. The number of patents applications per 1000 firms provides a simple index for patent intensity. In half of the industries, less than 10 EPO applications were filed during the period per 1000 Norwegian firms.

The propensity to patent according to this measure is highest in four of the 27 industries. Firms in the Chemicals and Pharmaceuticals on average filed two EPO applications during the period. Firms involved in the area of Research and Development are also among the most intensive users of European patents, with 427 applications per 1000 firms during the period. The other two areas of high intensity were the field of Electrical and Optical Instruments and Mining and Quarrying, which encompasses oil-extraction activities which are important in the Norwegian economy.

Table 4-6 EPO applications by firm-size (2005) and industrial activity (2000-2005): fractional counts

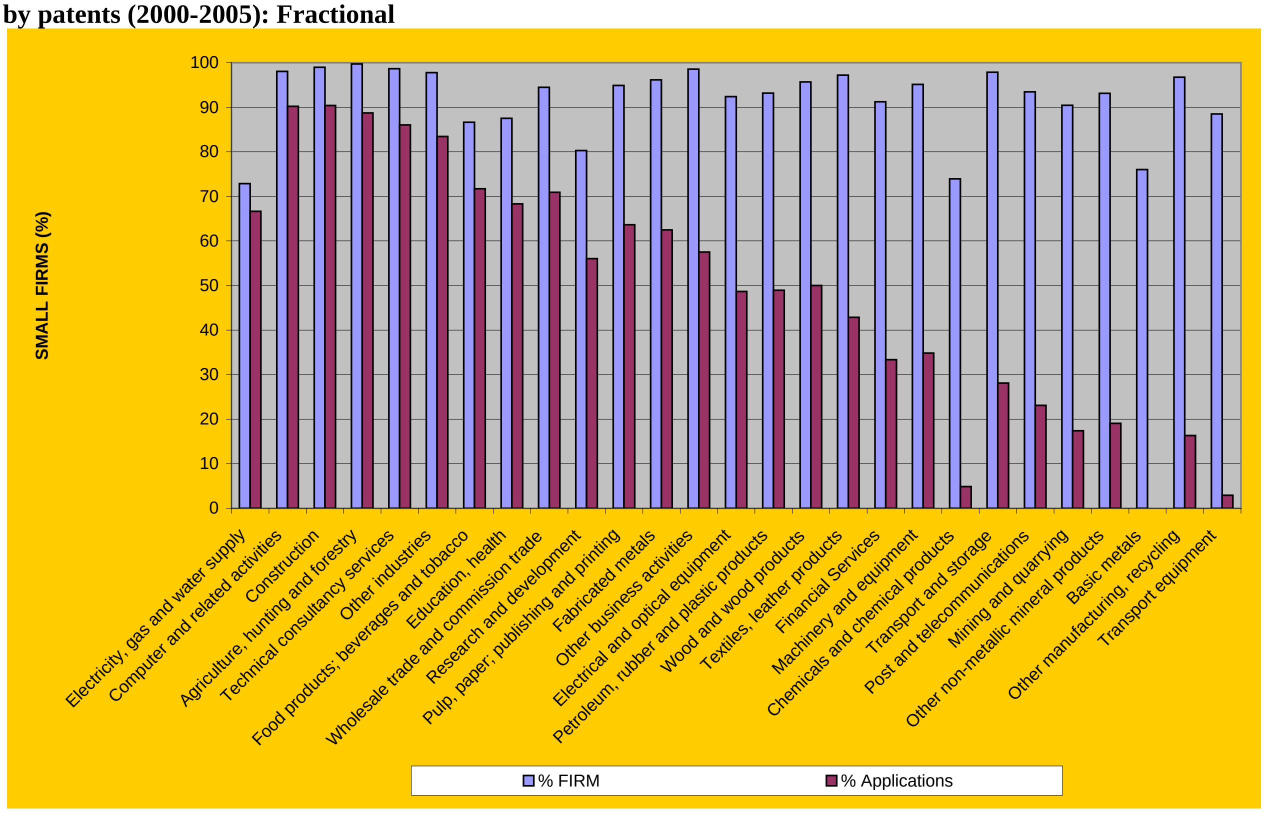
	patent applications by size-class* 2005 in total population					Totals 2000-2005		
	Other	Micro	Small	Medium	Large	Total EP-A	Total Firms	Applications per 1000 firm
Agriculture, h	8	22	2	3		35	39380	1
Mining and q	4	11		1	64	79	671	118
Food products; beverages a		5	14	3	5	27	1683	16
Textiles, leather products		2	1	4		7	1072	7
Wood and wood products		2		1	1	4	1561	3
Pulp, paper; publishing and		3	1		2	6	2537	2
Petroleum, rubber and plast		9	3	9	3	24	353	67
Chemicals an	3	15		13	328	359	184	1951
Other non-metallic mineral p		2		5	4	11	671	16
Basic metals				2		2	146	14
Fabricated metals		2	3	3		8	1990	4
Machinery an	2	16	19	28	42	107	2031	53
Electrical and	1	54	20	9	69	153	1066	143
Transport equipment		1		9	23	33	1088	30
Other manufa	2	4	2	32	6	45	1548	29
Electricity, gas and water su		4			2	6	453	13
Construction	2	15	2		2	21	30487	1
Wholesale tra	2	24	13	11	1	51	13270	4
Transport and	1	6		2	16	25	17296	1
Post and telecommunication		5	1	6	14	26	1038	25
Financial Services		2		4		6	1142	5
Computer and related activit		67	7	4	2	80	5013	16
Research and	2	38	23	29	20	113	264	427
Technical con	18	107	35	5	10	175	6503	27
Other busines	12	56	10	48	6	131	21187	6
Education, health						0	3133	0
Other industri	7	18	7	4	10	46	67916	1
Unknown	1	7	3	2		13	19579	1
TOTAL	65	494	166	236	630	1591		

Note: 449 applications are not included: 301 from private persons and 118 from uncategorized firms

These are largely fields where there are high propensities to patent. It becomes clear when looking at the size-distribution of these patents (again, fractional counts are used), large firms account for almost of the patenting activity in the Chemicals and many in the Mining and Quarrying industries. Patenting by the Research and Development industry is more evenly distributed by size-classes. Patenting in the Instruments industry is split between very small and large firms.

Figure 6 compares the proportion of applications emerging from small firms (less than 50 employees or equivalent, including those without registered employment) against the overall percentage of small firms in those industries. As demonstrated in the first section, small firms dominate in number in most industries. The level of European patenting is as expected out of keeping with the overwhelming dominance of small firms in Norwegian industry. What the figure shows is that the degree of imbalance between the proportion of small firms and the proportion of small firm patenting varies widely by industry.

Figure 4-6 Comparison of the proportion of small firms (<50 employees) by industrial activity (2005) and by patents (2000-2005): Fractional



Source: EPO data Questel & Patstat.

Small firms account for over half the patenting in roughly half (14) of the industries. The proportion is nearly 90 percent in the case of Computers and Technical Consultancy where small firms dominate the demographics. On the other side of the scale, the figure suggests that large firms dominate in metals, chemicals, oil-extraction, transport, and telephone patenting.

4.2. Indications of patent life-cycles by firm-size

One dimension of the relationship between firm-size and patenting is the relative degree to which patent protection is sought. The number of applications, while indicative of inventive activity with some strategic outlook for the firm, is not necessarily important if those inventions are never granted patents and/or never used. It is therefore important to entertain the question of what happens subsequent to application and how it varies by firm-sizes. Some measures that are made possible by the approach are briefly presented below.

A primary question in this context is whether patents are actually granted. Table five compares the volume of European patents patented and granted by firm-size. It shows that in broad terms the proportion of patents granted for each size-class is in line with its proportion of applications.

Table 4-7 EPO applications and grants by Firm-size and Technological Areas: 2000-2005 (fractional)

	EP APPLICATIONS 2000-2005						
	Person	**Other**	**Micro**	**Small**	**Medium**	**Large**	**Total**
Chemistry, pharmaceutics	**48**	**24**	**89**	**43**	**34**	**204**	**442**
Mechanical engineering, machinery	**91**	**9**	**68**	**16**	**39**	**113**	**336**
Process engineering	**62**	**8**	**78**	**26**	**51**	**98**	**322**
Instruments	**87**	**14**	**83**	**41**	**35**	**82**	**342**
Civil engineering, building, mining	**55**	**3**	**52**	**12**	**13**	**64**	**197**
Electricity - electronics	**61**	**4**	**100**	**23**	**37**	**52**	**276**
Consumer goods and equipment	**45**	**5**	**25**	**6**	**29**	**17**	**126**
Total	**449**	**66**	**494**	**166**	**236**	**630**	**2041**
Percent	**22**	**3**	**24**	**8**	**12**	**31**	**100**
	EP-GRANTS 2000-2005						
Electricity - electronics	**7**	**0**	**22**	**8**	**8**	**9**	**54**
Instruments	**27**	**5**	**11**	**13**	**11**	**16**	**83**
Chemistry, pharmaceutics	**10**	**15**	**13**	**13**	**8**	**81**	**139**
Process engineering	**23**	**2**	**26**	**14**	**10**	**41**	**115**
Mechanical engineering, machinery	**31**	**2**	**17**	**5**	**23**	**49**	**127**
Consumer goods and equipment	**21**		**8**	**1**	**6**	**2**	**37**
Civil engineering, building, mining	**14**		**24**	**3**	**2**	**20**	**62**
Total	**132**	**24**	**120**	**56**	**68**	**216**	**615**
Percent	**21**	**4**	**19**	**9**	**11**	**35**	**100**

The proportion of grants to Micro firms is however substantially less (19 percent) than its share of total applications (24 percent). This may suggest that the applications of these firms are less successful than that of the Large firms where grant rates are substantially higher than application rates. This might on the other hand indicate that Norwegian patenting in this area is emergent during the period, and that there was not a large backlog of patents already in this area. Greater study would have to be done to interpret what is happening in this and other technological areas.

Another concern is that small firm patents do not realize the expected value as well as large companies and are abandoned subsequent to grant. Table 6 looks at patents granted at the EPO between 2000-2005, comparing the latest year in which protection lapses in one or more EPO countries. It also explores the degree to which these patents have been opposed through opposition procedures found at the EPO.

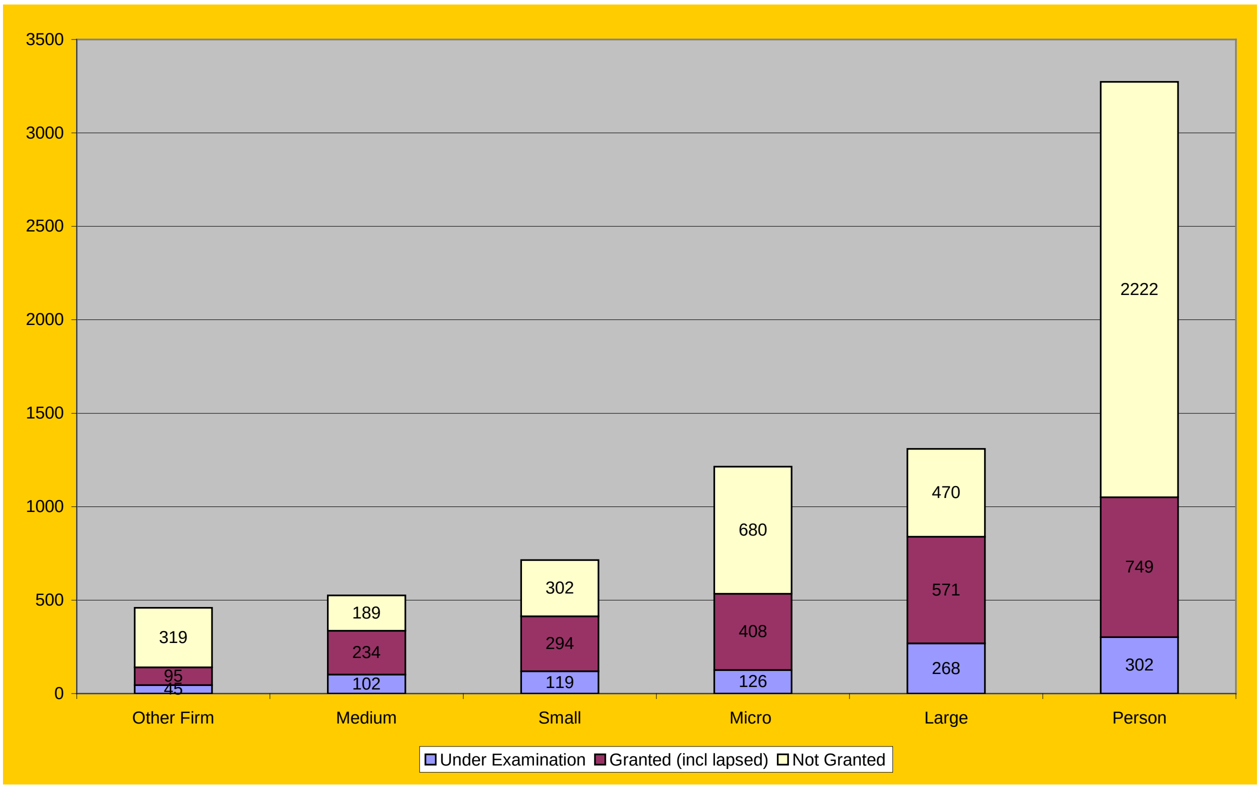
Table 4-8 Patents granted by the EPO 1996-2000: Percentage lapsed and/or opposed by 2005

	Person	Other	Micro	Small	Medium	Large	Number
Lapsed Grants	**Lapsed Patents Granted 1996-2000**						
lapsed within 5 years	34	44	36	35	29	36	**35**
lapsed during next 5 years	13	19	9	11	12	13	**13**
Not Yet Lapsed	53	38	56	54	59	51	**52**
Opposition	**Opposed Patents Granted 1996-2000**						
Opposition Initiated	8	6	9	8	10	6	**7**
Patent Revoked after Opposition	1	0	0	3	2	1	**1**
Patent Upheld after Opposition	1	0	0	3	0	2	**1**
Granted 1996-2000	**178**	**16**	**81**	**37**	**41**	**292**	**645**

This population is limited to about 650 grants (fractionally counted), of which 35 percent lapsed in at least one jurisdiction within the first five years after grant. There are no major differences in relative proportions here, with one exception. Other firms (firms without reported employment) account for a larger proportion of these early deaths. There is no clear firm-size based that emerges from the opposition data here. Opposition procedures were initiated in about 7 percent of these grants. These tended to be spread relatively evenly across firm-size.

A more detailed look at what happens to patents could for example look at whether the patent died before grant. One main reason for patents not to proceed to grant is that they are abandoned by the applicant at a stage during the application and examination process. The final figure compiles evidence from the current (2006) status of domestic patent applications filed between 1996-2000. It differentiates between applications still under examination, those that have been granted (including those that have subsequently lapsed), and those that have died without being granted.

Figure 4-7 Domestic Patents filed with the Norwegian Patent Office by size-class and Status (2006): 1996-2000



Note: "Not Granted" includes rejection, patents withdrawn by the applicants or other failure to pay fees

The category of Not Granted includes applications for which fees were not paid during the application period or were otherwise withdrawn by the applicant. In a very small number of cases, the patent was rejected outright. Figure 7 demonstrates that the incidence of Non-Grant is skewed, with the highest proportions found among the smallest applicants. It is especially the falling number of applications filed by private persons which do not proceed to grant. However, the proportion of non-grant among micro-firms is disproportionate to the overall level of application. This appears to be an area where the potential for improvement as policy attempts to improve IPR use among small and medium-size enterprises.

5. Conclusion

The chapter addresses the need for better information about SME use of IPR as Norway enters the EPO. It draws on a cross-country framework to shed light on how different types of firms approach and use the IPR system differently. Understanding the defining dimensions of this relationship stands to contribute to more effective, knowledge-driven policymaking on this front. In turn, more effective and more coordinated policymaking stands to improve the climate for the relationship between SMEs and IPRs. This chapter provides further evidence of the extent to which SMEs dominate the Norwegian population. Small firms (less than 50 employees or the equivalent) represent 97 percent of Norwegian enterprises. It shows that most applications filed by Norwegian firms at the EPO involve large firms, but that also a large group of applications originate in country's smallest firms.

The chapter demonstrates a couple of ways to index the patenting activity of different size-classes. This exercise suggests that large firms file on average 1 EPO filing for every 2 domestic applications, while small firms (10-49) file on average 1 EPO application per every 4 domestic applications. Breaking down the relative propensity to seek patent protection by industry, the chapter illustrates that patent intensity by number of firms and employment is highest in the Chemicals sectors, followed by the R&D sector. These are industries where the proportion of small firms (<50 employees) is lowest. However, it also shows that small firms account for over half the patenting in roughly half (14) of the industries. The proportion is nearly 90 percent in the case of Computers and Technical Consultancy where small firms dominate the demographics. Furthermore, certain industries show a preference for domestic and not European patenting, especially technical consultancy where small firms dominate.

The chapter also made a foray into what happens after application in order to identify patterns where firm-size seems to play a role. One indication is that the proportion of grants to Micro firms is substantially less (19 percent) than its share of total applications (24 percent). This suggests that the applications of these firms are less successful than that of the large firms where grant rates are substantially higher than application rates. In addition, evidence from domestic patenting, which is important in the period since Norway had yet to join the EPO, confirms that the incidence of Non-Grant is skewed, with the highest proportions found among the smallest applicants. These findings indicate that further work is possible and necessary in order to better understand the relationship between small and medium-size enterprises and intellectual property rights.

Annex Essay 4:

Annex 4-1 Totals and Shares of firms by size-class* and industry: 2005**

Activity breakdown by NACE	Other	Micro	Small	Medium	Large	total firms	total employm	Turnover M€*	Percent Small
TITLE	*number of enterprises by size-class* 2005 in total population*								
Agriculture, hunting and forestry	570	38232	473	95	7	39377	63 453	5 409	99,7
Mining and quarrying	8	482	117	35	29	671	39 621	8 661	90,5
Food products; beverages and tobacco	32	860	566	170	55	1683	51 106	16 683	86,6
Textiles, leather products	23	925	94	30	0	1072	5 532	711	97,2
Wood and wood products	31	1207	256	63	4	1561	15 607	2 419	95,7
Pulp, paper; publishing and printing	59	1944	403	106	24	2536	33 528	6 251	94,9
Petroleum, rubber and plastic products	4	226	99	22	2	353	5 317	921	93,2
Chemicals and chemical products	4	100	32	26	22	184	13 199	4 960	73,9
Other non-metallic mineral products	15	504	106	34	12	671	11 006	1 976	93,1
Basic metals	1	83	27	20	15	146	11 172	6 850	76,0
Fabricated metals	30	1454	429	74	3	1990	19 495	2 338	96,1
Machinery and equipment	35	1601	296	78	21	2031	23 959	5 040	95,1
Electrical and optical equipment	30	784	171	64	17	1066	18 846	3 984	92,4
Transport equipment	17	700	246	84	41	1088	36 486	6 800	88,5
Other manufacturing, recycling	31	1277	190	44	6	1548	12 077	1 771	96,8
Electricity, gas and water supply	11	180	139	94	29	453	14 305	7 408	72,8
Construction	478	26839	2863	274	33	30487	154 555	19 261	99,0
Wholesale trade and commission trade	508	9602	2426	594	140	13270	102 588	52 989	94,5
Transport and storage	246	15381	1297	277	94	17295	119 788	20 438	97,9
Post and telecommunications	16	878	76	47	21	1038	37 404	8 065	93,4
Financial Services	3	787	252	68	32	1142	45 257	304	91,2
Computer and related activities	153	4280	481	82	16	5012	36 014	4 455	98,0
Research and development	8	139	65	44	8	264	10 892	613	80,3
Technical consultancy services	181	5699	536	65	20	6501	35 531	4 327	98,7
Other business activities	519	19033	1328	247	59	21186	122 654	8 935	98,6
Education, health**	8	18062	2099	764	471	21404	648 241	154	94,2
Other Activities**	1617	56316	9017	1258	279	68487	556 135	63 942	97,8
Unknown	1	744	1	0	0	746	861	6	100,0
TOTAL	4639	208319	24085	4759	1460	243262	2 244 629	265 673	97,4

*****according to the EU SME definition involving employment and turnover (see below)**including hospitals, government bodies and other non-business entities *fractional counts**

Annex 4-2 Totals and Shares of firms by size-class* and industry: 2005**

	Other	Micro	Small	Mid	Big	total firms
AGRICULTURE, HUNTING, FORESTRY AND FISHING	572	38371	349	82	3	39 377
MINING AND QUARRYING	8	487	118	31	27	671
MANUFACTURING	317	11897	2839	728	148	15 929
ELECTRICITY, GAS AND WATER SUPPLY	13	213	160	59	8	453
CONSTRUCTION	486	26963	2766	244	28	30 487
WHOLESALE AND RETAIL TRADE; RESTAURANTS AND HOTELS	1420	41089	7530	730	132	50 901
TRANSPORT AND STORAGE AND COMMUNICATION	272	16572	1190	223	76	18 333
FINANCE, INSURANCE, REAL ESTATE AND BUSINESS SERVICES	1423	38885	2934	518	126	43 886
COMMUNITY SOCIAL AND PERSONAL SERVICES **	0	18385	2681	1076	585	22 727
OTHER**	182	18025	1333	169	24	19 733
Uknown	20	744	1	0	0	765
TOTAL	4713	211631	21901	3860	1 157	243 262

***Size-class by employment only.

Annex 4-3 Share and totals of patent applicants and applications/grants by technological area

	Person	Other	Micro	Small	Medium	Large	Number	Share of Tota	Small firms
Electrical devices, electrical engineering, electrica	12		14	6	8	8	48	1,4	54,7
Audiovisual technology	8	3	14	5	3	13	45	2,2	53,3
Telecommunications	15		11	5	20	16	67	1,6	38,3
Information technology	25	1	50	7	6	12	101	3,2	75,2
Semiconductors	1		12			3	16	0,2	81,3
Optics	3	2	9	7	1		22	0,4	63,6
Analysis, measurement, control technology	40	8	37	25	32	56	199	9,2	43,1
Medical technology	42	4	37	9	2	25	119	4,8	69,6
Nuclear engineering	2						2	0,1	100,0
Organic fine chemistry	3	2	8	6	4	37	59	3,4	20,9
Pharmaceutics, cosmetics	9	11	22	16	6	59	123	5,9	34,0
Biotechnology	17	1	21	9	4	9	61	2,0	63,8
Agriculture, food chemistry	7	3	14	7	8	11	49	1,9	48,5
Materials, metallurgy	5	1	4	4	1	42	57	3,7	16,7
Surface technology, coating	3	5	10			15	33	1,4	54,5
Macromolecular chemistry, polymers	2	1	2	2	5	13	25	1,3	18,4
Petrochemical and basic chemical materials	2	1	9		6	18	36	2,5	34,4
Chemical engineering	17	1	26	8	5	46	102	5,8	43,0
Materials processing, textiles,	4		7	1	5	5	22	1,0	48,8
Handling, printing	18	2	16	9	8	20	73	4,1	49,3
Agricultural and food processing machinery and a|	15	2	15	5	29	12	77	3,8	41,3
Environmental technology	8	3	15	4	4	15	49	2,9	52,6
Machine tools	4	2	10		5	14	35	1,6	45,7
Engines, pumps, turbines	15	1	18	2	1	10	46	1,7	74,1
Thermal processes and apparatus	6	1	9	4	6	18	44	3,3	36,8
Mechanical elements	25	3	11	6	8	30	81	4,9	46,5
Transport	40	1	18	4	19	29	112	7,6	52,6
Space technology, weapons	2	1	2			13	18	1,1	27,8
Consumer goods and equipment	45	5	25	6	29	17	126	6,0	59,5
Civil engineering, building, mining	55	3	52	12	13	64	197	11,0	55,3
NA									
Individual Norwegian Applicants	107	73	525	172	246	682			
Share of Norwegian Applicants	5,9	4,0	29,1	9,5	13,6	37,8			

e and totals of patent applicants and applications by technological area 2000-2005

	Size class breakdown						*EP_A 2000-2005*		
	Person	Other	Micro	Small	Medium	Large	Number	Share	Small firms
Electricity - electronics	61	4	100	23	37	52	276	8,6	59,6
Instruments	87	14	83	41	35	82	342	14,5	53,9
Chemistry, pharmaceutics	48	24	89	43	34	204	442	22,2	36,5
Process engineering	62	8	78	26	51	98	322	17,6	45,8
Mechanical engineering, machinery	91	9	68	16	39	113	336	20,1	50,0
Consumer goods and equipment	45	5	25	6	29	17	126	6,0	59,5
Civil engineering, building, mining	55	3	52	12	13	64	197	11,0	55,3
Individual Applicants	107	73	525	172	246	682			
Share of Applicants	6	4	29	10	14	38			

e and totals of patent grants by technological area

	Size class breakdown						*EP_B 2000-2005*		
	Person	Other	Micro	Small	Medium	Large	Number	Share	Small firms
Electricity - electronics	7	0	22	8	8	9	54	12,9	53,7
Instruments	27	5	11	13	11	16	83	17,6	52,7
Chemistry, pharmaceutics	10	15	13	13	8	81	139	18,7	27,1
Process engineering	23	2	26	14	10	41	115	17,1	44,1
Mechanical engineering, machinery	31	2	17	5	23	49	127	17,3	39,3
Consumer goods and equipment	21		8	1	6	2	37	5,5	76,7
Civil engineering, building, mining	14		24	3	2	20	62	10,9	60,0
Individual Applicants	28	25	125	57	69	231			
Share of Applicants	12	11	53	24	29	98			

Annex 4-4 Share of patent applications by industry and technological area

TITLE	Electricity - ele	Instruments	Chemistry, ph	Process engir	Mechanical er	Consumer go	Civil engineer	Number	Share
Agriculture, huntin	2	3	9	12	4	4	3	36	1,7
Mining and quarryi	2	7	20	24	13	1	19	83	4,1
Food products; beverages and tc		2	22	1		2		27	1,3
Textiles, leather products		1		2	2	1	1	7	0,3
Wood and wood products		1	2		1			4	0,2
Pulp, paper; publis	1	1		3		1		6	0,3
Petroleum, rubber	2	1	6	9	6			24	1,2
Chemicals and ch	3	37	194	50	46	2	28	359	17,6
Other non-metallic mineral products			2	1	3		5	11	0,5
Basic metals			1				1	2	0,1
Fabricated metals	1	1	1	2	1	1	1	8	0,4
Machinery and equ	4	11	4	44	31	3	11	107	5,3
Electrical and optic	45	70	7	6	17	3	7	155	7,6
Transport equipment				4	17	1	12	34	1,7
Other manufacturing, recycling		3	3	1	8	32		46	2,3
Electricity, gas and water supply				1	3		2	6	0,3
Construction	2	2	2	3	2	1	10	21	1,0
Wholesale trade a	6	1	13	17	7	6	6	55	2,7
Transport and storage			0	7	14	1	3	25	1,2
Post and telecomr	25			1				26	1,3
Financial Services		1	2	1			2	6	0,3
Computer and rela	63	14		1	2	1	1	82	4,0
Research and dev	8	55	28	9	12		1	113	5,5
Technical consulta	13	23	48	35	38	7	23	186	9,1
Other business ac	26	15	27	34	16	12	6	134	6,6
Education, health	13	9	4	2	7	9	5	47	2,3
Other industries	3	3	3	2	1		1	12	0,6
Uknown	19	21	30	13	34	3	12	130	6,4
Individual Applicants									
Private Individuals	42	66	21	44	54	37	38	302	14,8

Annex 4-5 Share of patent applications and applicants to the national office by country

		Applications Share		Applicants 2000-2005	
		2000-2002	2003-2005	Tot	Shares
Domestic	Norway	20,3	20,4	3553	33,7
Nordic Countries		10,1	8,6	1033	9,8
	Sweden	5,7	4,6	535	5,1
	Denmark	1,9	1,8	261	2,5
	Finland	2,5	2,0	208	2,0
	Iceland	0,1	0,1	29	0,3
European Countries		34,1	32,8		
	Germany	10,7	9,2	813	7,7
	Great Britian	5,2	4,8	645	6,1
	France	5,3	4,4	405	3,8
	Switzerland	4,0	4,6	241	2,3
	The Netherlar	3,8	4,5	202	1,9
	Other	4,9	5,3		
Other Countries		35,3	38,1		
	USA	26,5	29,1	1877	17,8
	Japan	4,4	4,1	295	2,8
	Other	4,4	5,0		
Applications Total		19500	17365	10550	100,0
Indivdiual applicants		1962	1591	3553	33,7

Annex 4-6 Share of patent applications and applicants through the EPO office by country of origin: co-applications

		Applications Share		Applicants 2000-2005	
		2000-2002	2003-2005	Total	Shares
Domestic	Norway	77,3	74,3	2041	75,8
Nordic Countries		9,8	9,0	254	9,4
	Sweden	5,8	5,5	151	5,6
	Denmark	1,1	1,0	28	1,0
	Finland	3,0	2,6	75	2,8
	Iceland	0,0	0,0	0	0,0
European Countries		7,8	10,0	241	9,0
	Germany	1,4	2,6	54	2,0
	Great Britian	2,7	2,1	65	2,4
	France	1,6	1,5	42	1,6
	Switzerland	1,4	2,1	48	1,8
	The Netherlands	0,4	0,9	18	0,7
	Other	0,3	0,7	14	1
Other Countries		5,1	6,6	158	5,9
	USA	3,7	5,1	119	4,4
	Japan	0,1	0,2	4	0,1
	Other	1,3	1,3	35	1
Applications Total		1283	1411	2695	100,0

Chapter 5: A baseline for the impact of academic patenting legislation in Norway

This chapter follows up the theme of growth accounting methods from essay 4 in light of another substantial change in the Norwegian patent system. The focus of "A baseline for the impact of academic patenting legislation in Norway" (co-authored in Scientometrics: see below) is legislative changes that went into effect in Norway in 2003 to encourage greater commercialization through patenting research results. This policy ambition faces the problem that no record of the patenting activity of academic researchers is available before 2003 when the "professor's privilege" was phased out here as it had been in several other countries.

Theme	Questions
Essay 1: Knowledge formation and patenting	What role does the patent system play in knowledge accumulation?
Essay 2: The diversification and specialization of IPR use in a small open economy	How does use of the IPR system reflect the innovative processes of different agents? What role is played by small firms in specialization and diversification of innovative activity?
Essay 3: The growing use of patents among small firms: areas of growth and challenges	If SME patenting is increasing (see last essay), what technological areas and market dimensions? Do they face greater challenges than larger firms?
Essay 4: Small firm patenting and the transition to European Patent Office	How do Norwegian SMEs use the European Patent System? How the effects of this transition be measured?
Essay 5: Academic patenting and the transition to an institution-based patenting regime	**To what degree do academic researchers already patent and will the introduction in Norway of Bayh-Dole-like legislation improve conditions for academic patenting?**
Essay 6: The impact of patenting on research collaboration	Does patenting increase the probability for research collaboration? What role do other factors play?

The essay reviews the relationship between patenting and academic research which involves important issues from a theoretical and a practical point of view. In light of other efforts, the essay develops and demonstrates a three step methodology to baseline changes in the extent and focus of academic patents. Details of this method are spelled out and choices discussed. The assumption that university researchers did not patent and that legislation was therefore needed is not supported.

Publication Information: Iversen EJ, Klitkou A & Gulbrandsen M (2007) A baseline for the impact of academic patenting legislation in Norway. In Leydesdorff L & M Meyer (eds) Scientometrics Special Edition on Triple Helix indicators. Vol 70, 2.

5. A baseline for the impact of academic patenting legislation in Norway

Eric J. Iversen[**/***], Magnus Gulbrandsen, and Antje Klitkou[84]

Abstract

As the commercialization of academic research has risen as a target area in many countries, the need for better empirical data collection to evaluate policy changes on this front has increasingly been recognized. This need is exemplified in the Norwegian case where legislative changes went into effect in 2003 expressly to encourage greater commercialization through patenting research results. This policy ambition faces the problem that no record of the patenting activity of academic researchers is available before 2003 when the country's "professor's privilege" was phased out. This article addresses the fundamental difficulty of how to empirically test the effect of such policy aims. It develops a methodology which can be used to reliably baseline changes in the extent and focus of academic patents. The purpose is to describe the empirical approach and results, while also providing insight into the changes in Norwegian policy on this front and their context.

1. Introduction

The commercialization of academic research is an important area of innovation policy in Norway as it is in a rash of other countries (see GEUNA & NESTA, 2003). Recent Norwegian legislation has removed the "teacher exemption clause" or "professor's privilege" and given higher education institutions a formal responsibility for commercializing patentable research results. This new legislation, which makes the question of the new role of academic research largely a question of patenting, is expected to substantially change the basis for commercializing academic research. An expressed objective is to increase the rate and degree of exploitation of the science base in Norway, thereby improving the basis for economic growth.

The controversial legislative change was accompanied by a set of expectations among policy-makers in Norway, as well as by an explicit obligation to monitor the effects of the change. Despite this, a viable way to assess the effect of the new measures was not envisioned when the new regulations went into effect in January 2003. A prerequisite is clearly to establish the extent to which academic patenting had taken place before the change, and in which fields, under what expectations etc. Establishing such a baseline is however problematic. No record of the patenting activity that preceded the change is readily available exactly because the "professor's privilege" regime placed

84 ***All authors are at NIFU STEP Studies in Innovation, Research and Education, Oslo, Norway. The corresponding author is also affiliated with the Australian Innovation Research Center (AIRC), Faculty of Business, The University of Tasmania.
The authors wish to acknowledge the helpful suggestions of the journal editors and two anonymous referees.

patent-rights in the researcher's name: patents involving academic inventors are therefore difficult to distinguish from other domestic patents.

This paper addresses the need for an accurate ex ante account of public researcher involvement in patenting which can subsequently be compared with the ex post situation. It develops a registry-based procedure to identify academic inventions and to take stock of the patenting of researchers in public-sector research organizations (hereafter PSR). The intention is that such a baseline will allow comparisons over time, and potentially, across countries, and that it could become instrumental to informing the future development of this important innovation policy area. The paper will predominantly showcase the methodological approach and the results from the identification of academic patents. First the paper touches on some issues and perspectives and briefly surveys some relevant institutional and regulatory aspects. In the main section the paper presents some features of the approach before turning to the results, including e.g. interpretation of the various types of "patent match", number of patents, technological fields and disciplinary differences.

2. Issues and perspective

It is well documented that the climate and the practice of academic patenting have changed dramatically during the past couple of decades. At the same time we recognize that the division between academic research, associated with "open science" and the ideal of "communalism", and the patent system, characterized by a technological focus and a commercial focus, has perhaps never been very clean cut. Some basic dimensions of academic patenting are worthwhile reviewing before we proceed to identify its recent history in Norway.

2.1. Schematic dimensions

Universities and colleges are seen as key actors or organisations in national innovation systems, not least because these organisations constitute vital infrastructure for the private research laboratories where many of the innovative activities are carried out (FREEMAN, 1987, LUNDVALL, 1992; NELSON, 1993). The frequently indirect nature of the relationship between universities and industry is emphasised – universities train industry personnel, create a pool of fundamental knowledge and, varying with discipline, engages in more direct contract work for private companies (ROSENBERG & NELSON, 1994). Increased direct interactions between universities and industry is often taken as an indication of a new form of knowledge production or a changed social contract for science (GIBBONS ET AL., 1994; GUSTON & KENNISTON, 1994; ETZKOWITZ & LEYDESDORFF,2000; MARTIN & ETZKOWITZ, 2000; MARTIN, 2003). Policy-makers have pushed for such a development, including an increased focus on the direct commercialisation of academic research results (Godin & Gingras 2000; Van Looy et al. 2004). Through changed funding regimes and changed legislation regarding ownership of research results in many countries, policy-makers aim for a close "triple helix" relationship between universities, governments and industry (ETZKOWITZ & LEYDESDORFF, 2000).

Some are worried about these developments, based on a possible decrease in long-term research or changed research agendas, tensions between the culture of open science and increased commodification and commercialisation, and increased pressures on the researchers and the traditional teaching and basic research tasks they carry out (cf. SLAUGHTER & RHOADES, 1996; VAVAKOVA, 1998; GEUNA, 2001; NELSON, 2001; GEUNA & NESTA, 2003). This has been termed "drift of epistemic criteria" (ELZINGA, 1983) or "skewing" and "secrecy" problems (FLORIDA & COHEN, 1999). On the other hand, it has been argued that universities may strengthen their traditional norms and their research and teaching activities as a "second academic revolution" leads them into becoming "entrepreneurial institutions" with closer and more productive relationships with industry and the public sector (cf. CLARK 1998; ETZKOWITZ, 1998; ETZKOWITZ & LEYDESDORFF, 2000). Instead of being a question of either/or, successful universities and university researchers manage to combine academic excellence with industrial contacts and/or entrepreneurial contributions (GODIN & GINGRAS, 2000; VAN LOOY ET AL., 2004).

What is lacking to test many of these claims, models and theories is a firm empirical base. There are admittedly good sources for funding and publications in public sector research organisations, but fewer and often much poorer options when studying patenting. Earlier investigations focusing e.g. on the relationship between funding, commercial and academic outputs, have had to rely on crude self-reported measures of patents and other commercial results (VAN LOOY ET AL., 2004; GULBRANDSEN & SMEBY, 2005). Our methodology and resulting database for identifying academic patents and patent inventors may be one important piece to fit into this larger conceptual and tension-filled puzzle.

2.2. Growth accounting for academic patenting

The commercial logic of applying for a patent—as well as a certain cultural factor— has traditionally made patenting the domain of industry. Patenting is typically biased towards the applied nature of new technical knowledge. On its side, it can be said that "basic research" is typically biased against the idea manifest in the patent regime, that knowledge can be owned by someone and that others can be excluded from using it. Thus a more fundamental obstacle dividing university-research from patenting has been cultural. Such attitudes may have contributed to a situation in which patent-protection has not been carefully considered in all but special cases.

But even in cases where the basic science of university research does meet patentability requirements, an economic incentive is needed to outweigh the costs associated with patent protection. Since, “the outputs of basic research rarely possess intrinsic economic value,” (DAVID, MOWERY, & STEINMUELLER, 1994) and since the traditional research university is not geared to developing and marketing any technological innovation that might arise, patenting has most often not been considered generally relevant for the fundamental research of universities and other non-profit R&D institutes.

On top of these two fundamental factors, a practical set of reasons has kept academic research from seriously considering patent-protection as an option. A lack of clear guidelines for university patenting combined with a lack of practical support in effectively managing “intellectual property” (applying for and capitalizing on patented inventions) has made the prospects of recouping the investment in the patenting process remote indeed for university research. Although a piece research may be patentable (or otherwise commercializable), the higher education institution has had few incentives for pursuing this in centralized European university systems like the Norwegian one where funds are largely distributed based on student numbers and where the researchers own the intellectual property rights.

This schematic division between patenting and academic research has of course never really been accurate. Instead academic research has long been associated with increasing innovation in the economy. Internationally, patenting of academic knowledge and concerted measures designed to promote commercialization of academic research both trace back to the early part of last century (MOWERY & SAMPAT, 2005; MOWERY & ZIEDONIS, 2002).

In Norway, there is also a legacy that substantially predates the new legislation. In a survey among academic personnel in Norway in 2001, seven percent of all university researchers in Norway stated that their research at one time or another had led to patents (GULBRANDSEN & SMEBY, 2005). Also a recent interview study among Norwegian entrepreneurial professors indicates that patenting is relatively common in academia, although somewhat “hidden” as the institutions have played a miniscule role in the process and have had no routines for registering commercial outputs (GULBRANDSEN, 2003). Patenting and commercialization has largely been the arena of individuals, of academic entrepreneurs (MEYER, 2003a, 2003b; MEYER, SINILÄINEN, & UTECHT, 2003). Famous Norwegian researchers like physics professor Birkeland and chemistry professor Ugelstad combined basic research with patenting. Birkeland gained world recognition for his explanation of *aurora borealis* at the end of the 19th century, and had his name on no less than 58 patent applications during his career at the University of Oslo, which has named its TTO after him. Danish data furthermore indicate that university researchers may relatively often be listed as inventors in patents granted to industry (VALENTIN & JENSEN, 2003).

Nonetheless the intensity of academic patenting has by all accounts changed in the course of the past decade or two. Qualitatively, the base-line of what is being patented is widening. Corporate and university patenting is each stretching what is patentable both in the direction of applied and basic science. There is growing overlap of university and corporate patenting, increasingly through collaborations between them (TRAJTENBERG, HENDERSON, & JAFFE, 1997). Simultaneously, increased patenting can be observed in the realm of basic science (incidentally, where both universities and corporations are active, often in tandem) but also in the other direction through an apparent weakening of the non-obviousness criterion (JAFFE & LERNER, 2004).

Quantitatively, a gathering set of studies have shown the increase of academic patenting especially in the US (see in particular MOWERY ET AL., 2004). Henderson *et al.* (HENDERSON, JAFFE, & TRAJTENBERG, 1998) showed that academic patents increased 15-fold between 1965 and 1988.[85] This increase in intensity is recognized to involve a set of interlinking changes, including changes in the roles of universities (GIBBONS ET AL., 1994);(WEBSTER, 2003); (ETZKOWITZ, 1998; ETZKOWITZ, WEBSTER, GEBHARDT, & TERRA, 2000), changes in technology (MOWERY, 2004), and, relatedly, changes in the patent-system (JAFFE & LERNER, 2004). Legal, regulatory and, not least, institutional elements all contribute to a climate for increased interaction between academic knowledge bases and those in the economy otherwise. Mowery and colleagues (2004) argue that academic patenting is not a new phenomenon, but that it goes back much further than the Bayh-Dole Act of 1980. Whole industries, with semiconductors, computers and biotechnology as famous examples, have their roots in investments in public sector research, and this is also the case with earlier industries like petroleum engineering and petrochemicals. In general, the enormous federal investments (and increases in these investments) constitute a central explanation for the academic patenting in the U.S.

2.3. Regulatory and institutional context

Academic research makes up a large component of national research efforts in countries like Norway. Policy interest in quickening the return to society from it is by no means new however. Policymakers began to see it as "an underutilized resource" in the 1980s (MARTIN, 2003), for which there was a rising tendency to 'adopt appropriate policies' (STANKIEWICZ, 1986). Since then, more and more countries have been occupied by concerns to (continue to) improve the climate for commercializing university research, and by concerns to improve links between public research institutions and industry. Particularly during the 1980s, the funding climate of higher education

85 The explosion of university patents however has accompanied a peaking of this quality-measure during the mid-80s, suggesting, "that the rate of increase of important patents from universities is much less than the overall rate of increase of university patenting in the period" (HENDERSON ET AL., 1998).

changed, and important new disciplines grew rapidly like biotechnology and ICT. Some countries also changed their laws with the Bayh-Dole act of the U.S. setting an example for many other countries.

Inspired by Bayh-Dole and after many years of discussion, new legislation went into effect in Norway in 2003 that substantially changed the basis for commercializing academic research. The measure effectively removes the "teacher's exemption"/"professor's privilege" from the legal corpus and places the responsibility for commercialization of academic research on the universities. Legislative changes (most of them quite similar) can be seen in a number of countries, e.g. Denmark, Germany, the Netherlands, Italy, Finland and France.

The linchpin of the formative Norwegian policy takes the form of two amendments. The general objective to increase the rate and degree of exploitation of the science base, in order to improve the basis for economic growth:

Proposition No. 40 to the Odelsting (2001–2002): Amendment to expand the societal responsibilities of universities and colleges to include promoting the practical application of research methods and results, not least in industry. Although the responsibility adheres formally to *patentable research results* only, the Ministry of Research and Education has specified that the higher education institutions also should deal with commercializable results that cannot be patented.

Proposition No. 67 to the Odelsting (2001–2002): Amendment to increase the commercial exploitation of inventions by revoking the "professor's privilege". A division of income with one-third each to the individual(s), the department and the institution was suggested. The researcher still has a formal right to publish scientifically, even if this would make patenting or commercialization impossible.

Adaptation of the institutional framework (TTOs, new seed-funding, adjustments of funding mechanisms, etc). All the Norwegian universities now have set up TTOs, largely based on extraordinary government funding. New seed funding is expected to be set up in late 2005 in the university cities.

With the new legal amendments, the policy-makers hope to increase commercial utilization of academy-based inventions. An important point is that it intends to do so while maintaining the academy's traditional goals, namely free-research and higher education. In fact, the expressed intention is to strengthen the traditional goal of universities in spreading research results to society. To do so, the amendment substantially readdresses the role of academic research. It widens the interpretation of the university sector's obligation to disseminate research results to include commercialization as a channel for such dissemination. In order to do this the amendment changes the right to industrial application/commercialization of 'inventions' formally from the researcher to the university sector institution. The legislation about intellectual property rights is therefore now the same in all public research organizations, as there has not been a "professor's privilege" in the university hospitals or the research institutes. This was a central motivation behind the legislative changes, as different IPR legislation complicated commercialization processes in which researchers from different public organizations were involved.

The change imposes new obligations on the researcher and the university. In the new environment, researchers are obligated to orient the university about results with potential industrial application ('notification obligation'). The university has to respond within 4 months to this notification, and if the response is negative (the university does not claim the rights), the researcher may patent or otherwise commercialize without the institution's involvement. If the university accepts the property rights, it now has a formal obligation to try to commercialize the idea in question. Financial incentives may be on their way as well, as university funding processes are increasingly based on output indicators, which may include patents sometime in the future.

The recent international spread of initiatives that focus on increasing the rate and degree of exploitation of the science base brings with it a recognized need for better empirical tools to evaluate. The need for a robust and reliable empirical basis on which to assess commercialization practices over time and across countries was indeed the basis for recent OECD work on the licensing and patenting of public research organizations; the need for continued effort in this direction was also one of the work's major recommendations (OECD, 2003). The international policy environment continues to be characterized by a state of flux in spite of the experience already amassed and in spite of attempts to coordinate the direction of policies. In this setting, there is no doubt that there is pronounced, "need for timely and accurate information on the nature and extent of research collaboration between universities and industry, and on how it varies across discipline, type of university, sector, firm-ownership and time" (CALVERT & PATEL, 2003).

3. Approach and methodology

The methodological aim presented in this paper addresses this need for empirical information. The paper is designed to identify and analyze the involvement of academic researchers in patenting with an eye to creating a baseline which will allow comparisons over time, and potentially, across countries. This empirical analysis will be instrumental to informing the future development of this important innovation policy area. The approach identifies the involvement of academic researchers in domestic patenting by linking researcher-registry data with concurrent domestic patent data. This creates the basis for a targeted survey which will be used to evaluate the database match. The principle objective is to develop empirical tools to better analyze the changing role of public R&D in economic growth in a country where one will rarely, if ever, find the name of a higher education institution in a patent application.

The rash of legislative changes internationally has coincided with increased interest in the nature and extent of academic patenting. During the past few years, several studies have focused on different aspect of academic patenting including, BALDINI, GRIMALDI, & SOBRERO, 2005; BALCONI, BRESCHI & LISSONI (2004); BASSECOULARD & ZITT, 2004; DU PLESSIS, LOOY, DEBACKERE, & MAGERMAN, 2005; MEYER, 2003A, 2003B; SAMPAT & NELSON, 2002; SAPSALIS, LOOY, POTTELSBERGHE, CALLAERT, & DEBACKERE, 2005; AND SCHMOCH, 2004. The combined approach we present here contributes to the identification of academic patenting and its analysis in this area.

3.1. General challenges and approaches

A set of challenges must be overcome in order to identify patents stemming from the research of public-sector institutions, especially universities. In a 'professor's privilege' environment, the patent record will generally not provide the indication of the inventor's institutional affiliation: the academic patent will tend to reside in the name of the researcher and/or a sponsor. In this situation patented results of academic research will initially remain invisible in the patent data.

Different strategies have been developed in such an environment (such as Finland, Italy, Germany, and Belgium) to identify cases where the population of PSR researchers overlaps the population of inventors. These have faced a common trade-off between the limitations of existing data and the considerable effort to identify academic inventors from that data.

Absent special circumstances[86], running the names of 'academic' researchers against inventors in the patent record forms the only route towards identification. This approach provides the benefit of full information about the patenting activity (frequency, technological orientation, collaborators etc). DU PLESSIS ET AL. (2005) for example link EPO patent applications and granted patents (1978-2001), granted US patents (1991-2001) and personnel data of the Flemish universities for 1990-2000. However this approach of course assumes the availability and reliability of name lists (preferably linked to institutional affiliation and other information) over a substantial period of time. This temporal dimension is important since the patenting event and the researching event are sequential, with the former activity tending to extend considerably backwards in time. In pursuing networks of inventors, BALCONI ET AL. (2004) for example used a list of professors at Italian universities for a

---

[86] Such as the existence of periodic reporting (e.g. through national surveys) efforts which includes relevant questions.

given year (2003) and matched it against 1978 to 1999, then confirmed by a direct contact. The approach as a result underestimated the total population.

Moreover, the name-link approach risks generating large numbers of false-positives and of false-negatives for example due to the same-name problem (e.g. John Smith) or due to propensity for orthographic problems. These problems are compounded in countries like Norway which have standard name-forms (such as Hansen, Iversen, Gulbrandsen…) and atypical character sets (æ, å, ø) which may be error-prone in database programs.

The main alternative strategy is to systematically survey academic researchers on their patenting activities or to survey patent inventors on their affiliation. The Patval project (http://www.zew.de/en/forschung/projekte.php3?action=detail&nr=469) for example surveyed the inventors on samples of EPO patents in a number of European countries. This survey was not designed to identify academic inventors but does address the question of academic affiliations in its sample. An alternative approach has targeted public research affiliation among assignee addresses to identify academic patenting. It does so at the expense of excluding the considerable number of university invention filed for either by collaborating companies or private persons (SAPSALIS ET AL., 2005; SAPSALIS & POTTERIE, 2003; SARAGOSSI & POTTERIE, 2003).

In general, survey-based approaches, where successful, have the strength that they provide contextual information that is valuable to understanding the purpose, orientation and context of the researchers' patenting activity. On the other hand it relies on the researcher's own account of the patent particulars (such as the patent numbers, IPC classes, etc) which opens up some initial difficulties. Furthermore, it again assumes current addresses of researcher that preferably includes additional information to avoid overburdening the respondent. Securing reliable responses for a representative set of researchers poses many challenges especially in larger countries with large and diverse researcher populations. Moreover, there are a set of daunting trade-offs. These include the trade-off between selection criteria and rrepresentativeness and between the amount of information in the questionnaire and the critical question of response-rates.

3.2. Registry-data and a three-stage matching procedure

In this way, the identification of academic patents has tended to take two basic routes: either to identify inventors among available lists of PSR researchers or to identify PSR researchers from among available lists of inventors. Likewise, two basic strategies have been employed: one utilizing a survey-based strategy and the other relying on data-based matching procedures. These approaches tend to focus on general estimates of academic patenting designed as input to other theoretical discussions.

Our objective is rather to create a baseline to calibrate the extent and orientation of academic inventions at the transition of a new legislative regime. Here it is important to establish specific relationships between research-environments and patenting activity. It is therefore important not to introduce assumptions that will systematically overestimate or underestimate academic patenting. Special pains have therefore been taken to verify the identification while assembling information that may be important to analyze future changes in academic patenting.

The general approach is based on project which addresses the patenting of academic and other public sector researchers in two main rounds. In the first, the overall project links registry data covering all researchers in Norway with concurrent domestic patent data. This step affords the opportunity to identify and analyze the involvement of academic researchers in patenting. Furthermore it lays the basis for a targeted survey to explore qualitative aspects of commercialization, including attitudes, motivations to patent, the role of support services, etc. Stage two of the project surveys researchers identified in stage one. The second round serves both to provide qualitative interpretative information about academic patenting (reported in Gulbrandsen et al 2005) as well as to help verify (and revise) the accurateness of the identification exercise. The identification and the complementary survey can then provide a baseline against which to monitor and analyze Norwegian developments in academic patenting.

In the following we present the three-stage approach we developed in that project designed to identify PR inventors and their patents. A previous two stage approach corresponding first to the identification-procedure and then to the survey ran into the difficulty of dealing with non-responses in the survey verification stage. (IVERSEN ET AL., 2005) This paper introduces a further step to verify links.

4. The Data

Our procedure relies on the unique combination of two registry data which together provides full count data over inventors and of researchers. The patent-data is taken from all patents applied for at the Norwegian Patent Office (NPO) and includes front-page information. The Researcher Register includes all researchers working in universities, colleges or in the country’s extensive research institute-sector and is updated on a yearly basis for use in official Norwegian statistics.

The Patent Data includes full first-page information including the inventor and assignee names, addresses, patent-classes, and more. The patent register is based on 7,780 domestic patents[87],

[87] These are applications with a Norwegian address in the inventors and/or the applicant fields. These applications make up twenty percent of the total volume of patent-application (38,225) received by the Norwegian Patent Office during the six-year period (1998-2003).

involving a total of 6,590 different inventors[88]. All in all, these 6,600 individuals were involved 11,884[89] times in the 7,800 domestic applications. The patent data, encompassing 7,781 patents in total, was linked to the unique registry of researchers using the names and addresses of the researcher with the names and addresses (zip-codes) of patent inventors/assignees[90]. The correspondence between the researcher's area and the technological area of the patent was also used[91] at this stage to identify possible false-positives.

The Researcher Register covers on an annual basis all researchers in universities, colleges, and institutions receiving public funding. The information includes details of institutional affiliation and position, in addition to the names and addresses. This data allows us to avoid the problem faced by for example BALCONI ET AL (2004) whose approach underestimated the number of academic inventors.

The researcher registry reflects a yearly average of 25,728 researchers in positions at the various UIH institutions. The composite picture based on 1997, 1999, 2001, and 2003 runs to 51,000 separate observations, since it captures turnover both in terms of researchers and the positions and institutions they are employed at. Twenty-one percent (10,615) of these observations were in the institute sector and the rest (39,881) were in the University and College sector. In cases where researchers change positions/affiliations in the time-frame, the latest one is used.

Stage 1 starts the identification of researchers from these public research organizations in domestic patenting by linking researcher-registry data with concurrent domestic patent data. The patent data centers on domestic patents that involve Norwegian inventors[92] that were applied for at the Norwegian Patent Office in the period 1998-2003. The first five years of the period thus involve patenting under the 'teacher's privilege regime', while the last will reflect the first affects of the new legislation. The choice of time-frame is one of many tradeoffs between taking stock of patenting activity over a longer period of time on the one hand, and lowering the response rate of the researchers surveyed in the next stage on the other. A five-year baseline is assumed to provide sufficient time-span in which to establish the extent and the orientation of academic patenting preceding the change in law in a way that can be compared to the patenting activity after the law

88 A unique key is given to individuals by the Patent Office. It is fairly accurate but contains some duplicates. Unifying this key among the sample reduces the total from 6,684.

89 Five additional occurrences of inventors are without any information and therefore dropped.

90 The postcodes were associated to county and district-levels via the Norwegian Post's database.

91 The primary IPC classes of the patent applications were associated to Technological Areas by a widely-used Correspondence Key: the INPI/OST/ISI Key, Version 3, also used by BALCONI ET AL (2004).

92 That is, inventors with a Norwegian address regardless of the nationality of the applicant.

takes affect. We found no reason to assume that a longer period would provide a more accurate picture of the situation before the change.

The match was conducted on the basis of names (last names and first names), addresses, and technological areas of both the patents (see footnote) and the research area of the specific research entity of the researcher. The process was an iterative one which essentially involved striking a balance between false negatives and false positives in view of both sets of information. A sequence of operations was undertaken whereby direct links were followed by same names/different addresses where the patent subject and the particular research group of the researcher were consistent. With reasonably clear cases established, further iterations looked into similar names initially excluded due to slight differences in the presentation of names (the variable use of middle names, orthographic mistakes, etc). Uncertain cases with regard to names and addresses were also manually checked (different sources including the online phonebook).

Stage 2 starts from the list of 809[93] researchers that resulted from the previous stage. In addition to more straightforward links, this list includes a small set of grey cases in order to avoid false-negatives: these included name-duplicates and other cases where allowances were made as to spellings and addresses. This created the basis in a second stage for a targeted survey. The survey was first and foremost designed to establish baselines for motivations, tendencies, concerns, and other more subjective data which may be affected by the change in regime and which will be valuable to compare in future iterations. This dimension of the baseline is presented elsewhere (GULBRANDSEN ET AL, 2005).

The survey also had a valuable secondary purpose which we focus on here, namely to confirm the identification of academic inventors in the database match. Removing further duplicates, the survey encompassed 801 researchers. Of these, 316 (40 %) provided complete responses, while a further four percent indicated that they were involved in a patent but disputed its relevance on other grounds[94]. Nine percent of the population (73) explicitly denied involvement (66) or returned the survey without comment. Taking into account other surveys that were returned without reaching the intended researcher (e.g. moved), this left 266 or 33% of overall non-response.

Stage 3: An affiliation networks approach was introduced to address non-responses. The second round of verification by survey provided the basis to deflate the false-positives towards a more accurate population but left a large proportion of unresolved cases. A third stage was therefore developed to resolve the 266 cases left open by the last stage. In this iteration, we opted not to

---

93 After several initial duplicates removed.

94 For example, that it was the result of another affiliation..

estimate based on the positive and negative responses at this stage so as to maintain as far as possible a one to one relationship between individual researchers and specific patent-information. Therefore we plugged in the output of the survey against the patent-data and looked for two types of relationships between the unresolved category and signs of PSR affiliations either at the level of (i.) the patent-assignee or (ii) co-inventors.

This approach follows the logic of the "affiliation networks approach" which BALCONI ET AL (2004) used to study 'networks of inventors'. This approach demonstrates that 'connectedness' of actors (inventors) are demonstrated via co-invention in groups of patents. Co-invention points to underlying cognitive relationships which indicate direct links between the actors. We therefore look for combinations between researchers who responded to the survey in patents with other researchers who did not. The direct link between co-inventors, combined with the original linking procedure, indicate quite clearly that the identification of the non-respondent was non-random.

These cases confirm the participation of the researcher in patenting and are thus classed as 'Collaborating Inventor Confirmation' (below). There remains the question of whether this patenting activity is linked to the researcher's activities at the public research organization. Here we assume affiliation on line with those who responded in the survey that they were involved in a patent but disputed its relevance on other grounds. This approach allows us to confirm a total of 87 researchers not confirmed in stage 2.

A further 118 researchers left unconfirmed in the last stage are confirmed by looking at the link to the assignee. These involve cases where the assignee is either a public research organization itself or closely linked to a PRO, such as through a TTO or a science park. An additional number of spin-offs which either list a PSR address and/or feature high proportions of co-inventors are also tallied here: 13 such researchers are included here.

This three-stage approach thus confirms that a total of 569 researchers from Norwegian public research organizations were involved in at least one patent application in the period of 1998-2003. These researchers are involved in 10-11 percent of domestic patent applications, which we will examine in the next section. There remain a further 154 unresolved cases after these stages. In future, a more aggregated study could in a further stage estimate the likely proportion of confirmed researcher-inventors among this population.

5. Results

The three stage identification procedure distinguishes between seven categories, four of which provide a qualified verification of the link. Overall we distinguish between inventors and their patents that show an affiliation with public research organizations (Confirmed), those that rejected the link in the survey (Rejected), those that cannot be confirmed (Unresolved), and those with no apparent link (Others).

Table 1 shows the breakdown[95] of these categories by inventor, by patents (both fractional counts of inventors and the total number of individual patents involved), and by the total number of times the inventors appear on patents (frequency). It indicates that 71% (or 569) of the original 800 survey recipients have been confirmed in this iteration. These confirmed public research organization researcher-inventors make up 8.6% of all inventors in the period. Nearly 10% (828) of all Norwegian patents in the period involved at least one public research organization researcher. PSR patenting accounts for 12% (1,437) of the inventive activity in the Norwegian patent record.

95 The approach was significantly modified since a previous version: Iversen et al., 2005. In addition to the introduction of new categories discussed below, this presentation differs from the previous version of the paper in the number of Survey Confirmations, from 313 to 316. The change includes the inclusion of 2 respondents who filled out the survey without confirming their participation in Norwegian patenting. One of these ambiguous cases accounts for over 60 single-inventor patent applications. The present approach also includes two late responses not included in the last version, including a positive response.

TABLE 1 Norwegian inventors and patents by survey-based categories, 1998-2003

CATEGORY	CODE	DESCRIPTION	Inventors	Patent 1	Patent 2	Patenting
				fractional counts	Individual case	Frequency
PUBLIC SECTOR RESEARCHERS[a]	*10-15*	*CONFIRMED*	*569*	*635*	*1085*	*1437*
	10	*Survey confirmation*[b]	*316*	*402*	*613*	*783*
	12, 15	*Applicant-based confirmation (PSR)*[c]	*131*	*119*	*222*	*351*
	13	*Collaborating inventor confirmation*[d]	*86*	*79*	*175*	*223*
	14	*Other affiliation*[e]	*36*	*38*	*75*	*80*
UNRESOLVED	*20, 50*	*UNRESOLVED*	*154*	*150*	*228*	*239*
	20	*Moved*	*44*	*42*	*66*	*66*
	50	*Non-Response*	*110*	*108*	*162*	*173*
NEGATIVE	*30, 21, 60*	*REJECTED*	*77*	*88*	*142*	*145*
	30	*Survey rejection*	*65*	*74*	*123*	*126*
	21	*Researcher unknown*	*12*	*14*	*19*	*19*
OTHERS	60	OTHER INVENTORS	5790	6908	7197	10063
TOTALS			6590	7781	7781	11884

Source: Norwegian Patent Office-Inventor (Nifu Step), Norwegian Researcher Registry (Nifu Step)

[a] Since information in a given patent helps in some cases to categorize the inventor (see stages described above), a researcher may be found in different subcategories. In this situation, all patenting of that researcher is re-assigned to the lowest category found (code 11, 12, 13 etc).
[b] Full survey response confirms identity. Duplicates are removed from patent-list. The results include 2 full responses who do not confirm link to Norwegian patents (64 patents involved in single case)
[c] The patent-assignee is a public research organization or directly affiliated (24 patents—involving 13 inventors—are the products of start-up companies with obvious PSR links).
[d] Fellow inventors are confirmed PSR researchers, suggesting that this also goes for the unresolved researchers in those patents.
[e] Survey response indicates that the inventor is the PSR researcher, but that the patents in question involved another position (for example after the respondent left the PSR sector).

5.1. Patenting and public research organizations

The following tables and figures explore general dimensions of public research organization patenting. The purpose is to lay the basis for further analysis of main dimensions of this activity. This explorative exercise will into the breakdown of academic patenting by technological area and by the subcategories of the PSR sector. In addition the grant-records will be briefly considered.

A total of 828 patents –or 10.6% of domestic patents—involves at least one PSR inventor. A fractional count compensates for the variable number of inventors per patent by dividing the patent among contributing inventors. This unification process reveals that the inventor contribution of university inventors is 4.4%, college inventors 0.6% and research institutes 3.2%, or a (fractional-based count) total of 8.2% for all public research organization inventors.

Public research organization invention however varies strongly across technological areas. A focus on the total number of times confirmed PSR researchers were involved in Norwegian patents relative to other Norwegian inventors illustrates this. It also allows us to compare our results with the basic data used in BALCONI ET AL (2004) who use the same technological categories for frequencies of academic patents over the total set of Italian patents registered at the EPO.

BALCONI ET AL (2004), who underestimate the academic inventions, report that the frequency of academic patenting in Italian patents is 3 %. Table 2 demonstrates that 6.8% of Norwegian domestic patenting (number of times academic inventors were listed as inventors in Norwegian patents relative to the total) involves inventors either from universities or colleges. Nearly 21% (versus 12% in the Italian study) of chemical and pharmaceutical patenting in Norway involve academic researchers and 11.5% of medical technologies and other Instruments. Thus these strong results serve to confirm SCHMOCH's (2004) observation that PRS inventors play a major role in certain science-based technology areas.

Table 2. Confirmed PRO inventors, freqency count by sectors of inventors in Norwegian patent-applications and corresponding percentages: 1998-2003.

Patenting areas	Academy	Institution	Total	% UC	% INST	PRO %
Chemicals & pharma	364	143	1737	21,0	8,2	29,2
Instruments	171	170	1485	11,5	11,4	23,0
Electronics[a]	124	64	1602	7,7	4,0	11,7
Process engineering	48	78	1802	2,7	4,3	7,0
Mechanical engineering	96	168	4300	2,2	3,9	6,1
Consumer goods	4	6	935	0,4	0,6	1,1
All fields	808	629	11884[b]	6,8	5,3	12,1

Source: Norwegian Patent Office-Inventor (Nifu Step), Norwegian Researcher Registry (Nifu Step)

[a] Includes 64 patents registered under Academy that are uncertain. See footnote above.
[b] a total of 23 (1 among academic inventions) did not link to the technological classifications.

Table 2 also demonstrates that academic and research institution patents have distinct profiles in Norway. Whereas the contribution is remarkably similar in the field of Instruments, the contribution of the institutional sector is greater in the mechanical and processing fields (which include petroleum technologies).

Trend over time: An average of 10.7% of Norwegian patents involved at least one public research organization researcher in the five years leading up to 2003. In 2003, when the new law to promote academic patenting unexpectedly took effect earlier than expected, the proportion of academic patents in fact dropped considerably in 2003 to 10.3%. Although our baseline exercise identifies the drop, the reason for it can only guessed at without further inquiry. One factor behind the drop was that the introduction of the law created a period of uncertainty for some researchers about how the division of labor would change between researcher and institution. While the overall tendency of applications fell from the first half of the 6 year period to the second, the academic patents were more stable.

Table 3. Annual breakdown of unified patent applications[a] by response category

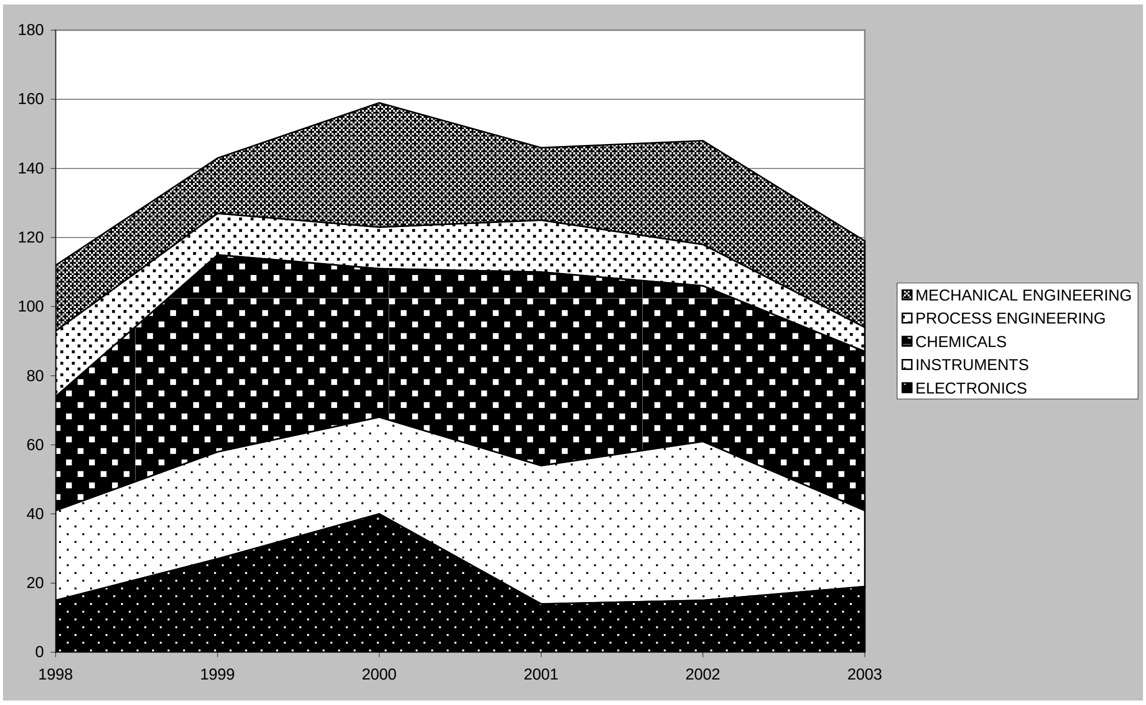
Response category	1998	1999	2000	2001	2002	2003	Total
CONFIRMED	112	143	159	147	148	119	828
NEGATIVE	24	24	19	22	17	17	123
UNRESOLVED	21	32	47	36	44	46	226
OTHERS	1162	1164	1195	1092	1019	968	6604
CONFIRMED %	8,5	10,5	11,2	11,3	12,1	10,3	10,6
Total Numbers	1319	1363	1420	1297	1228	1150	7781

Source: Norwegian Patent Office-Inventor (Nifu Step), Norwegian Researcher Registry (Nifu Step)

[a] At least one Pro researcher contributing.

There were 414 patents with at least one PSR researcher both in 1998-2000 and in 2001-2003, while the number of other patents (including unresolved, negative and others) fell 11.6% from 3688 to 3261 from the end of the 1990s to the beginning of the 21st century. Academic patenting peaked as a proportion of total Norwegian patents within this period in 2002. Note that the period covers an economic downturn (2001). This down turn principally affected private sector patenting, particularly in the area of information technology. The IT-bubble affect is visible in Figure 1 which illustrates the year on year development of confirmed PSR patents by technological field. In 2003, academic patenting fell most significantly in the fields of process engineering and instruments.

Figure 1. Annual trend of academic patents[a] by technological area (N=828)



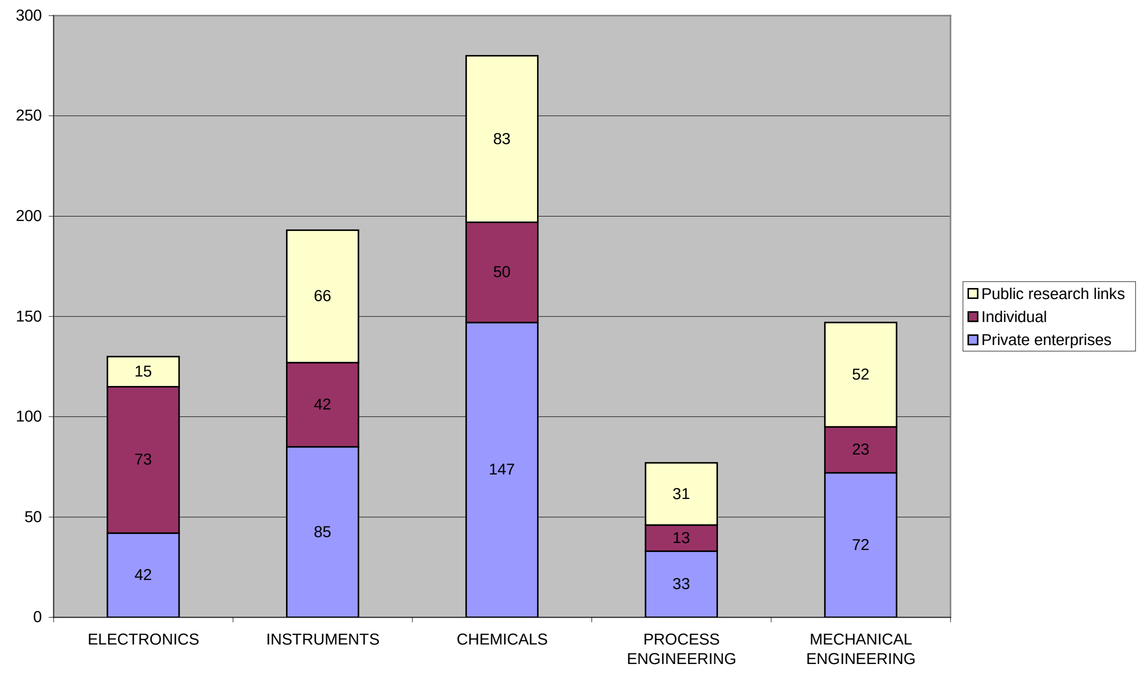
Source: Norwegian Patent Office-Inventor (Nifu Step), Norwegian Researcher Registry (Nifu Step)

[a] At least one Pro researcher contributing. The electronics area includes 64 applications which might not be attributable to the academic researcher who responded.

Assignees: The new law grants title to the university or college who employs the researcher. This change of title will tend to change who applies for academic patents, so it is important to get an idea of the profile of applicants in the years leading up to the legislative change. Figure 2 breaks down the patent-applications with at least one confirmed academic inventor for the 1998-2003 period according to the primary assignee type.

This breakdown indicates that the conception of 'professor privilege' patents as predominantly single-inventor patents held by the researcher himself tends to be inaccurate in most sectors. Individual PSR inventor patents are in fact relatively limited. The exception here is Electronics, which includes a single applicant with 64 applications in the area of IT. As indicated above, it remains uncertain that the researcher is behind these Norwegian patents. In general the roles of two types of assignees are important. The first are private enterprise assignees which tend to play a significant role in academic patenting. Figure 2 demonstrates that this role is proportionally greatest in the case of Chemicals and Pharmaceuticals. It also constitutes nearly half of the Mechanical Engineering patents.

Figure 2. Type of primary assignees applying for patents with at least one academic inventor. (N=828)[a]



[a] One PRO patent does not link to a technological area. 63 of the electronic patents assigned to individuals involve one researcher and are uncertain. See elsewhere for discussion.

The other significant assignee type is what we call 'public research links'. These include research institutes themselves (e.g. SINTEF), spin-off companies with clear affiliation to the public research sector (see above for a discussion), as well as technology transfer offices with explicit links to public research organizations. A small number of science parks are also listed as assignees. 'Public research links' are especially important assignees for Instrument and Chemical and Pharmaceutical inventions. It is expected that the profile of assignees will change following the new legislation. The important question will be what these changes will be and how they will affect the use of patents as a vehicle to disseminate academic research.

Grants: The above analysis has primarily focused on different dimensions of patent applications linked to public research organization researchers. An application in itself does not necessary indicate that the invention is patentable or, even so, if it is commercially interesting. In this sense, patent-grants tell us more about the relative merits of inventions while pointing to its success in being disseminated by patenting.

A granted patent provides a better indication of the aim of the new legislation. Grants however take time, typically three years. The final table in this explorative paper takes a preliminary look at what happens to the applications from PSR inventors. It looks at the status of PSR patent applications (as of the end of 2003) filed in 1998 as a proportion of all applications.

Table 4. Patents applied for in 1998 granted in the period, PRO application as percent of all. Status as of the end of 2003.

Status	ELECTRONICS	INSTRUMENTS	CHEMICALS	PROCESS ENGINEERING	MECHANICAL ENGINEERING	Total[a]
Grant	10,5	18,2	22,7	18,9	5,2	11,3
Nongrant Withdrawal	8,4	14,0	28,1	4,2	1,7	6,4
Pending	0,0	36,4	45,5	0,0	0,0	15,8
Total%	8,9	17,1	27,7	9,6	2,8	8,5
Total	169	152	119	198	678	1319

[a] 19 applications of the total without affiliation (one is PRO, withdrawn).

In 1998 112 patents were applied for that involved at least one public research organization inventor. That accounts for 8.5% of the total 1319 Norwegian applications that year, which was the lowest level in the period. A significantly higher proportion of PSR patents were granted by the end of 2003 than the rest of the 1998 cohort. Whereas 35% of the cohort applications were granted, 46% –or 52 PSR patents— had been granted. The ration of grants to application was highest among PSR patents in the cases of Process Engineering and Mechanical Engineering.

6. Conclusions

This paper has addressed the fundamental difficulty of empirically assessing changing policy aims in the area of academic patenting. It has presented results from a project designed to provide necessary empirical basis on which to analyze changes in extent and focus of academic patents. The purpose has been in short to describe the project's empirical approach and results, while also providing insight into the changes in Norwegian policy on this front and their context.

The paper presented a novel three-stage approach where the first stage links registry-data to identify public sector researcher involvement in patents; the second stage employs a survey which in part is used to verify the accuracy of the link; while the third combines the results from the survey with the registry-data to decide any cases left unresolved after the second stage. We argue that the use of an 'affiliation network approach' (BALCONI ET AL., 2004) in the third stage is an effective way to resolve such cases. Overall, it is argued that the approach provides an accurate baseline for evaluating the effect of legislative changes in Norway which removed the "professor's privilege" and gave the higher education institutions formal responsibility for commercializing research results whenever possible.

The preliminary results of this approach are reported here. The paper demonstrates that more than 10% of all Norwegian patents involve public research organization inventors (or 12 percent of the times Norwegian inventors were involved in patent applications during the period). The majority of the PSR patents were linked with university and colleges. Academy patents made up nearly 5 percent of the fractional count of Norwegian patents (or 6.8% of the frequency). The contribution of university and college researchers was especially high in Chemical and Pharmaceutical patenting, accounting for nearly 18% (fractional count). This result confirms the conjecture (SCHMOCH, 2004) that PRS inventors play a major role in certain science-based technology areas. The baseline also indicates that PSR patents enjoy a high grant-rate relative to other domestic patents. 46 % of the PSR patents applied for in 1998 were subsequently granted, as opposed to 34% for the population otherwise.

The proportion of public research organizations patents increased over the period 1998 to 2002, when 12 percent involved at least one PSR researcher. The baseline uncovers the interesting fact that the year the new legislation went into force, 2003, to improve academic patenting, the level actually fell back to 10%. While the baseline itself cannot explain why the level fell, our conjecture is that the earlier than expected implementation of the legislation and the lack of established practice at the universities led to uncertainty among researchers. In this situation researchers preferred to postpone applications.

These results demonstrate some of key dimensions of the baseline of PSR patenting we constructed. Future iterations are envisioned, whereby this exercise is repeated periodically (every three years) together with the accompanying survey. This design will allow comparisons over time—and potentially, across countries—and should become instrumental to informing the future development of this important innovation policy area.

Chapter 6: The impact of patenting on research collaboration: Survey evidence from Norway

The preceding empirical chapters studied the propensity of different populations of firms and other actors to patent (and to register trademarks). The final chapter investigates the relationship between patenting in terms of how different actors collaborate. This empirical essay addresses the scope of the patent-system to facilitate coordination of (technological) knowledge production among different actors—either in sequence or in parallel. The chapter studies this relationship between patenting and research collaboration using a balanced panel of Norwegian responses to two waves of the Community Innovation Survey (4 and 5), with a combined observation period of 2002-2006.

Theme	Questions
Essay 1: Knowledge formation and patenting	What role does the patent system play in knowledge accumulation?
Essay 2: The diversification and specialization of IPR use in a small open economy	How does use of the IPR system reflect the innovative processes of different agents? What role is played by small firms in specialization and diversification of innovative activity?
Essay 3: The growing use of patents among small firms: areas of growth and challenges	If SME patenting is increasing (see last essay), what technological areas and market dimensions? Do they face greater challenges than larger firms?
Essay 4: Small firm patenting and the transition to European Patent Office	How do Norwegian SMEs use the European Patent System? How the effects of this transition be measured?
Essay 5: Academic patenting and the transition to an institution-based patenting regime	To what degree do academic researchers already patent and will the introduction in Norway of Bayh-Dole-like legislation improve conditions for academic patenting?
Essay 6: The impact of patenting on research collaboration	**Does patenting increase the probability for research collaboration? What role do other factors play?**

The essay discusses contexts in which research collaborations may involve patenting. The mainly industrial organization literature has tended to focus on patenting that follows collaboration. This essay instead focuses on the potential for patenting to lead (simultaneously or subsequently) to research collaboration. The analysis accounts for a range of other factors that might affect the propensity to collaborate. In addition to R&D activity, industry dummies, and firm-size, we account for strategic activity, fiscal constraints, and technological dimensions. Thus the chapter returns to conclusions of the first essay which indicated that patents may play an apparently increasingly important role in facilitation research collaborations among different actors.

6. The impact of patenting on collaboration: Evidence from a Norwegian panel of two waves of the Community Innovation Survey

Eric J. Iversen

Abstract

The paper addresses the scope of the patent-system to facilitate coordination of (technological) knowledge production among different actors. The coordination function is rooted in the long discourse of the role of the patent system. However its importance has reemerged as knowledge production processes evolve. The paper starts from the position that ongoing patent reform initiatives need to take into consideration this dimension of the patent system. The paper links the coordinative role of patents to the analysis of networks of innovators in an 'industrial networks' approach. Here, it addresses the need to develop empirical approaches that capture this coordination function. The paper develops an empirical approach against this backdrop using Community Innovation Survey data for Norway.

1. Introduction

In addition to creating incentives to innovate, patenting influences coordination costs and therefore can affect the way industries organize. (Somaya & Teece 2000) An important way in which patent regimes may shape organizational patterns is through the scope to encourage or discourage coordination of (technological) knowledge production among different actors. An expanding set of literature has pointed to the growing importance of cooperation in knowledge production. During the same period patenting has surged well beyond its traditional peg to R&D expenditures. (Hall & Ziedonis, 2001) The coinciding surge in patenting and growing collaboration activities raises the question of the relationship between the two.

This paper focuses on the scope of the patent-system to facilitate coordination of (technological) knowledge production among different actors. In particular, it links this growing focus to the question of coordination in 'networks of innovators' or 'industrial network settings'. This paper is concerned with how firms manage exchanges with other organizations in order to improve their access to new knowledge and to develop new products. (see discussion in Iversen, 2009) In general, patenting may precede collaborative effort, may accompany it, and/or may follow it. The latter scenario is the more prominent focus of the (mainly industrial organization) literature. (Spence, 1984, ff)

The focus of this paper is instead on patenting as a precursor of research collaboration. It looks at the extent to which the recent patenting activity of an enterprise influences its likelihood to engage in collaborative innovation activities. We examine how patenting affects the incidence and duration of innovation collaboration and whether there are differences emerge based on different types of partnerships: following Janne & Frenz (2006), we differentiate between collaborations that are horizontal (ie. competitors), vertical (e.g. suppliers) or that involve outside research organizations. The aim is to study the coordinative role of the patent system in a way that will contribute to policy relevant analysis.

This paper studies this relationship between patenting and research collaboration using a balanced panel of Norwegian responses (N=2448) to two waves of the Community Innovation Survey (4 and 5), with a combined observation period of 2002-2006. We discuss contexts in which research collaborations may involve patenting. We base the analysis on patenting (and the controls) taking place in the first period while looking for a collaboration effect to continue into the second. In general, we assume that patents play a larger role in the strategies of these collaborating firms than non-collaborative firms. We account for a range of other factors that might affect the propensity to collaborate. In addition to R&D activity, industry dummies, and firm-size, we account for Strategic activity, including reported changes in the basis for partner relationships; Fiscal constraints including sensitivity to high development costs; Technological dimensions, such as technological complexity and the reliability of lead-time that might affect the propensity to collaborate; and length of product-cycles, where we use an ordinal variable of product-cycles from the Norwegian survey.

The paper proceeds as follows: An introduction of the theoretical background in Section 2 gives way to an overview of different empirical approaches in Section 3. Section 4 goes on to develop hypotheses and to introduce the data and methodology to study it. Results are presented in Section 5, and the final section concludes.

2. Innovation collaborations and patenting

Inter-firm innovation activity has increased in number (e.g. Hagedoorn & Narula, 1996) and variety (e.g. Hagedoorn & Schankenraad (1990) in the modern economy.96 This development can be thought of in stylized terms as involving the spread of corporate R&D activities (Chandler, 1992), to increased combination between internal and external R&D activities (Mowery, 1983), to more widespread and more complex 'networks of innovators'. (Freeman, 1991)

The more fruitful of these collaborative networks are expected to integrate rather than merely reassemble the complementary knowledge of the individual collaborators. Powell et al (1996) argue that the trend towards greater collaboration points to a reorientation of the locus of innovation, and,

[96] Relevant literature is diverse. See Grandori & Soda (1995) illustrates the trends in the organizational studies literature; Caloghirou et al.(2003) survey relevant literature in areas of industrial organization and strategic management. In the current period of renewed interest, Negassi (2004) or Grimpe & Kaiser (2010) provide reviews that confirm that formal R&D collaboration remains a focus.

potentially, to the development of networks of learning. If so the shift can affect where innovation takes place, with whom, and how the process is coordinated. This raises a set of questions which has exercised the literature, including the determinants of collaboration, their dimensions, and impacts (e.g. the danger of cartel). We start by considering some of these questions before focusing on the role that patenting plays in coordination process. We distinguish different types of innovator networks, since collaboration may take on a variety of forms.

The expansion of collaborative forms has coincided with the changing factors both within the firm and without. The literature indicates that co-operations between two or more agents can take a variety of forms, depending on: (i) the type of partner (e.g. collaboration with competitors, suppliers/customers or universities and research organizations); (ii) the governance of the collaboration (e.g. sub-contracting, strategic alliances, joint ventures, research consortia); (iii) the geographical distance between collaborating partners (local collaborations or cross-border co-operation); (iv) the type of activity carried out in the cooperation (e.g. innovation-specific, pre-competitive or near market research); (v) the duration of the cooperation and (vi) whether or not the exchange is a repeated exchange or a one off.

Networks of innovators have grown to encompass a widening range of external agreements both to other firms and to other institutions (primarily universities and other public and private research institutions). The 'peculiar attributes' of new knowledge (highlighted in Arrow, 1962), the need for a minimal level of 'absorptive capacity' in the contracting firm, and the pervasive uncertainty surrounding market and technological factors during the innovation process have supported this premise.[97]

3. Patents and innovation collaboration: empirical

The proliferation of research collaborations has spawned interest in the more specific role played by patent in research oriented collaboration. A variety of recent articles provide literature reviews of the relationship between collaboration, inter-mural R&D, and innovation output (including patents or new products). The mainly theoretical industrial organizational work has tended to consider collaboration among competitors.[98] This dominant tradition (Spence, 1984 ff) tends to consider research collaboration mainly between rival firms who are likely to retain varying degrees of

[97] A contrary current has emerged in the Open Innovation literature. (Chesbrough, 2003) Here the focus on complementarities between internal and external innovation efforts has given way to one substitution. In this stream, 'markets for knowledge' are thought to have become sufficiently efficient while the tradability of new knowledge has increased. There is however less empirical work to corroborate this position.

98 However, Kleinknecht and Van Reijnen, 1992 also consider the type of partner (supplier, customer, public labs, etc.) or of the type of agreement (joint venture, research partnerships, license contracts, equity holding).

competitive intent towards one another. (Prahalad and Hamel, 1990 and Hamel, 1991, Shapiro and Willig, 1990)

Given this focus, this dominant mode of inquiry finds that collaborative agreements are more beneficial in cases where it is difficult to appropriate emerging knowledge. [99] In this view, collaboration provides a mode to internalize the externalities (appropriate) that emerge under these circumstances and to share research results among consortium partners. For these firms, the underlying goal of maintaining competitive advantage is offset by the need to coordinate information flows during collaborative technological innovation. Knowledge spillovers increase the incentives to cooperate especially if cooperation allows knowledge transfers to take place among the collaborating partners more securely. If they work well, R&D alliances and other forms of collaboration are expected to lead to patenting as these spillovers are made appropriable. In addition to increasing the patenting activity of the individual participant firms, collaboration may also lead to co-patenting. During collaboration, knowledge is expected to spill over between partners, who also share other risks as well as costs associated with joint research work. This may lead to one or another form of co-patenting. In this case patenting (and patent-based licensing arrangements) is more likely to evolve at an intermediate stage as a byproduct of the collaboration. Studying the patenting activity of 145 R&D alliances in Japan, Branstetter & Sakakibara (2002) show that research consortia tend to increase their patenting after entering a consortium.

However, data which can be used to study collaboration and patenting has not been readily available. Several empirical approaches can be differentiated in the literature that has blossomed here. We should first note that much of this literature studies the determinants and/or outputs of collaborative innovation. In this literature, the relationship between collaboration and patenting is itself something of a bi-product. In most cases, patenting enters into the equation as a proxy for innovation output.

We differentiate approaches that primarily focus on survey data from that which focuses primarily on patent-data: these two main approaches have increasingly been merged to include elements of patent data in the analysis of survey data (see Grimpe & Kaiser, 2010 for a recent example of this) or elements of survey data in the analysis of patent-data. (see Fontana & Geuna, 2010 for a recent example of this) We consider some aspects and findings of these two approaches.

[99] See Spence, 1984 for a seminal paper in this tradition. For a review of the overlapping issues, consult Caloghirou et al. (2003). or the review sections of Negassi (2004); Czarnitzki, D. et al. (2006); as well as Grimpe & Kaiser (2010)

3.1. Co-patenting analysis

Hagedoorn (2003) provides an exploratory look at the joint-patenting of firms. This form of co-patenting activity (co-assignees who co-own title to the invention) is shown to be highly industry-specific. This is especially the case for chemicals and information technology, where the propensity to patent is high, such as those relevant to technology –based networks. Information in the patents themselves provides other more indirect evidence of collaboration. Gay et al (2008) study 'collective knowledge' by focusing on the incidence of co-invention in US patents with European applicants. They document an increase tendency for patents to include multiple inventors (and with increasing average numbers of inventors).

Co-patenting indicates a form of collaboration, but provides limited insight into the nature of collaboration. A new approach combines the information in the patent-document with information from a survey of the patent's inventors. This approach was developed in the European Patval database, which addressed a cross-country survey to inventors involved in a sample of EPO (European Patent Office) patents applied for in 1993-1997. Fontana & Geuna (2010) used this data to study research cooperation based on specific patents. They find that almost 30 percent of the patents in the Patval population involved some form of co-patenting, while over 20 percent involved other formal collaborative agreements. A small minority involved a licensing agreement without a form of co-invention. Among other things this study indicates that there are national differences in collaborations especially among the less formal relationships (e.g. co-inventorships).

The Patval inventor survey has led to similar surveys in other countries, including the Australia, the US and Japan. Nagaoka & Walsh (2009a; 2009b) carried out a Patval-based study to compare patent uses in the US and Japan. The results of these inventor-based surveys corroborate the picture that, while there are national differences, invention in both countries draws heavily on outside knowledge sources and often involves cooperative activity. National and international surveys continue to be the most prevalent mode to study collaboration and, more or less directly, the role of patenting. Cohen et al (2002) follow the tradition of national surveys that target the R&D labs of manufacturing firms (Yale and Carnagie Mellon), showing that patents are used more often in Japan than the US to facilitate intra-industry spillovers.

3.2. Surveys and the Community Innovation Survey

A growing number of studies have used the European Community Innovation Survey(CIS). The CIS is perhaps the most comprehensive – in terms of the breadth of sectors and firms and in terms of the breadth of information – survey readily available The CIS is a periodic survey of enterprises in EU (current) member states as well as a number of associated countries including Norway. It is based on a core-set of common questions (deriving from the Oslo Manual, 1994) as well as a small number of country-specific questions.[100] A basic set of question is currently run every two years.

One advantage of the CIS itself is that it is comprehensive: it includes information about the enterprise, product and process innovation, innovation activity and expenditure, effects of innovation, innovation co-operation, public finding of innovation, information source for innovation, and patents. This provides a broad vantage point to study the interplay between propensities to patent and to cooperate in the context of other factors that might influence each. Another advantage of CIS is that it is periodic, leading to the ability to use panels of responses.

Different configurations of CIS data have been used to study different aspects of the collaboration. The configurations of data used vary in terms of geographic scope (single country, two countries or multiple countries) and temporal scope (cross-section; two or more wave panels). In addition, studies have supplemented the survey data with other data such as R&D budgets (Negassi, 2004) or the patent-stock of the respondent enterprises. (Czarnitzki et al, 2007; Grimpe & Kaiser, 2010) CIS based studies have looked at different dimensions of collaboration, which bear on the relationship between patenting and collaboration in different ways. Areas of analysis include:

1. The determinants of R&D co-operation and its impact on innovative performance. (Cassiman & Veugelers, 2002; 2006; Negassi, 2004; Faria & Schmidt (2004); López (2008))
2. Complementarities of innovation activities in terms of innovative output, (Schmiedeberg, 2008; Grimpe and Kaiser, 2010)
3. As well as more heterogeneous studies that for example focus on differences in collaboration strategies (Belderbos et al 2004) or the relationship between R&D collaboration, subsidies and patenting activity (Czarnitzki et al. (2007).

These different studies provide a number of observations that speak to the question of how patenting and collaboration interrelate. Studies of the determinants of collaborative innovation tend to show that firms that rate ‘strategic IP protection’ (patent, design, and trademark) highly are more likely to engage in internal R&D activities while those that rely on other modes of protection—such as lead-time and technological complexity— also engage in all R&D activities. (Cassiman & Veugelers, 2002; 2006; Schmeideberg, 2008) This is consistent with the industrial organizational premise, that spillovers increase incentives to cooperate. Thus patents are expected to follow from collaboration.

[100] For an English review of the Norwegian data see the English section of http://www.ssb.no/emner/10/03/rapp_innov/rapp_200946/rapp_200946.pdf.

The two country study (Germany and Portugal) of Faria & Schmidt (2004) uses cross-sectional data (CIS3) to identify factors that influence the probability of a firm cooperating with a foreign partner on innovation activities. It posits that IPR protection should correlate with a lower incidence to collaborate on the premise that firms that find IPR important are unlikely to collaborate for fear that intramural knowledge will spill over to partners. This traditional expectation is not supported. They show that patents and other protection methods positively influence the decision to cooperate with foreign partners. They reason that firms may be more likely to use protection methods if they cooperate in order to protect their knowledge from spilling over to the cooperation partner, but are unable to study this more closely due to an acknowledged problem of the cross-sectional data.[101] Using CIS4 for Germany, Schmidt (2006) goes on to tests the hypothesis that patent protection is used to prevent knowledge spillovers, but does not arrive at robust conclusions.

Janne & Frenz (2006) turn this expectation around. They again use cross-sectional data (CIS4) for the UK to show that patenting is strongly related to firms that engage in different types of collaboration (see below), especially those that have research cooperation (ie. cooperation with universities and other research institutions). These studies indicate that patenting accompanies collaboration on the basis shown in Japan where research consortia tend to increase their patenting after entering a consortium. (Branstetter & Sakakibara, 2002). The premise that concurrent patenting may enhance knowledge transfers among the collaborating partners is furthermore supported by the co-patenting studies cited above.

A third way to conceive of the relationship is that patents precede collaboration. Czarnitzki et al. (2007) conceive of patenting both as precursor and as output of R&D collaboration while whether firms' innovation activities are stimulated by public funding and/or co-operation. Based on two waves of CIS data, this two country study uses patent stocks (linked via patent-data) as a measure of successful R&D. Following the general IO premise, it expects collaborative firms to invest more in R&D as well as to patent more if spill-over effects in R&D co-operations are high. Pre-collaboration patents are furthermore used as a means to signal potential partners that the firm has important capabilities and that it is worth collaborating with. This is similar to the position taken in Grimpe & Kaiser (2010) who use the patent stock of the firm (also using linked patent data) and a patent-dummy to proxy the accumulated prior knowledge base of the firm. The focus of these two studies is not directly on the relationship between patenting and collaboration however.

---

[101] This is the acknowledged endogeneity problem which is encountered when trying to observe patents and collaboration in the same reference period.

3.3. Determinants of the interplay between patents and collaboration

Thus, this growing set of empirical studies serves to focus on the relationship between patenting and research collaboration. The survey based literature points to some basic determinants of collaboration. Fritsch and Lukas (2001) indicate a positive impact of firm size and of R&D intensity of firms on R&D cooperation. López (2008) shows that collaborations might be motivated by the need to defray high-costs and a high risks. And Janne & Frenz (2006) show that the relationship between patenting and collaboration is highly industry-specific, as are patterns of collaboration that emerge in the patent-based studies reviewed above (e.g. Hagedoorn, 2003).

In addition, the empirical literature indicates that patenting affects different stages of research collaborations. Three types of relationships are highlighted above: patenting may precede collaboration, it may accompany it and/or may follow it. In addition, the literature points to the importance of distinguishing between the type of cooperation. For theoretical reasons, (i.e. to highlight the partitioning of knowledge externalities between rival firms) the traditional focus has involved collaborations between competitors (e.g. Branstetter & Sakakibara, 2002) or between firms and universities (e.g Mowery, 1983). However, Tether (2002) shows that there are differences between the way service and manufacturing firms interact with specialist knowledge providers. Belderbos et al (2004) emphasize the importance of differentiating three types of partner (horizontal, vertical, and university–firm cooperation) to study cooperation strategies (using two waves of Dutch CIS). Relying on one wave of the CIS in the UK, Janne & Frenz (2006) take this distinction further to study whether patenting accompanies collaboration.

4. Data and methodology

In this paper, we expect innovative firms that participate in collaborative relationships to be more patent-active than other innovative firms (i.e. that launch significantly improved products): other things being equal. In a research-based collaboration, the collaborators are assumed to have complementary research capabilities. In order to enter into formal research collaborations we assume that each collaborator will already have a knowledge strategy that covers the commercially valuable knowledge it brings to the collaboration (a) and the new knowledge that emerges from the collaboration (b).

We pick up on the observation above that patenting may play a role at different stages of research collaborations: that it may precede collaborative effort, may accompany it and/or may follow it. The latter scenario is as demonstrated above the more prominent focus of the (mainly industrial organization) literature. Following the literature above, we focus on patenting as a precursor for or byproduct of collaboration. Patenting may be expected to predate innovative collaborations for a variety of reasons.

1. Predisposition at the firm-level: A preliminary reason for existing patenting to correlate with subsequent collaboration involves firm-level strategy. Firms that engage in collaborations will on average have a more outwardly-oriented innovation strategy than others. (see the governance literature, e.g. Granstrand, 2006) Such a strategy also makes the choice of patenting more likely as it provides a means to coordinate and control certain types of commercially significant knowledge during partnerships with other entities. Firm management may be more likely to initiate or okay potential collaborations if patents are felt to be an important way to reduce the risk of losing control of proprietary knowledge. However, a more-outwardly oriented firm-strategy may make both patenting and collaboration more likely. This entails to a degree endogenous factor of strategy which we address with by trying to control for firm-level strategy.
2. Helping firms find collaborators: In bringing collaborators together, patenting may act as a signal to potential collaborators which marks its knowledge endowment (e.g. Grimpe & Kaiser, 2010) in a given technological space. (viz prospects-theory, Kitch 1972) Previous-patenting may further increase the likelihood that firms find each other in the first place (the signaling effect). If collaboration tends to be rooted in existing commercial relationships, the signal effect might be strongest in cases where firms are searching for complementary knowledge which is more basic. If so, it might be instrumental in collaborations involving university research where a pre-relationship is less likely.
3. Initiating collaborations and keeping them together: The more prevalent and instrumental rationale involves the effect of patenting on contractual relationships. Patents may strengthen non-disclosure and other agreements that accompany collaborations and may lay the basis for cross-licensing arrangements. (viz contract theory of patents e.g. Denicolo and Franzoni, 2003) Patenting strengthens contractual relationships and affords the firm with room for maneuver which may be a precondition to enter into relationships with other entities. In facilitating collaboration among partners which maintain some degree of commercial rivalry, this is thought to be precondition. This is especially the case if the collaboration is to be successful in the sense that it lays the basis for new commercially viable innovations. Patenting of own knowledge also involves a temporal aspect when entering a research collaboration. Absorption, in turn, is higher when a firm carries out own R&D (Cohen and Levinthal, 1989). Agreeing on access to knowledge, transparency and trust are all important elements in collaborations, and, in turn, will condition whether and how patents

may be used to distribution and generate knowledge via collaborations. But this will differ according to the nature of the participants, the nature of the relationships, and according to other factors

4.1. Data

In focusing on the relationship between patenting and collaboration, this study follows in the tradition of CIS based studies. It uses balanced panel of Norwegian enterprises that responded both to the fourth and fifth Community Innovation Surveys (CIS4 and CIS5) [102].

- CIS4, reference year 2004 and observation period from 2002-2004
- CIS2006, reference year 2006 and observation period from 2004-2006.

In this study, we use the responses from 2448 Norwegian enterprises who responded in both waves of the survey. Our dependent variables relate to collaboration on innovation. We concentrate on two aspects of this relationship. First we explore how patenting affects different stages of research collaborations: here the dependent variable distinguishes between sporadic and continuous collaborations. Second, we investigate how patenting might affect different types of partnerships: here the dependent variable distinguishes between horizontal, vertical, and university–firm cooperation.

Our primary independent variable is patenting. Here we rely on a binary variable for whether the firm patented in the first period. We follow the literature (e.g. Schmiedeberg, 2008) to assume that differences between patenting and not patenting firms are more important than marginal effects of additional patents In addition we take into account a range of determinants suggested by the literature.

Duration of innovation collaboration:

To understand whether patenting acts as a precursor—and/or is concurrent— to research collaboration, the study focuses on the effect that patenting (in the first period) has on the propensity to engage in cooperative activity in the total period. In short the study posits that a firm that patents early innovative activities will be more likely to collaborate throughout the period. Accordingly, our dependent variable (DVcoop) takes the following categories/scores: no cooperation (value of 0), sporadic or intermittent cooperation (value of 1) and continuous cooperation (value of 2). . Different types of cooperation, sporadic or continuous, are associated with the relevance of patents to protect innovations in CIS4 (reference period 2002 to 2004). Thus we differentiate

[102] CIS http://epp.eurostat.ec.europa.eu/portal/page/portal/microdata/cis : it is based on random sampling of manufacturing and service enterprises, stratified by firm-size, region, and industry. See above for an introduction.

between research collaboration that is sporadic (i.e. it takes place in only one of the periods) from that which is persistent (the firm engages in it) in the model. The prior assumption is that the latter reflects a stronger climate for collaboration which is what we posit that patenting contributes to. The third possible outcome is no collaboration.

Type of partnership in innovation collaboration We then distinguish the propensity to collaborate based on type of collaboration partner. The dependent variables ("DVcoop_vert", "DVcoop_hor" and "DVcoop_kb") are used to estimate the effect patenting has on horizontal (competitors), vertical (suppliers), and institutional cooperation (university and other research institutes), respectively.

4.2. Approach

Probability or generalized-linear models have become widely used to evaluate ordinal response data, especially in conjunction with CIS. These probability models regress a function of the probability that a case (e.g. a firm that patents in period 1) falls within a given category (firms that collaborate continuously) when the combination of independent variables are fitted to a line (i.e. the cumulative normal probability distribution in probit and the cumulative logistic distribution in the case of logit). The coefficients measure the change in the probability that an event occurs (ie. a firm engages in sporadic or continuous collaboration) if the independent variable (patenting) changes value (i.e. from 0 to 1), holding the effect of all other variables constant. (see Gujarati, 2003: Chapter 15)

We employ a combination of these probability models (namely ordered probit and multinomial logit), first, to evaluate how precursor patents affect the probability of the three ordered outcomes: no collaboration, sporadic collaboration, or continuous collaboration; and then to evaluate how patents affect the probability of the three types collaboration; horizontal, vertical, and institutional cooperation.

In addition to patenting, a range of factors can help to determine collaborative propensity/behavior. It is important to take into account variables that might affect the propensity to collaborate, especially given that logistic estimations are known to be sensitive to unobserved heterogeneity (Mood, 2009). A primary predictor is that a firm has own research activity. Own research activity is of course a precondition for collaborative research (cf Fritsch and Lukas, 2001); in addition it raises the firm's absorptive capacity. We apply a measure for sporadic and continuous internal R&D (dummy variables) as well measures of R&D expenditure (log of R&D expenditure in the first period) to control for this. Firm-size and industry are two other acknowledged predictors of the propensity to collaborate (see discussion above). The natural log of number of employees and industry dummies at the two-digit level are included to capture these two noted determinants.

These aggregations may hide other structural factors that otherwise might raise or lower the probability of collaborative activity. We use controls based on the:

Strategy: A firm’s overall strategy is expected to influence its interest and openness to partnerships, as observed above. To account for this, we use responses by the firm on whether, in the first period (2004), they introduced new strategies, management structures, knowledge management techniques to deal with partners and internal to the enterprise.

Fiscal constraints: Firms may seek partnerships due to impracticalities of going it alone. We control for whether the firm finds (in 2004) high development costs, the existence of dominant market players, lack of in-house technological know-how or skilled labor to hinder their innovation, since partnerships may be a way for the firm to overcome these barriers.

Technological dimensions: The technology itself will also affect the propensity to collaborate. Firms responded on whether the firm relied on complexity of technology or on lead-time help the firm to maintain their innovative advantage. We control for these two proxies of technological complexity since they also serve to make collaboration more attractive (modular technologies and division of labor) and more secure, especially alongside patenting. These are multinomial measures on the same basis as the dependent variable: whether they were relied on sporadically, continuously or not at all.

Product Cycles: In addition, information about the product-life cycle of the firm’s technology is used based on a special question in the Norwegian CIS (2004). A firm might team up to be competitive if product cycles in its markets are shorter than average but over a certain minimum threshold. This effect is controlled for.

Table 6-1 Descriptive Statistics

Variable	Description	Observations	Mean	Stand Dev	Min	Max
DVcoop	Cooperation duration: 0= no collaboration 1= sporadic cooperation (either period), 2= continuous cooperation (both periods)	2447	0,51	0,73	0	2
DVcoop_horizontal	Cooperation with competitors:0= no collaboration 1= sporadic cooperation (either period), 2= continuous cooperation (both periods)	2448	0,17	0,49	0	2
DVcoop_vert	Cooperation with suppliers or customers:0= no collaboration 1= sporadic cooperation (either period), 2= continuous cooperation (both periods)	2448	0,45	0,74	0	2
DVcoop_kb	Cooperation with university and other research institutes:0= no collaboration 1= sporadic cooperation (either period), 2= continuous cooperation (both periods)	2448	0,41	0,71	0	2
patents	Firm applied for patents in 2002-2004	2390	0,14	0,35	0	1
lnemp	Natural log of employment 2004	2448	4,18	1,21	2,3	9,3
RD	R&D active in both periods=2 in one period =2 not at all =0	2448	0,81	0,90	0	2
lnRD4	Average R&D expediture for both periods	1047	7,74	1,71	0	13,2
complexity	Complexity of design: sporadic or continuous importance	2274	0,30	0,59	0	2
headstart	Lead-time advantage on competitors: sporadic or continuous importance	2280	0,52	0,74	0	2
prod_life	Product life-cycle: five intervals	2310	4,84	1,38	1	6
strategy	Change in business strategy (yes or no) 2002-2004	2328	0,24	0,43	0	1
mantech	Change in management techniques (yes or no) 2002-2004	1930	0,17	0,38	0	1
structure	Change in firm organization (yes or no) 2002-2004	1929	0,31	0,46	0	1
hcos_4	High innovation costs a constraint: (Likert-scale) 2004	2303	1,04	1,07	0	3
hper_4	Problem with retaining or recruiting qualified personnel a constraint: (Likert-scale) 2004	2294	0,73	0,84	0	3

* values are converted into dummy variables in the estimations. **We also use 2-digit level industry dummies (SIC). The presentation of the correlation matrix is found in the Annex.

We also conduct a series of standard tests. The mean variance inflation factors (VIF) is 2.97 for the wide definition of R&D (N=1701) and 2.6 for the narrower definition (N=756). There are higher values among the industry dummies, but all variables are well under ten.

5. Results

In the first step, an ordered probit model is used to test whether patenting affects the odds that the firm also collaborates (DVcoop), taking into account the above control variables. R&D is a major determinant of collaboration. We run the model twice. The first uses two dummy variables to account for whether the firm reports intermittent R&D or persistent R&D activity, respectively, through the two periods. The second uses R&D expenditures (log of R&D in 2004).

The first is a looser definition of the underlying activity the firms might collaborate on. It allows us to consider the importance of patents among a group firms with broader R&D activities. It fits the responses of 1701 firms to the probability of collaboration, both intermittent and continuous. The stricter definition of the second estimation allows us to focus on the effect of patenting on more traditional R&D active companies. It fits the responses of 756 firms to the probability of collaboration, both intermittent and continuous. Reporting the two separately provides a composite view of R&D activities which we will return to when looking at the importance of different types of partners.

Both estimations present a clear indication that precursor patents contribute, rather than detract from, the propensity to collaborate. Our other major independent variables have largely the expected signs. Patenting in period 1 is positive and significant. Firm size (natural log of employment "lnemp") is as expected positive. In addition to patenting in period 1, the continuous importance of lead-time in product markets appears to be an even strong positive predictor. The fact that the firm introduced new strategies also increases odds of collaboration, although only overall corporate strategy is statistically significant in both equations. The odds of cooperation are also heightened if complexity of technological design is continuously important, a result that is statistically significant in the second equation. The high cost of innovation, lack of internal technological know-how, and to a lesser degree the lack of skills are also positive, but these results are not statistically significant. The product life information does not provide a clear story here.

Table 6-2 The impact of patenting and other covariates on the odds for sporadic and continuous innovation collaboration: Results Ordered Probit: R&D accounted for by dummies (i) and expenditure (ii)

Dependent variable:	Cooperation: none, sporadic, continuous		Cooperation: none, sporadic, continuous	
Est. model	Ordered probit		Ordered probit	
Independent variables	coef	se	coef	se
Patents Applied for 2004	0,382***	0,10	0,425***	0,10
Lead-time advantage used continuously	0,434***	0,12	0,458***	0,13
Product life-cycle: <1 year	0,219	0,24	-0,161	0,36
Product life-cycle: 1-3 years	0,005	0,16	0,081	0,18
Product life-cycle: 4-6 years	-0,155	0,12	-0,153	0,14
Product life-cycle: 7-9 years	-0,198	0,15	-0,188	0,17
Product life-cycle: 10+ years	0,032	0,08	0,039	0,11
Complexity of design continuously important	0,210	0,14	0,204***	0,15
Log employment	0,167***	0,03	0,147***	0,05
R&D Sporadic	0,882***	0,10		
R&D Continuous	1,563***	0,10		
Change to corporate strategy	0,175**	0,08	0,253***	0,10
Management techniques	0,271***	0,10	0,171	0,12
Organisational structure	0,194**	0,08	0,170	0,11
Marketing strategy	0,059	0,08	0,091	0,09
Cost: high impact	0,012	0,14	-0,073	0,17
Skills: high impact	0,073	0,20	0,082	0,24
Technological knowledge: high	0,331	0,27	0,465	0,33
Market knowledge: high impact	-0,166	0,23	-0,195	0,25
Log R&D expenditure			0,082**	0,04
Industry dummies	included		included	
/cut1	0,963	0,59	-0,158	0,75
/cut2	2,156***	0,59	0,904	0,74
Number of observations	1701		756	
R2	0.3166		0.1203	
Loglikelihood	-1076.091		-730.3528	
Wald chi2	957.50		205.37	
notes: *** p<0.01, ** p<0.05, * p<0.1				

CIS4 and CIS2006: Balanced Panel of Norwegian Respondents.

Notes: The base group for the multinomial logit is no cooperation; for patents the base group is 'not used'. For the factors hampering innovation, risk, cost, skills, technological and market knowledge, the base group is 'no impact'. For product cycle, the category 'uknown' is the base group. For the change of strategy variables (market, management techniques, organizational structure, and marketing), the base group is none. Some scale variables are omitted for presentation.

We note first that the equation based on R&D dummies is highly skewed. The values of Cut1 and Cut2 indicate that this equation is based on a population, of which about 15 percent of the reference group fall into the sporadically collaborating category and only 1.6 in the continuously collaborating category. The second equation based on R&D expenditure is more balanced: with 43 percent not collaborating, 39 percent collaborating intermittently, and 18 percent collaborating continuously.

In both cases, the results demonstrate a consistent relationship between patenting and the probability of collaboration. The model which uses R&D dummies indicates that patenting in 2004 increases the odds of collaboration by .38 standard deviations relative to the outcome of no collaboration. In the narrower model, the impact is higher (.43 standard deviations), while narrowing the difference with the coefficient for lead-time.

However, the coefficients need to be interpreted carefully since they represent standard normal scores (z statistics) in terms of a latent variable that represents the propensity to collaborate. We first report the marginal effects (AME) of patenting in each equation. A table with marginal effects for all variables is provided in Annex 2. This step indicates that the outcome of sporadic collaboration is different than that of continuous collaboration. And that the type of R&D reported should be accounted for.

Table 6-3 Marginal effects of Patenting on Sporadic and Continuous Collaboration: for R&D dummy and R&D expenditure equations respectively

	Outcomes	Variable	dy/dx	z	P>z
RD Dummies	Sporadic Collaboration	patents	0,03	3,64	0
	Continuous Collaboration	patents	0,06	4	0
RD expenditure	Sporadic Collaboration	patents	0	0,44	0,66
	Continuous Collaboration	patents	0,13	4,22	0

Stata 11SE: Average marginal effects, Robust VCE model.

Accounting for the effects of the other variables, patenting in 2004 has a marginal effect of about 3 percent on the probability of sporadic collaboration and 6 percent in terms of continuous collaboration. (both highly significant) The effect doubles when moving from intermittent to persistent collaboration. The effect of patenting on collaboration among firms reporting R&D expenditure in 2004 indicates that patenting is a stronger predictor of continuous collaboration. In this equation, the effect of patenting is negligible and statistically insignificant, while the effect of patenting on the odds that the firm engages in continuous collaboration is 13 percent and highly significant.

The importance of patenting increases in step with more persistent collaboration. In the next step, we look more closely at the responses from the 756 firms that report R&D expenditures in 2004. We use a multinomial logit model to indicate the effects patenting and the other covariates on sporadic and continuous collaboration, relative to a base outcome of no collaboration.

Table 6-4 The impact of patenting and other factors on the odds for sporadic and continuous innovation collaboration: Multinomial Logit: R&D accounted for by expenditure (2004)

Est. Model: multinomial Logit	**Cooperation: *Base outcome= no collaboration***			
	sporadic		**continuous**	
Independent variables	**coef**	**se**	**coef**	**se**
Patents Applied for 2004	**0,706*****	**0,256**	**1,005*****	**0,263**
Lead-time advantage used continuously	**0,347**	**0,292**	**1,164*****	**0,325**
Product life-cycle: <1 year	**0,775**	**0,865**	**-13,94*****	**0,785**
Product life-cycle: 1-3 years	**0,408**	**0,425**	**0,266**	**0,490**
Product life-cycle: 4-6 years	**-0,612***	**0,317**	**-0,409**	**0,334**
Product life-cycle: 7-9 years	**-0,540**	**0,373**	**-0,517**	**0,413**
Product life-cycle: 10+ years	**-0,146**	**0,255**	**0,058**	**0,283**
Complexity of design continuously important	**1,176*****	**0,416**	**0,725***	**0,416**
Log employment	**0,231****	**0,110**	**0,360*****	**0,117**
R&D Expenditure (log)	**0,059**	**0,081**	**0,219****	**0,093**
Change to corporate strategy	**0,520****	**0,228**	**0,634*****	**0,236**
Management techniques	**0,744*****	**0,289**	**0,470**	**0,327**
Organisational structure	**-0,147**	**0,240**	**0,409**	**0,258**
Marketing strategy	**-0,062**	**0,212**	**0,214**	**0,224**
Cost: high impact	**0,070**	**0,393**	**-0,147**	**0,448**
Skills: high impact	**-0,227**	**0,676**	**0,300**	**0,701**
Technological knowledge: high	**0,231**	**0,694**	**0,914**	**0,760**
Market knowledge: high impact	**0,273**	**0,576**	**-0,269**	**0,701**
constant	**-15,49*****	**1,390**	**-2,395**	**1,531**
Industry dummies	**Included**		**Included**	
Number of observations	**756**			
Pseudo R2	**0.1612**			
Loglikelihood	**-696.40982**			
Wald chi2	**NA**			
note: *** p<0.01, ** p<0.05, * p<0.1				

CIS4 and CIS2006: Balanced Panel of Norwegian Respondents.Notes: The base group for the multinomial logit is no cooperation; for patents the base group is 'not used'. For the factors hampering innovation, risk, cost, skills, technological and market knowledge, the base group is 'no impact'. For product cycle, the category 'uknown' is the base group. For the change of strategy variables (market, management techniques, organizational structure, and marketing), the base group is none. Some scale variables are omitted for presentation.

Noting the relationship between probit and logit models[103], the multinomial logit focuses on the responses of 756 of those firms (based on logged R&D expenditure in 2004). The base outcome is no collaboration. The results reinforce the picture created in the results above, providing output that is consistent with expectations. It illustrates again that patenting is an important predictor of collaboration but that its effect increases the likelihood more for continuous than for intermittent collaboration. Important structural factors (Firm-size and R&D expenditures) follow this same pattern. Firms that continuously rely on lead-time advantage are also much more likely to engage in continuous collaborations rather than not collaborating or collaborating only sporadically. The same goes for the effect that changes in corporate strategy have on collaboration, while the other forms of strategic change lose predictive power and/or are statistically insignificant.

On the other hand, reliance on complexity of design is more important as a predictor of sporadic rather than continuous collaboration. The introduction of new management techniques corresponds here with a robust effect on the odds of sporadic collaboration. One interesting new thing is that product lifecycle 1 (products with lifecycles under 1 year) is strongly negative for continuous collaboration: again an intuitive outcome. A positive (but insignificant) effect is suggested for firms with product-cycles that are shorter than average (between 1 and 3 years), but more than 1 year.

In the final step we consider whether patenting affects the probability of different types of collaborators. Following earlier work (see above: e.g. Belderbos et al, 2004; Janne & Frenz, 2006), we distinguish between vertical and knowledge-based relationships, i.e. those mainly between suppliers and those mainly with universities, respectively. The estimations involving Horizontal collaborations with competitors failed. The following presentation is therefore based on collaborations with two types of partners: suppliers and customers (vertical) and university and other research institutes (institutional cooperation). We maintain the ordered categories between firms that collaborate intermittently and those that do so continuously.

[103] Comparisons of logit and probit coefficients can be made by dividing the logit coefficients by 1.8. (Gujarati, 2003; 615)

Table 6-5 The impact of patenting and other factors on vertical and research institution collaboration: Multinomial Logit: R&D accounted for by expenditure (2004)

Dependent variable:	Vertical Collaboration				Collaboration with research organizations			
Est. Model: multinomial Logit	sporadic		continuous		sporadic		continuous	
Independent variables	coef	se	coef	se	coef	se	coef	se
Patents Applied for 2004	0,495*	0,270	1,064***	0,238	0,414*	0,248	1,035***	0,242
Lead-time advantage used continuously	0,362	0,319	0,828***	0,286	0,079	0,285	0,999***	0,305
Product life-cycle: <1 year	-13,852***	0,700	0,512	1,019	1,183	0,779	-14,136***	0,736
Product life-cycle: 1-3 years	0,123	0,459	0,595	0,415	-0,741*	0,445	-0,376	0,433
Product life-cycle: 4-6 years	-0,177	0,336	-0,373	0,317	-0,182	0,316	-0,504	0,327
Product life-cycle: 7-9 years	-0,527	0,435	-0,248	0,378	-0,394	0,365	-0,592	0,394
Product life-cycle: 10+ years	0,172	0,264	-0,135	0,265	0,094	0,254	-0,227	0,275
Complexity of design continuously important	0,892**	0,396	0,977***	0,360	0,397	0,345	0,279	0,354
Log employment	0,109	0,119	0,190*	0,105	0,355***	0,110	0,451***	0,114
R&D Expenditure (log)	0,010	0,081	0,171*	0,096	0,016	0,074	0,191*	0,101
Change to corporate strategy	0,647***	0,229	0,604***	0,221	0,287	0,218	0,514**	0,224
Management techniques	0,101	0,296	0,661**	0,281	0,066	0,265	0,269	0,289
Organisational structure	0,303	0,247	0,230	0,234	0,096	0,223	0,087	0,240
Marketing strategy	0,184	0,229	0,126	0,209	0,151	0,208	0,334	0,215
Cost: high impact	0,060	0,403	0,089	0,388	0,025	0,386	-0,183	0,415
Skills: low impact	-0,847**	0,404	-0,798**	0,367	-0,623*	0,351	-0,244	0,440
Technological knowledge: high	0,389	0,790	1,429**	0,654	-0,204	0,847	0,707	0,794
Market knowledge: high impact	-0,224	0,590	-0,054	0,599	-0,219	0,609	0,026	0,688
constant	-0,432	1,474	-1,854	1,429	-0,747	1,394	-2,959**	1,424
Number of observations	756				756			
Pseudo R2	0.1545				0.1472			
Loglikelihood	-677.85597				-692.93803			
Wald chi2	1144.08				1423.40			
note: *** p<0.01, ** p<0.05, * p<0.1: Industry dummies not reported								

Source: CIS4 and CIS2006: Balanced Panel of Norwegian Respondents.

Notes: The base group for the multinomial logit is no cooperation; for patents the base group is 'not used'. For the factors hampering innovation, risk, cost, skills, technological and market knowledge, the base group is 'no impact'. For product cycle, the category 'uknown' is the base group. For the change of strategy variables (market, management techniques, organizational structure, and marketing), the base group is none. Some scale variables are omitted for presentation.

The results indicate some added distinctions in the relationship of these covariates of collaboration already presented. Disaggregated in this way, the size-effect is now seen to be strongest (and most strongly significant) in relation to the collaborations with research organizations, both in terms of the odds that firms collaborate intermittently or continuously. R&D expenditures are much more strongly associated with continuous than sporadic collaboration with both types of partners, but the results are less robust. (significant at the 10 percent level) The strongly negative result for the shortest product-cycles is found in both groups, but isolated to the propensity for continuous collaboration.

The importance of lead-time advantage is again seen in terms of increasing the probability of continuous collaboration also with both suppliers (vertical) and with research organizations. The importance of complexity of design also has a positive effect, but this is found in relation to vertical collaborations and not to collaborations with research organizations. The effect of the introduction of new management techniques influences the odds of collaborations with suppliers and customers more than those with research organizations, although corporate structure effects are strong for continuous collaboration with either set of collaborator.

Firms that name the lack of technological knowledge as having a high impact on their innovation activities, are much more likely to collaborate vertically with suppliers and customers on a continuous basis (significant at the 5 % level). Meanwhile, the lack of skilled employees has a negative effect on vertical collaborations of both durations.

Patenting is again consistently positive in relation to both types of collaboration: however it is a stronger predictor of continuous than of sporadic collaboration. It remains positive (and weakly significant, now at the 10 percent level) for sporadic collaboration. The most important effect of patenting is on the propensity to collaborate continuously. This impression is confirmed when looking more closely at the marginal effect of patenting in the first period on both sporadic and continuous collaborations involving each of the two types of collaborators. Marginal effects are reported for all variables in Annex 3 and 4.

Table 6-6 Marginal effects of Patenting on Sporadic and Continuous Collaboration: for collaborations with suppliers and with research organizations respectively

Equations	Outcomes	Variable	dy/dx	z	P>z
Vertical collaboration	Sporadic Collaboration	patents	0,00	0,06	0,95
	Continuous Collaboration	patents	0,16	4,34	0,00
Collaboration with Research Organizations	Sporadic Collaboration	patents	-0,02	-0,91	0,36
	Continuous Collaboration	patents	0,07	4,68	0,00

Stata 11SE: Average marginal effects, Robust VCE model.

The effect of patenting in 2004 has negligible (and in the case of collaboration with research organizations a negative impact) on the likelihood of intermittent collaboration: this effect is very weak and statistically insignificant. Patenting however has a strong positive (and highly significant) effect on the probability of continuous collaboration. This rings true for both types of collaborators but is strongest (16 percent) for collaborations involving suppliers or other vertical relationships.

6. Conclusions

If patenting were solely about keeping knowledge resources in house, there might be very little collaboration among patenting firms. A textbook firm that uses patents to minimize knowledge outflows and to maximize the capture of rents from knowledge generated outside (e.g. from universities) would be an unwilling research collaborator and an unattractive partner. Yet, patenting and of research-based collaborations have risen hand in hand the past two or three decades, suggesting a positive relationship between the two.

This paper studied this relationship between patenting and research collaboration using a balanced panel of Norwegian responses (N=2448) to two waves of the Community Innovation Survey (4 and 5), with a combined observation period of 2002-2006. We discussed contexts in which research collaborations may involve patenting, given that patenting may precede collaborative effort, may accompany it, and/or may follow it. The latter scenario is established as the more prominent focus of the (mainly industrial organization) literature. The focus of this paper has instead been on patenting leading simultaneous with or subsequent to research collaboration. In general, we assume that patents play a larger role in the strategies of these collaborating firms than n non-collaborative firms. We account for a range of other factors that might affect the propensity to collaborate. In addition to

R&D activity (dummy and expenditure), industry dummies, and firm-size, we account for **Strategic activity**, including reported changes in the basis for partner relationships; **Fiscal constraints** including sensitivity to high development costs; **Technological dimensions**, such as technological complexity and the reliability of lead-time that might affect the propensity to collaborate; and length of product-cycles, where we use an ordinal variable of product-cycles from the Norwegian survey. We do so to minimize unobserved heterogeneity.

We use standard generalized-linear models (ordered probit and multinomial logit) procedures to evaluate how precursor patents affect the probability of the three ordered outcomes: no collaboration, sporadic collaboration, or continuous collaboration. Collaboration is then differentiated to analyze the effect patenting has on collaborations that involve competitors (horizontal), that involve suppliers and customers (vertical), and that involve involving outside research organizations.

The results find a strong and consistently positive effect of patenting on the probability that the firm collaborates. This effect comes into relief most strongly when using R&D expenditures (logs 2004) to account for the role of R&D in the collaborations. Patenting affects the propensity for continuous collaboration most strongly but it also increases the odds of sporadic collaborations significantly.

The higher impact on continual collaboration comes through still more strongly when the distinction between horizontal, vertical and research organization collaboration are studied. Unfortunately we have insufficient observations to study the horizontal partnerships. Looking at vertical and research organization collaboration, we find patenting to again be consistently positive in relation to both types of collaboration. Patenting is here again a stronger predictor of continuous than of sporadic collaboration.

These estimations support the position that patenting of own knowledge contributes to the probability that the firm also collaborates with other firms. Patenting is positive and significant in each model, but clearest in relation to the probability that the firm will continue to collaborate. Furthermore it is clearest in relationship to continuous collaborations with suppliers and customers. (i.e. vertical collaboration)

The paper contributes to a better appreciation of the relationship of patenting and research collaboration, in terms of the persistence of (continuous & intermittent) as well as in terms of the type of collaboration (horizontal, vertical, and research organizations). Furthermore it provides an understanding of the role that other factors—Structural (e.g. size), Strategic activity, Fiscal constraints, Technological dimensions, and product cycles— have on research collaboration.

Annexes

Annex 5-1 Correspondence Matrix

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Cooperation: Values 0,1,2	1,00													
Patents applied for (2004)	0,25	1,00												
log enterprise size (2004)	0,18	0,10	1,00											
R&D active: Values 0,1,2	0,33	0,20	0,04	1,00										
log R&D expenditures (2004)	0,23	0,30	0,25	0,35	1,00									
Complexity of design: Values 0,1,2	0,19	0,22	-0,02	0,22	0,30	1,00								
Lead-time advantage: Values 0,1,2	0,25	0,21	0,03	0,33	0,31	0,51	1,00							
Product life-cycle: five intervals	0,02	-0,05	0,26	-0,14	-0,16	-0,19	-0,18	1,00						
Business strategy: 2002-04	0,15	0,05	0,15	0,09	0,15	0,05	0,13	0,00	1,00					
Management techniques: 2002-04	0,15	0,02	0,18	0,12	0,15	0,06	0,14	0,03	0,10	1,00				
Firm organization: 2002-04	0,16	0,09	0,07	0,16	0,21	0,16	0,20	-0,07	0,13	0,43	1,00			
High costs constraint: 2004	0,05	0,01	-0,09	0,03	0,05	0,09	0,10	-0,08	0,10	-0,01	0,03	1,00		
Skilled personnel constraint: 2004	0,08	0,13	0,00	0,06	0,11	0,05	0,08	-0,10	0,03	0,02	0,05	0,29	1,00	
Tech knowledge constraint: 2004	0,10	0,02	-0,07	0,05	0,03	0,11	0,09	-0,06	0,06	-0,03	0,03	0,31	0,50	1,00

Annex 5-2 Collaboration Duration: Marginal Errors for Broad R&D Category (using R&D dummies): Ordered Probit Model

Ordered Probit Model	Sporadic Collaboration			Continuous Collaboration		
	ME	Z		ME	Z	
patents	0,03	3,64	***	0,06	4,00	***
leadtime3	0,03	3,42	***	0,07	3,51	***
life_cycle1	0,02	0,90		0,03	0,90	
life_cycle2	0,00	0,03		0,00	0,03	
life_cycle3	-0,01	-1,28		-0,02	-1,30	
life_cycle4	-0,02	-1,34		-0,03	-1,35	
life_cycle5	0,00	0,38		0,00	0,38	
complex3	0,02	1,43		0,03	1,46	
lnemp	0,01	4,42	***	0,03	4,87	***
RD2	0,07	9,24	***	0,13	8,61	***
RD3	0,12	13,36	***	0,24	14,28	***
strategy	0,01	2,21	**	0,03	2,25	**
mantech	0,02	2,70	***	0,04	2,83	***
structure	0,01	2,38	**	0,03	2,40	**
marketing	0,00	0,77		0,01	0,77	
cost4	0,00	0,09		0,00	0,09	
skill4	0,01	0,36		0,01	0,36	
tech4	0,03	1,22		0,05	1,22	
market4	-0,01	-0,71		-0,03	-0,71	
N	1701					
chi2	957.5					
df_m	47					

*Some variables including industry dummies and intermediate variables are not reported

Annex 5-3 Collaboration Duration: Marginal Errors for narrow R&D Category (using log R&D expenditure): Ordered Probit Model

	Sporadic Collaboration			Continuous Collaboration		
	ME	Z		ME	Z	
patents	0,002	0,44	***	0,13	4,22	***
leadtime3	0,002	0,45	***	0,14	3,42	***
life_cycle1	-0,001	-0,33		-0,05	-0,45	
life_cycle2	0,000	0,31		0,02	0,44	
life_cycle3	-0,001	-0,41		-0,05	-1,08	
life_cycle4	-0,001	-0,41		-0,06	-1,10	
life_cycle5	0,000	0,28		0,01	0,34	
complex3	0,001	0,41		0,06	1,37	
lnemp	0,001	0,44	***	0,04	3,09	***
lnRD4	0,000	0,44		0,02	2,27	**
strategy	0,001	0,44	***	0,08	2,69	***
mantech	0,001	0,42		0,05	1,39	
structure	0,001	0,44		0,05	1,61	
marketing	0,000	0,41		0,03	0,98	
cost4	0,000	-0,31		-0,02	-0,42	
skill4	0,000	0,27		0,02	0,34	
tech4	0,002	0,43		0,14	1,40	
market4	-0,001	-0,39		-0,06	-0,77	
N	756					
chi2	205.4					
df_m	46					

*Some variables including industry dummies and intermediate variables are not reported

Annex 5-4 Vertical Collaboration: Marginal Errors for narrow R&D Category (using R&D dummies): mlogit

Vertical Collaboration		Sporadic Collaboration			Continuous Collaboration	
Est model: mlogit	ME	Z		ME	Z	
patents	0,002	0,06		0,16	4,34	***
leadtime3	-0,002	-0,04	*	0,12	2,64	***
life_cycle1	-2,204	-13,84	***	1,07	5,83	***
life_cycle2	-0,023	-0,36		0,10	1,47	
life_cycle3	-0,001	-0,03		-0,05	-1,08	
life_cycle4	-0,065	-1,05		-0,01	-0,12	
life_cycle5	0,037	0,97		-0,04	-0,85	
complex3	0,070	1,38		0,11	2,11	**
lnemp	0,004	0,21	*	0,03	1,51	*
lnRD4	-0,011	-0,9		0,03	1,9	*
strategy	0,059	1,87	*	0,06	1,81	*
mantech	-0,031	-0,8		0,11	2,64	***
structure	0,031	0,91		0,02	0,53	
marketing	0,020	0,6		0,01	0,28	
cost4	0,003	0,05		0,01	0,18	
skill4	-0,115	-1,19		0,01	0,14	
tech4	-0,040	-0,34		0,23	2,04	**
market4	-0,031	-0,36		0,01	0,06	
N	756					
chi2	1423.4					
df_m	92					

*Some variables including industry dummies and intermediate variables are not reported

Annex 5-5 Vertical Collaboration: Marginal Errors for narrow R&D Category (using R&D dummies): mlogit

Institution	Sporadic Collaboration			Continuous Collaboration		
	ME	Z		ME	Z	
patents	0,00	0,01		0,14	4,22	***
leadtime3	-0,06	-1,27		0,16	3,59	***
life_cycle1	1,22	8,80	***	-2,42	-15,64	***
life_cycle2	-0,11	-1,42		-0,01	-0,14	
life_cycle3	0,00	0,07		-0,07	-1,45	
life_cycle4	-0,03	-0,46		-0,07	-1,15	
life_cycle5	0,03	0,81		-0,04	-1,09	
complex3	0,05	0,94		0,02	0,35	
lnemp	0,03	1,75	*	0,05	2,88	***
lnRD4	-0,01	-0,86		0,03	1,99	**
strategy	0,01	0,42		0,06	1,95	**
mantech	-0,01	-0,17		0,04	0,93	
structure	0,01	0,30		0,01	0,21	
marketing	0,00	0,09		0,04	1,35	
cost4	0,02	0,28		-0,03	-0,51	
skill4	-0,03	-0,29		0,06	0,63	
tech4	-0,09	-0,67		0,13	1,19	
market4	-0,04	-0,42		0,02	0,19	
N	756					
chi2	1423.4					
df_m	92					

*Some variables including industry dummies and intermediate variables are not reported

All References

Acs, Z. J. and D. B. Audretsch (1988). "Innovation in Large and Small Firms: An Empirical Analysis." American Economic Review **78**(4): 678-90.

Albaladejo, M. and H. Romijn (2000). Determinants of innovation capability in small UK firms: an empirical analysis, Eindhoven Center for Innovation Studies (ECIS).

Allison, J. R., M. A. Lemley, et al. (2003). Valuable Patents. George Mason Law & Economics Research Paper.

Andersen, B. (2001). Technological Change and the Evolution of Corporate Innovation: The Structure of Patenting, 1890-1990. Cheltenham, Edward Elgar.

Andersen, B. and S. Konzelmann (2008). "In search of a useful theory of the productive potential of intellectual property rights." Research Policy **37**(1): 12-28.

Andersen, E. S. (2004). Population Thinking and Evolutionary Economic Analysis: Exploring Marshall's Fable of the Trees, DRUID, Copenhagen Business School, Department of Industrial Economics and Strategy/Aalborg University, Department of Business Studies.

Andersson, M. and O. Ejermo (2006). Technology and Trade - an analysis of technology specialization and export flows, Royal Institute of Technology, CESIS - Centre of Excellence for Science and Innovation Studies.

Antonelli, C. (2001). The microeconomics of technological systems, Oxford University Press, USA.

Antonelli, C. (2002). The Economics of Innovation, New Technologies and Structural Change, Routledge.

Antonelli, C. and M. Quéré (2002). "The governance of interactive learning within innovation systems." Urban Studies **39**(5-6): 1051-1063.

Archibugi, D. and M. Pianta (1992). "Specialization and size of technological activities in industrial countries: The analysis of patent data." Research Policy **21**(1): 79-93.

Arora, A. (1995). "Licensing tacit knowledge: intellectual property rights and the market for know-how." Economics of Innovation and New Technology **4**(1): 41-60.

Arora, A. (1997). "Patents, licensing, and market structure in the chemical industry." Research Policy **26**(4-5): 391-403.

Arora, A., A. Fosfuri, et al. (2001). Markets for Technology: The Economics of Innovation and Corporate Strategy, MIT Press.

Arora, A. and A. Gambardella (1994). "The changing technology of technological change: general and abstract knowledge and the division of innovative labour." Research Policy **23**(5): 523-532.

Arora, A. and R. P. Merges (2004). "Specialized supply firms, property rights and firm boundaries." Industrial and Corporate Change **13**(3): 451-475.

Arrow, K. (1962). "Economic welfare and the allocation of resources for invention." 1962.

Arundel, A. and I. Kabla (1998). "What percentage of innovations are patented? Empirical estimates for European firms." Research Policy **27**(2): 127-141.

Balconi, M., S. Breschi, et al. (2004). "Networks of inventors and the role of academia: an exploration of Italian patent data." Research Policy **33**(1): 127-145.

Baldini, N., Grimaldi, R. & Sobrero, M. (2005). Patenting at universities: a survey of Italian inventors. 5th Triple Helix International Conference: The Capitalization of Knowledge. Turin, Italy.

Basberg, B. (1984). Patenter og teknologisk endring i Norge 1840-1980, Bergen: Norges Handelshoyskole.

Bassecoulard, E. and M. Zitt (2005). Patents and Publications: the lexical connection. Handbook of Quantitative Science and Technology Research: the use of publication and patent statistics in studies of S&T systems. H. Moed, W. Glänzel and U. Schmoch, Springer Netherlands: 665-694.

Beck, R. L. (1983). "The prospect theory of the patent system and unproductive competition." Research in law and Economics **5**: 193-209.

Beneito, P. (2006). "The innovative performance of in-house and contracted R&D in terms of patents and utility models." Research Policy **35**(4): 502-517.

Berglund, F., K. Wendt, et al. (2004). Report on science & technology indicators for Norway: 2003. Oslo, The Research Council of Norway.

Besen, S. M. and L. J. Raskind (1991). "An introduction to the law and economics of intellectual property." The Journal of Economic Perspectives: 3-27.

Bessen, J. and E. Maskin (2006). "Sequential Innovation, Patents, and Imitation." RAND Journal of Economics

Bessen, J. and M. J. Meurer (2008). Patent failure: how judges, bureaucrats, and lawyers put innovators at risk, Princeton University Press.

Blind, K. and E. J. Iversen (2004). The interrelationship between IPR and standardisation: patterns and policies. EURAS Yearbook of Standardization M. J. Holler. Hamburg, European Academy for Standardization e.V. (EURAS).

Bosworth, D. and M. Rogers (2001). "Market value, R&D and intellectual property: an empirical analysis of large Australian firms." Economic Record **77**(239): 323-337.

Bound, J., C. Cummins, et al. (1990). Who Does R&D and Who Patents. R&D Patents, and Productivity Z. Griliches. Chicago and London, The University of Chicago Press.

Branstetter, L. G. and M. Sakakibara (2002). "When do research consortia work well and why? evidence from Japanese panel data." The American Economic Review **92**(1): 143-159.

Breschi, S., F. Malerba, et al. (2000). "Technological Regimes and Schumpeterian Patterns of Innovation." Economic Journal **110**(463): 388-410.

Bresnahan, T. F. and S. Greenstein (1999). "Technological competition and the structure of the computer industry." Journal of Industrial Economics: 1-40.

Britto, J. (2004). Technological Diversity and Industrial Networks: An Analysis of the Modus Operandi of Co-operative Arrangements. SPRU Electronic Working Papers Series, Science Policy Research Unit. **4:** 40.

Bruland, K. and K. Smith (2010). Knowledge Flows and Catching-Up Industrialization in the Nordic Countries: The Roles of Patent Systems. Intellectual Property Rights, Development, and Catch-Up. H. Odagiri, A. Goto, A. Sunami and R. Nelson. Oxford, Oxford University Press.

Caloghirou, Y., G. Hondroyiannis, et al. (2003). "The performance of research partnerships." Managerial and Decision Economics **24**(2-3): 85-99.

Calvert, J. and P. Patel (2003). "University-industry research collaborations in the UK: bibliometric trends." Science and Public Policy **30**(2): 85-96.

Cantwell, J. (2006). The economics of patents, Edward Elgar.

Cantwell, J. and G. Vertova (2004). "Historical evolution of technological diversification." Research Policy **33**(3): 511-529.

Carlsson, B. and R. Stankiewicz (1991). "On the nature, function and composition of technological systems." Journal of Evolutionary Economics **1**(2): 93-118.

Chandler, A. D. (1992). "Corporate strategy, structure and control methods in the United States during the 20th century." Industrial and Corporate Change **1**(2): 263-284.

Chesbrough, H. W. (2006). Emerging Secondary Markets for Intellectual Property: US and Japanese Comparisons, NCIPI.

Clark, B. R. (1998). Creating entrepreneurial universities: organizational pathways of transformation. New York, Pergamon.

Coase, R. H. (1992). "The Institutional Structure of Production: 1991 Alfred Nobel Memorial Prize Lecture in Economic Sciences." American Economic Review **82**(4): 713-719.

Cohen, W. (1995). Empirical studies of innovative activity. Handbook of the Economics of Innovation and Technological Change. P. Stoneman. Oxford, Blackwell.

Cohen, W., R. R. Nelson, et al. (1996). "Appropriability conditions and why firms patent and why they do not." NBER Working Paper, Cambridge, Massachusetts.

Cohen, W. M., A. Goto, et al. (2002). "R&D spillovers, patents and the incentives to innovate in Japan and the United States." Research Policy **31**(8-9): 1349-1367.

Cohen, W. M. and S. Klepper (1992). "The tradeoff between firm size and diversity in the pursuit of technological progress." Small Business Economics **4**(1): 1-14.

Cohen, W. M., R. C. Levin, et al. (1987). "Firm size and R & D Intensity: a re-examination." The Journal of Industrial Economics **35**(4): 543-565.

Cohen, W. M. and D. A. Levinthal (1989). "Innovation and learning: the two faces of R & D." The economic journal: 569-596.

Cohen, W. M. and F. Malerba (2001). "Is the tendency to variation a chief cause of progress?" Industrial and Corporate Change **10**(3): 587-608.

Cohen, W. M., R. R. Nelson, et al. (2000). "Protecting their intellectual assets: appropriability conditions and why U.S. manufacturing firms patent (or not)." National Bureau of Economic Research Working Paper Series **No. 7552**.

Coombs, R., P. Saviotti, et al. (1987). Economics and technological change, Rowman & Littlefield.

Czarnitzki, D., B. Ebersberger, et al. (2004). The relationship between R&D collaboration, subsidies and patenting activity: empirical evidence from Finland and Germany. Discussion Paper No. 04-37. ZEW, Centre for European Economic Research (ZEW).

Dasgupta, P. and P. A. David (2002). "Toward a new economics of science." Science Bought and Sold: Essays in the Economics of Science: 219.

David, P. (1987). Some New Standards for the Economics of Standardization in the Information Age. Economic Policy and Technology Performance. P. Dasgupta and P. Stoneman. Cambridge, Cambridge University Press.

David, P. A. (1993). Intellectual property institutions and the panda's thumb: Patents, copyrights, and trade secrets in economic theory and history. Global Dimensions of Intellectual Property Rights in Science and Technology. M. E. M. Mitchel B. Wallerstein, and Robin A. Schoen**:** 19-61.

David, P. A. and D. Foray (1995). "Accessing and expanding the science and technology knowledge base." STI Review(16).

David, P. A., D. Mowery, et al. (1994). Analysing the economic payoffs from basic research Science and technology policy in interdependent economies. D. C. Mowery, Kluwer Academic Publishers**:** 57-78.

DeBresson, C. and F. Amesse (1991). "Networks of innovators: a review and introduction to the issue." Research Policy **20**(5): 363-379.

Dixon, P. and C. Greenhalgh (2002). The economics of intellectual property: a review to identify themes for future research Oxford Oxford Intellectual Property Research Centre**:** 1-64.

Dodgson, M. and R. Rothwell (1994). Innovation in small firms. The Handbook of Industrial Innovation. M. Dodgson and R. Rothwell. Cheltenham, Edward Elgar.

Dosi, G. (1888). The nature of the innovative process. Technical change and economic theory G. Dosi, C. Freeman, R. Nelson, G. Silverberg and L. Soete. London, Pinter.

Dosi, G., L. Marengo, et al. (2007). Knowledge, competition and appropriability: Is strong IPR protection always needed for more and better innovations? European Policy for Intellectual Property Conference. Lund, Sweden**:** 33.

du Plessis, M., B. V. Looy, et al. (2005). Assessing academic patent activity: the case of Flanders. 5th Triple Helix International Conference: The Capitalization of Knowledge. Turin, Italy.

Edquist, C. and B. Johnson (1997). Institutions and organizations in systems of innovation. Systems of innovation: technologies, institutions, and organizations. C. Edquist. London, Pinter Publishers/Cassell Academic.

Ernst, H. (2001). "Patent applications and subsequent changes of performance: evidence from time-series cross-section analyses on the firm level." Research Policy **30**(1): 143-157.

Etzkowitz, H. (1998). "The norms of entrepreneurial science: cognitive effects of the new university-industry linkages." Research Policy **27**(8): 823-833.

Etzkowitz, H. (2003). "Research groups as 'quasi-firms': the invention of the entrepreneurial university." Research Policy **32**(1): 109-121.

Etzkowitz, H. and L. Leydesdorff (2000). "The dynamics of innovation: from National Systems and "Mode 2" to a Triple Helix of university-industry-government relations." Research Policy **29**: 109-123.

Etzkowitz, H., A. Webster, et al. (2000). "The future of the university and the university of the future: evolution of ivory tower to entrepreneurial paradigm." Research Policy **29**: 313-330.

Faulker, W. and J. Senker (1995). "Policy and management issues in company links with academic and government laboratories: a cross-technology study." Journal of High Technology Management Research **6**(1): 95-112.

Florida, R. L. and W. M. Cohen (1999). Engine or infrastructure? The university role in economic development. Industrializing knowledge: university-industry linkages in Japan and the United States. L. M. Branscomb, F. Kodama and R. L. Florida, MIT Press: 313-330.

Fontana, R. and A. Geuna (2009). The nature of collaborative patenting activities, University of Turin.

Foray, D. and B. A. Lundvall (1998). "The knowledge-based economy: from the economics of knowledge to the learning economy." The Economic Impact of Knowledge: 115.

Freeman, C. (1987). Technology policy and economic performance : lessons from Japan. London, Pinter.

Freeman, C. (1991). "Networks of innovators: a synthesis of research issues." Research Policy **20**(5): 499-514.

Frenz, M. and G. Ietto-Gillies (2009). "The impact on innovation performance of different sources of knowledge: Evidence from the UK Community Innovation Survey." Research Policy **38**(7): 1125-1135.

Frenz, M. and R. Lambert (2008). Mapping closed and open innovation practices: a comparison across nine countries based on micro-level innovation survey data. DIME Working Papers On Intellectual Property Rights. **64**.

Fritsch, M. and R. Lukas (2001). "Who cooperates on R&D?" Research Policy **30**(2): 297-312.

FTC (2003). To Promote Innovation: The Proper Balance Of Competition And Patent Law And Policy. Washington, D.C., Federal Trade Commission.

Furseth, J. and A. Hauglund (2008). Arbeidsdeling mellom Brønnøysundregistrene (BR), NAV Aa-registeret og Statistisk Sentralbyrå (SSB). Oslo, Statistics Norway. **2008/18**.

Galbraith, J. (1952). American Capitalism. Boston, Houghton Mifflin.

Gallini, N. and S. Scotchmer (2002). "Intellectual Property: When is it the best incentive system?" Innovation policy and the economy: 51-77.

Gallini, N. T. (2002). "The economics of patents: Lessons from recent US patent reform." Journal of Economic Perspectives: 131-154.

Gambardella, A. (2005). Patents and the division of innovative labor, Oxford University Press. **14:** 1223-1233.

Gay, C., W. Latham, et al. (2008). "Collective knowledge, prolific inventors and the value of inventions: an empirical study of French, German and British patents in the U.S., 1975-1999." Economics of Innovation and New Technology **17**(1-2): 5.

Georghiou, L., J. S. Metcalfe, et al. (1986). Post-innovation performance: technological development and competition. Houndmills, Basingstoke, The Macmillan Press ltd

Geroski, P. A. (1995). Markets for technology : knowledge, innovation and appropriability. Handbook of the economics of innovation and technological change. P. Stoneman and D. F. Ball. Oxford, Blackwell.

Geuna, A. (2001). "The changing rationale for European university research funding: are there negative unintended consequences?" Journal of Economic Issues **XXXV**(3): 607-632.

Geuna, A. and L. Nesta (2003). University patenting and its effects on academic research. Brighton, SPRU-University of Sussex.

Gibbons, M. L., C. Limoges, et al. (1994). The new production of knowledge: the dynamics of science and research in contemporary societies, London: Sage. http://www. jrc. es/home/report/spanish/articles/vol79/ITP1S796. htm.

Gilbert, R. J. and C. Shapiro (1996). An economic analysis of unilateral refusals to license intellectual property, National Acad Sciences. **93:** 12749-12755.

Godin, B. and Y. Gingras (2000). "Impact of collaborative research on academic science." Science and Public Policy **27**: 65-73.

Graham, S. and D. Mowery (2004). "Submarines in Software? Continuations in US Software Patenting in the 1980s and 1990s." Economics of Innovation and New Technology **13**(5): 443-56.

Granstrand, O. (2006). Intellectual property rights for governance in and of innovation systems. Intellectual Property Rights: Innovation, Governance, and the Institutional Environment. B. Andersen. Cheltenham, Edward Elgar**:** 311.

Green, J. R. and S. Scotchmer (1995). "On the division of profit in sequential innovation." The RAND Journal of Economics: 20-33.

Griliches, Z. (1990). "Patent statistics as economic indicators: a survey." Journal of Economic Literature: 1661-1707.

Griliches, Z. (1992). "The search for R&D spillovers." The Scandinavian Journal of Economics **94**: 29-47.

Grimpe, C. and U. Kaiser (2010). "Balancing Internal and external knowledge acquisition: the gains and pains from R&D outsourcing." Journal of Management Studies **47**(8): 1483-1509.

Guellec, D. and B. van Pottelsberghe (2007). The economics of the European patent system. Oxford, Oxford University Press.

Guerrieri, P. and A. Tylecote (1994). "National competitive advantages and microeconomic behaviour." Economics of Innovation and New Technology **3**(1): 49 - 76.

Gujarati, D. (2003). Basic Econometrics.

Gulbrandsen, M. (2003). Jeg gjør jo ikke dette for å bli rik av det": kommersialisering av norsk universitetsforskning - en intervjustudie. NIFU Rapport. Oslo, Norsk institutt for studier av forskning og utdanning.

Gulbrandsen, M. and J.-C. Smeby (2005). "Industry funding and university professors' research performance." Research Policy **34**(6): 932-950.

Guston, D. H. and K. Keniston (1994). Introduction: the social contract for science. The fragile contract: university science and the federal government, MIT Press.

Hagedoorn, J. (2003). "Sharing intellectual property rightsâ€”an exploratory study of joint patenting amongst companies." Industrial and Corporate Change **12**(5): 1035-1050.

Hagedoorn, J. and J. Schakenraad (1990). Inter-firm partnerships and co-operative strategies in core technologies. New Explorations in the Economics of Technical Change: a theoretical framework. C. Freeman and L. Soete, Pinter**:** 1.

Hall, B. H. and R. H. Ziedonis (2001). "The patent paradox revisited: an empirical study of patenting in the U.S. semiconductor industry, 1979-1995 " RAND Journal of Economics **32**(1): 101-128.

Hamel, G. (1991). "Competition for competence and interpartner learning within international strategic alliances." Strategic Management Journal **12**(S1): 83-103.

Hayek, F. A. (1945). "The use of knowledge in society." The American Economic Review: 519-530.

Henderson, R., A. Jaffe, et al. (1999). "Universities as a Source of Commercial Technology: A Detailed Analysis of University Patenting 1965-1988." Review of Economics ans Statistics **80**(1): 119-127.

Henderson, R. M. and K. B. Clark (1990). "Architectural innovation: the reconfiguration of existing product technologies and the failure of established firms." Administrative science quarterly **35**(1).

Hoekman, J., K. Frenken, et al. (2008). "The geography of collaborative knowledge production in Europe." The Annals of Regional Science: 1-18.

Imai, K. and Y. Baba (1989). Systemic innovation and cross-border networks, paper presented at International Seminar on Science, Technology and Economic Growth, OECD, Paris.

Iversen, E. J. (1998). Understanding Innovation Indicators based on Patents. In K. Smith (ed) Science, Technology and Innovation Indicators- a Guide for Policymakers. Oslo, STEP Group Report.

Iversen, E. (2003). Norwegian SMEs and the IPR-system : Exploration and analysis. A study carried out for the World Intellectual Property Organization (WIPO). Switzerland, WIPO.

Iversen, E. J. (2005). Patenter Som Indikatorer. Det Norske Forsknings- og Innovasjonssystemet - Statistikk og Indikatorer. K. W. Maus and K. Wendt. Oslo, Norges Forskningsråd**:** 220-235.

Iversen, E. J. and A. Kaloudis (2006). IP-valuation as a tool to sustain innovation. The management of intellectual property. D. L. Bosworth and E. Webster, Edward Elgar.

Iversen, E. J., I. Mäkinen, et al. (2009). SNEDIG: Small Nordic Enterprises, Developing IPR in Global Competition. Oslo, Nordisk InnovasjonsCenter.

Jaffe, A. (2000). "The U.S. patent system in transition: policy irmovation and the innovation process." Research Policy **29**: 531-557.

Jaffe, A. B. and J. Lerner (2004). Innovation and its discontents: how our broken patent system is endangering innovation and progress, and what to do about it, Princeton University Press.

Jaffe, A. B., M. Trajtenberg, et al. (1993). "Geographic localization of knowledge spillovers as evidenced by patent citations." The Quarterly Journal of Economics: 577-598.

Janne, E. M. and M. Frenz (2006). Do firms patent to protect or transfer knowledge in support of their innovations? An analysis of the fourth UK Community Innovation Survey. Intellectual Property Rights for Business and Society. London.

Johnson, B. (1988). An Institutional Approach to the Small Country Problem. Small Countries Facing the Technological Revolution. C. Freeman and B.-Å. Lundvall. London and New York, Pinter Publishers.

Kaiser, U. S., C (2004). The CEBR Matched Patent/Patent Applicant/Employee Data Base: Part 1 –Patent Data and Applicant data. Copenhagen, Centre for Economic and Business Research.

Kamien, M. I. and N. L. Schwartz (1982). Market structure and innovation, Cambridge University Press.

Kaufer, E. (1989). The economics of the patent system, Harwood Academic Pub.

Kirzner, I. M. (1973). Competition and entrepreneurship, University of Chicago Press.

Kitch, E. W. (1977). "The nature and function of the patent system." Journal of Law and Economics: 265-290.

Kitch, E. W. (1980). "The law and economics of rights in valuable information." The Journal of Legal Studies: 683-723.

Kleinknecht, A. and J. O. N. Reijnen (1992). "Why do firms cooperate on R&D? an empirical study." Research Policy **21**(4): 347-360.

Klemperer, P. (1990). "How broad should the scope of patent protection be?" The RAND Journal of Economics: 113-130.

Knight, F. H. (1921). Risk, uncertainty and profit. Boston, Houghton-Mifflin.

Kortum, S. and J. Lerner (1998). "Stronger protection or technological revolution: what is behind the recent surge in patenting?" Carnegie-Rochester Confer. Series on Public Policy **48**: 247-304.

Landes, W. M. and R. A. Posner (2004). The political economy of intellectual property law, American Enterprise Institute.

Langlois, R. N. (1992). "Transaction-cost economics in real time." Industrial and Corporate Change **1**(1): 99-127.

Langlois, R. N. (2002). "Modularity in technology and organization." Journal of Economic Behavior and Organization **49**(1): 19-37.

Langlois, R. N. (2005). The Entrepreneurial Theory of the Firm and the Theory of the Entrepreneurial Firm, University of Connecticut, Department of Economics.

Langlois, R. N. and P. L. Robertson (1992). "Networks and innovation in a modular system: Lessons from the microcomputer and stereo component industries." Research Policy **21**(4): 297-313.

Langlois, R. N. and P. L. Robertson (1995). Firms, markets, and economic change: a dynamic theory of business institutions. London, Routledge.

Laursen, K. (1998). Revealed Comparative Advantage and the Alternatives as Measures of International Specialisation, DRUID, Copenhagen Business School, Department of Industrial Economics and Strategy/Aalborg University, Department of Business Studies.

Lazonick, W. (2004). The Theory of Innovation Enterprise. ATOM seminar. Universite de Paris-I.

Lazonick, W. and M. O'Sullivan (1996). "Organization, Finance and International Competition." Industrial and Corporate Change **5**(1): 1-50

Lemley, M. A. and C. Shapiro (2005). "Probabilistic Patents." Journal of Economic Perspectives **19**(2): 75-98

Levin, R. C., A. K. Klevorick, et al. (1987). "Appropriating the returns from industrial research and development." Brookings Papers on Economic Activity: 783-831.

López, A. (2008). "Determinants of R&D cooperation: Evidence from Spanish manufacturing firms." International Journal of Industrial Organization **26**(1): 113-136.

Lundgren, A. (1995). Technological innovation and network evolution, Routledge.

Lundvall, B.-Å. (1992). National Systems of Innovation: Toward a Theory of Innovation and Interactive Learning. London, Pinter Publishers.

Machlup, F. (1958). An Economic Review of the Patent System: . Subcommittee on Patents, Trademarks, and Copyrights of the Committee on the Judiciary, US Senate, Washington DC, US Senate.

Machlup, F. (1962). The production and distribution of knowledge in the United States, Princeton university press.

Machlup, F. (1980). Knowledge and Knowledge Production Princeton, New Jersey Princeton University Press

Machlup, F. and E. Penrose (1950). "The patent controversy in the nineteenth century." The Journal of Economic History: 1-29.

MacLeod, C. (1988). Inventing the industrial revolution, Cambridge University Press Cambridge.

Malerba, F. (2006). "Innovation and the evolution of industries." Journal of Evolutionary Economics **16**(1): 3-23.

Malerba, F. and L. Orsenigo (1996). "Schumpeterian patterns of innovation are technology specific." Research Policy **25**: 451-478.

Malerba, F. and L. Orsenigo (2002). "Innovation and market structure in the dynamics of the pharmaceutical industry and biotechnology: towards a historyâ€□friendly model." Industrial and Corporate Change **11**(4): 667-703.

Mansfield, E. (1986). "Patents and innovation: an empirical study." Management Science: 173-181.

Marshall, A. (1920). Principles of Economics: An Introductory Volume. London., Macmillan & Co.

Marsili, O. and B. Verspagen (2002). "Technology and the dynamics of industrial Structures: an empirical mapping of Dutch manufacturing." Industrial and Corporate Change **11**: 791-815

Martin, B. R. (2003). The Changing social contract for science and the evolution of the university. Science and Innovation: Rethinking the Rationales for Funding and Governance. A. Geuna, A. J. Salter and W. E. Steinmueller. Cheltenham, Edward Elgar Pub**:** 7-29.

Martin, B. R. and H. Etzkowitz (2000). "The origin and evolution of the university species." VEST Journal for Science and Technology Studies **13**(3-4): 9-34.

Martinson, G., H. Lööf, et al. (2009). Impact of economic crises on patenting activity: lessons from the economic downturn after the IT-bubble. The Patent Statistics for Decision-Makers Conference (EPO/OECD). October 2009. Vienna, Austria.

Mazzoleni, R. and R. R. Nelson (1998). "The benefits and costs of strong patent protection: a contribution to the current debate." Research Policy **27**(3): 273-284.

Menell, P. S. (1998). "Intellectual property: General theories." Encyclopedia of law and economics **2**.

Merges, R. P., R. R. Nelson, et al. (1992). On limiting or encouraging rivalry in technical progress: The effect of patent scope decisions, University of California at Berkeley, Center for Research in Management, Consortium on Competitiveness & Cooperation.

Merrill, S. A., R. C. Levin, et al. (2001). A Patent System for the 21st Century. Washington, D.C., THE NATIONAL ACADEMIES PRESS.

Metcalfe, J. S. (2001). "Institutions and Progress." Industrial and Corporate Change **10**(3): 561-586.

Meyer, M. (2003). "Academic entrepreneurs or entrepreneurial academics? research-based ventures and public support mechanisms." R&D Management **33**(2): 107-115.

Meyer, M. (2003). "Academic patents as an indicator of useful research? A new approach to measure academic inventiveness." Research Evaluation **12**(1): 17-27.

Meyer, M., T. Siniläinen, et al. (2003). "Towards hybrid Triple Helix indicators: A study of university-related patents and a survey of academic inventors." Scientometrics **58**(2): 321-350.

Mood, C. (2009). "Logistic Regression: Why We Cannot Do What We Think We Can Do, and What We Can Do About It." European Sociological Review **26**(1): 67-82.

Mowery, D. C. (1989). "Collaborative ventures between US and foreign manufacturing firms." Research Policy **18**(1): 19-32.

Mowery, D. C. and B. N. Sampat (2005). Universities in national innovation systems. The Oxford handbook of innovation. J. Fagerberg, D. C. Mowery and R. R. Nelson. Oxford, Oxford University Press: 209-239.

Mowery, D. C. and A. A. Ziedonis (2002). "Academic patent quality and quantity before and after the Bayh–Dole act in the United States." Research Policy **31**(3): 399-418.

Murmann, J. P. (2003). Knowledge and competitive advantage, Cambridge University Press New York.

Nagaoka, S. and J. P. Walsh (2009). Commercialization and other uses of patents in Japan and the US: Major findings from the RIETI-Georgia Tech inventor survey. RIETI Discussion Paper Series.

Nagaoka, S. and J. P. Walsh (2009). How "open" is innovation in the U.S. and Japan?: evidence from the RIETI-Georgia Tech inventor survey. RIETI Discussion Paper Series.

Negassi, S. (2004). "R&D co-operation and innovation a microeconometric study on French firms." Research Policy **33**(3): 365-384.

Nelson, R. R. (1993). National innovation systems: a comparative analysis, Oxford University Press.

Nelson, R. R. (2001). "Observations on the post-Bayh-Dole rise of patenting at American universities." The Journal of Technology Transfer **26**(1): 13-19.

Nielsen, A. O. (1998). A Selection model of patenting firms in Denmark, Aarhus School of Business - Department of Economics.

Nordhaus, W. D. (1969). Invention, growth, and welfare: A theoretical treatment of technological change, MIT Press Cambridge, MA.

North, D. C. (2005). Understanding the process of institutional change, Princeton, NJ: Princeton University Press.

OECD (2003). Turning science into business: patenting and licensing at public research organisations. Paris, Organisation for Economic Co-Operation and Development.

OECD (2009). Innovation in firms: A Microeconomic Perspective, OECD.

Patel, P. and K. Pavitt (1991). "Large firms in the production of the world's technology: an important case of "non-globalisation"." Journal of international business studies: 1-21.

Penrose, E. (1995). The economies of size and the economies of growth. The Theory of the Growth of the Firm. E. Penrose. Oxford, Oxford University Press.

Penrose, E. T. (1951). The Economics of the International Patent System, Johns Hopkins Press.

Peritz, R. (2008). Patents and Progress: The Economics of Patent Monopoly and Free Access:. Free Access to Use Patented Inventions. What Have We Learned in the Past Fifty Years? . Munich Germany, ATRIP/WIPO 2008 Annual Conference.

Pitkelthy, R. (2006). Patent valuations and real options. The Management of Intellectual Property. D. Bosworth and E. Webster, Edward Elgar.

Plant, A. (1934). "The Economic Theory concerning Patents for Inventions." Economica **1**(1): 30-51.

Potì, B. and R. Basile (2000). Regional differencies of innovation: Firms' organization, regional institutions and innovative performance. OECD-NIS Focus Group on Innovative Firms and Networks, Rome 2-3 October 2000. .

Powell, W. W., K. W. Koput, et al. (1996). "Interorganizational collaboration and the locus of innovation: Networks of learning in biotechnology." Administrative science quarterly: 116-145.

Pugatch, M. P. (2004). The international political economy of intellectual property rights. Cheltenham, Edward Elgar.

Quéré, M. (2008). "Knowledge and innovation: Promoting a system approach of innovation processes." Economics of Innovation and New Technology **17**(1&2): 137-152.

Rhoten, D. and W. W. Powell (2007). "The Frontiers of Intellectual Property: Expanded Protection versus New Models of Open Science." The Annual Review of Law and Social Science is **3**: 345-73.

Richardson, G. B. (1972). "The Organisation of Industry." Economic Journal **82**: 883-896.

Robertson, P. L. and R. N. Langlois (1995). "Innovation, networks, and vertical integration." Research Policy **24**(4): 543-562.

Rosenberg, N. (1995). "Innovation's uncertain terrain." The McKinsey Quarterly **3**: 170-185.

Rosenberg, N. and R. R. Nelson (1994). "American universities and technical advance in industry." Research Policy **23**(3): 323-348.

Sampat, B. N. and R. R. Nelson (2002). "The evolution of university patenting and licensing procedures: An empirical study of institutional change." Advances in Strategic Management **19**: 135-164.

Sapsalis, E., B. V. Looy, et al. (2005). On the Patenting Performance of European Universities. 5th Triple Helix International Conference : The Capitalization of Knowledge. Turin, Italy.

Sapsalis, E. and B. V. P. D. L. Potterie (2003). "Insight into the patenting performance of Belgian universities." Brussels Economic Journal **46**(3): 37-58.

Saragossi, S. and B. van Pottelsberghe de la Potterie (2003). "What Patent Data Reveal about Universities: The Case of Belgium." The Journal of Technology Transfer **28**(1): 47-51.

Saviotti, P. (1996). Technological Evolution, Variety and the Economy. Cheltenham, Edward Elgar Publishing Ltd.

Saviotti, P. and S. e. Metcalf (1991). Evolutionary Theories of Economic and Technological Change: Present State and Future Prospects London, Harvard.

Scherer, F. M. (1965). "Firm Size, Market Structure, Opportunity, and the Output of Patented Inventions." The American Economic Review **55**(5): 1097-1125.

Scherer, F. M. (2001). The Innovation Lottery. Expanding the Boundaries of Intellectual Property: Innovation Policy for the Knowledge Society R. C. Dreyfuss, D. L. Zimmerman and H. First. Oxford, Oxford University Press.

Scherer, F. M. (2005). "The propensity to patent." Patents: Economics, Policy, and Measurement **1**: 198.

Schmidt, T. (2006). An Empirical Analysis of the Effects of Patents and Secrecy on Knowledge Spillovers, ZEW - Zentrum für Europäische Wirtschaftsforschung / Center for European Economic Research.

Schmiedeberg, C. (2008). "Complementarities of innovation activities: An empirical analysis of the German manufacturing sector." Research Policy **37**(9): 1492-1503.

Schmoch, U. (2004). The technological output of scientific institutions. Handbook of quantitative science and technology research: the use of publication and patent statistics in studies of S & T systems. H. F. Moed, W. Glänzel and U. Schmoch, Kluwer Academic Publishers.

Schmookler, J. (1957). "Inventors past and present." Review of Economics and Statistics **39**: 321-333.

Schmookler, J. (1962). "Economic Sources of Inventive Activity." The Journal of Economic History **22**(1): 1-20.

Schneider, C. (2007). The Outcome of Patent Applications - Does Experience Matter? MPRA University Library of Munich, Germany.

Schumpeter, J. A. (1912). The theory of economic development: an inquiry into profits, capital, credit, interest, and the business cycle. New York, Oxford University Press.

Schumpeter, J. A. (1942). Capitalism, socialism and democracy. New York, Harper.

Scotchmer, S. (1991). "Standing on the shoulders of giants: cumulative research and the patent law." The Journal of Economic Perspectives: 29-41.

Sen, A. K. (1963). "Neo-classical and neo-Keynesian theories of distribution." The Economic Record **39**(85): 53-64.

Shapiro, C. and R. D. Willig (1990). "On the Antitrust Treatment of Production Joint Ventures." The Journal of Economic Perspectives **4**(3): 113-130.

Singh, K. (1997). "The impact of technological complexity and interfirm cooperation on business survival." Academy of Management Journal: 339-367.

Slaughter, S. and G. Rhoades (1996). "The Emergence of a Competitiveness Research and Development Policy Coalition and the Commercialization of Academic Science and Technology." Science, Technology & Human Values **21**(3): 303-339.

Smith, K. (2001). "Cross-country comparisons: Comparing economic performance in the presence of diversity." Science and Public Policy **28**(4): 267-276.

Somaya, D. and D. Teece (2001). "Combining Patent Inventions in Multi-Invention Products: Transactional Challenges and Organizational Choices." University of California at Berkeley Working Paper.

Stankiewicz, R. (1986). Academics and entrepreneurs: developing university-industry relations. London, Pinter.

Sutton, J. (2001). Technology and market structure: theory and history. Cambridge, MIT Press.

Suzuki, J. and F. Kodama (2004). "Technological diversity of persistent innovators in Japan Two case studies of large Japanese firms." Research Policy **33**(3): 531-549.

Symeonidis, G. (1996). Innovation, Firm Size and Market Structure: Schumpeterian Hypotheses and Some New Themes, OECD, Economics Department.

Takalo, T. (1999). Essays on the Economics of Intellectual Property Protection. University of Helsinki, Department of Economics, Department of Economics.

Teece, D. J. (1986). "Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy." Research Policy **15**: 285-305.

Teece, D. J. (1996). "Firm organization, industrial structure, and technological innovation." Journal of Economic Behavior and Organization **31**(2): 193-224.

Teece, D. J., G. Pisano, et al. (1997). "Dynamic capabilities and strategic management." Strategic management journal **18**(7).

The Research Council of Norway (2003). Det norske forsknings- og innovasjonssystemet - Statistikk og indikatorer. Det Norske forsknings- og innovasjonssystemet - statistikk og indikatorer. Oslo: 376 pages.

Tietze, F., O. Granstrand, et al. (2006). "Towards Strategic Intellectual Property Management-Events During the Development: Evidence from Biotech SMEs." Technology Management for the Global Future, 2006. PICMET 2006 **2**.

Trajtenberg, M., R. Henderson, et al. (1997). "University Versus Corporate Patents: A Window On The Basicness Of Invention." Economics of Innovation and New Technology **5**(1): 19 - 50.

Troy, I. and R. Werle (2008). Uncertainty and the Market for Patents. MPIfG Working Paper 08/2, MPIfG.

Valentin, F. and R. L. Jensen (2003). "Discontinuities and distributed innovation: the case of biotechnology in food production." Industry and Innovation **10**(3): 275-310.

Van Dijk, T. W. P. (1994). The limits of patent protection: Essays on the Economics of Intellectual Property Rights. UNU Merit. Maastricht, Maastricht University.

Van Looy, B., M. Ranga, et al. (2004). "Combining entrepreneurial and scientific performance in academia: towards a compounded and reciprocal Matthew-effect?" Research Policy **33**(3): 425-441.

Vavakova, B. (1998). "The new social contract between governments, universities and society: has the old one failed?" Minerva **36**: 209-228.

Wallerstein, M. B., M. E. Mogee, et al. (1993). Global dimensions of intellectual property rights in science and technology, National Academy Press.

Webster, A. (2003). "Knowledge Translations: Beyond the Public/Private Divide?" Journal of Education through Partnership **3**(2): 7-22.

Wilkins, L. and D. C. Karaomerlioglu (1999). "Integrating Research and Development in the Subsidiaries of Transnational Companies." Technology and Innovation Management, Portland, Oregon, USA, ISBN: 1-890843.

Wu, T. (2006). "Intellectual Property, Innovation, and Decentralized Decisions." Virginia Law Review: 123-147.

General Annexes: Databases and Compilation Issues

Annex 0-1 The compilation of the databases and their analysis

The database analysis conducted in this study is based on coupling the identity of Norwegian applicants for trademark and patents with firm-level information available for a full-count of Norwegian enterprises. We linked the Norwegian Patent Office databases covering patents and trademarks with publicly compiled registry-data covering all Norwegian enterprises. This was the clearly the best possible way to approach the question of who uses the patent and trademark systems in Norway. It was pursued because it could provide a totally unique and detailed picture of Norwegian applicants for these two types of rights.

Some problems were inevitably confronted which required more work than anticipated. The major reason for this was the fact that the link between databases had to be done on the bases of names (and zip codes) of the Norwegian applicant: there was no reliable identifier in the applications that would allow a join with the public registry data (see recommendations). Since errors or variations occur in the names columns of the databases involved, this required different approaches to make the links combined with a large degree of manual checking of the links.

Below we provide more information about the NPO databases and the Registry data, how the databases were linked, and assumptions made in their interpretation.

The NPO data

A. The selection of the trademark and patent data was done along the following lines:

1. The Time-Span: all applications that were active during the 1990s. By this we mean all applications that were received from January 1 1990 to December 31, 1999, or any application that was granted during that period, regardless of application date.
2. "Norwegian" applications are application in which at least one of the applicants (not necessarily inventor) provide a Norwegian address. Only a small proportion of the total applicants were mixed and most of these had the Norwegian addressee as the primary applicant.
3. The information included information about who of the application (the names of all applicants and an unreliable identity number), the where (applicant address and zip-code), the when (application date and, if applicable, grant/registry date), the what (application titles and the primary IPC class), and the how (the status of the patent application, for example whether granted, whether withdrawn/rejected and under what conditions, or whether still under examination).

B. This data was then cleaned, and the following links made:

1. the zipcodes were associated to county and district-levels via the Norwegian Post's database.
2. the primary IPC classes of the patent applications were associated to Technological Areas by a widely-used Correspondence Key: the INPI/OST/ISI Key, Version 3.

THE REGISTRY DATA

This data was then associated with full-count registry data of Norwegian enterprises. The enterprise-level information used here includes information about firm-size, industrial activity, number of companies, (in later years) annual turnover etc. It comes from a unique, publicly assembled registry covering all active Norwegian companies. This type of registry is only found in a limited number of countries, especially the Nordic countries.

The registry is put together by Statistics Norway on the bases of firm-level information from the Brønnøysund Register Centre (http://www.brreg.no/english/) register of Norwegian enterprises and companies and the National Insurance Service's (Rikstrygdeverket) registry of active employees and employers. This database gives us a picture of all enterprises (and subsidiary companies) who formally pay wages to at least one person. (a registered workforce of about 2million)

A. The selection of the registry data was conducted along the following lines:

1. Enterprises (foretak) versus Establishments (bedrift): the enterprise-level was used and all values (number of employees and turnover) were aggregated up to this level.
2. Industrial activity: The enterprise's industry is defined via the EU's NACE classificaiton (Nomenclature générale des Activités économices dans les Communautés Européennes). The activities of enterprises previous to 1994 when the NACE was introduced in Norway have been linked to the previous classification system used by Statistics Norway (=ISIC). Industrial activity is based on the enterprises' main product. In aggregating up from establishment to enterprise, the dominant NACE class has been used. (see NACE 74150, Holding company as special case) The most up-to-data classification is used if this had changed over time.
3. Zipcodes were associated to county and district-levels via the Norwegian Post's database, thus allowing us an additional criterion on which to check the identity of the applicants.

B. This data was then cleaned, and the data defined in the following way:

1. DEFINING "LARGE" Enterprises

Large enterprises are basically those with a total of at least 100 employees. Three additional criteria are used to define what is considered 'large' here as well. The first supplement involves enterprises which include at least 19 'establishments'; these include Norwegian parts of large franchises. Enterprises defined under NACE 74150 (Holding corporations) that employ more than 30 are also considered large. These include diversified corporations whose management is defined as a separate enterprise. In order to pick up all large scale operations, enterprises with a combined turnover of 99 MKR in at least one of the years for which we have turnover data (1997-1999) are also considered large.

There is a disruption at around 1995 in the data, both regarding NACE code and number of employees. One source of these difficulties is the transition to NACE from ISIC Rev 2 classification system. Another is the way the firm-level information was compiled. A third is the fact that several major Norwegian companies were undergoing restructuring at that time. (for example the telecoms operator, Telenor) These potential sources of errors have been screened, and any remaining inaccuracies are not expected to affect the results.

2. DEFINING "INDIVIDUAL"

The classification 'individual' is based on applications with no apparent affiliation with an enterprise or other organization. These are applications in which the assignee is listed on the basis of a first and last name, and which do not connect with the significant number of individually run enterprises when the county is also checked. This population potentially includes inventions made at universities, since Norwegian law currently allows academic researchers to own their inventions. The addresses were hand-checked to help prevent incorrectly classifying them.

3. DEFINING "UNKNOWN"

A number of IPR applicants whose names seem to be that of an enterprise or institution would not connect with the AA register or Enhetsregister. (2001) In other words, these entities are not registered in the registry material. These may be companies who died before they could be registered or who are in the process of registering. Or there might be a mistake that makes it impossible to link the name in the application to the name in the registry database. This population was manually checked to try to isolate any apparent mistake. We assume that entities in this population are most probably not large companies.

4. DEFINING "UNREGISTERED"

Another population has been called 'unregistered'. These include entities that have an identifiable enterprise number but which cannot be connected with substantive information in the registry database we have. This indicates that there are no employees, especially if the link was made with the registry-data in the period, 1989-95.

Annex 0-2 PATSTAT DESCRIPTION

Over the last several years, the OECD Directorate for Science, Technology and Industry, jointly with other members of the OECD Patent Statistics Taskforce,8 have developed a patent database that is suitable for statistical analysis – the OECD Patent Statistics Database. Further work has recently been undertaken by the Taskforce members towards developing a world-wide patent database – The EPO/OECD Worldwide Patent Statistical Database (PATSTAT). The European Patent Office (EPO) has taken over responsibility for development and management of the database.

The PATSTAT database is drawn directly from the EPO's master database (Rollinson and Lingua 2007). It has been developed specifically for use by governmental/ intergovernmental organizations and academic institutions, and optimised for use in the statistical analysis of patent data. It has become a primary source of patent data information for statisticians, academics, and policy advisors (Rollinson and Heijnar 2006).

The PATSTAT database has a world-wide coverage (over 80 patent offices), spanning a time period stretching back to 1880 for some countries. It contains over 70 million patent documents. It is updated twice a year. Patent documents are categorised using the international patent classification (IPC) and some national classification systems. In addition to the basic bibliometric and legal data, the database also includes patent descriptions (abstracts), applicant and inventor names, as well as citation data. The PATSTAT database is thus an ideal source of patent data information for the purposes of this report.

Other Taskforce members include the European Patent Office (EPO), Japan Patent Office (JPO), United States Patent and Trademark Office (USPTO), World Intellectual Property Organisation (WIPO), National Science Foundation (NSF), EUROSTAT, and DG Research.