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Intellectual Property Strategies and Innovation

Causes and Consequences for Firms and Nations

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Department of Technology Management and Economics
CHALMERS UNIVERSITY OF TECHNOLOGY
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THESIS FOR THE DEGREE OF LICENTIATE OF ENGINEERING

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Abstract

New and useful ideas and knowledge, commonly denoted innovations after coming into use, are of decisive importance for economic growth and welfare. To promote the generation and diffusion of innovations, most, if not all, industrialized and industrializing societies rely on some form of an intellectual property rights (IPRs) system. As technological diversification, technological convergence, and open innovation become increasingly important, proper management of and strategies for IPRs and intellectual property (IP) becomes ever more central for the competitiveness of firms and nations. The general purpose of this thesis it to explore and explain the causes and consequences of IP strategies and policies at firm, national, and international levels in different industrial contexts with different types and degrees of openness in innovation. With focus on technological innovations and technology-related IP, various methods are employed to fulfill the purpose.

The results show that, due to IP policy developments at national and international level, large firms have increasingly developed various IP strategies, especially patent strategies, to appropriate returns from innovations. As an example, large firms were found to in a first step increase their patenting (in terms of quantity), and in a second step focus more on selective and quality-oriented patenting in which the IP-related work is also internationalized. This internationalization of IP heavily impacts the patent offices and IP policies, especially in small countries where the national patenting tend to decrease as a result. Small firms on the other hand cannot gain the same benefits as large firms from an IPR system, especially from the patent system as currently designed, since they do not have enough resources for monitoring and enforcing their rights, which in turn limits the protective function of patents. Instead, small firms use patents to attract customers and investors. Patents then provide a governance mechanism for early stage financing of innovations.

A new measure based on statistics at the national level indicates that the preferred markets for patenting from firms and inventors in various countries become increasingly similar. In addition, there is a convergence of national legal IPR systems around the world. Developing and industrializing nations in this convergence process typically switch from a weak to a strong IP regime in their national innovation systems, at a point in time when the mainly innovative benefits of a strong regime outweigh the mainly imitative benefits of a weak regime for the nation and its firms. A similar switch from a weak to a strong IP regime can be seen in various innovation systems, e.g. in mobile telecommunications. The openness of innovation in such a corporate innovation system is closely related to the IP strategies of the involved firms, and the results show that the openness in a system is directly and strongly affected by changes in the IP strategies of its firms.

The thesis shows the importance of the interaction between IP strategies of large and small firms, between different large and small nations' IP policies, and between IP strategies of firms and IP policies of nations. Such interactions are essential to consider for future research, as are the roles of IPRs and IP management in innovation systems with various degrees of openness.

Keywords: *Intellectual property; intellectual property right; patent; technology; innovation; open innovation; economics; management; appropriation; strategy; policy*

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List of appended papers

Paper I

Holgersson, M. Patent propensity, appropriation and motives for patenting innovations: A literature review and an empirical study of entrepreneurial SMEs. Submitted to *R&D Management*.

Paper II

Granstrand, O., and Holgersson, M. The anatomy of rise and fall of patenting and propensity to patent: The case of Sweden. Submitted to *Research Policy*.

Paper III

Granstrand, O., and Holgersson, M. Managing multinational technology and intellectual property (IP) – Is there global convergence? Submitted to *International Journal of Technology Management*.

Paper IV

Bogers, M., Granstrand, O., and Holgersson, M. The dynamics of multi-layered openness in innovation systems: The role of distributed knowledge and intellectual property. Work in progress. To be submitted.

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List of abbreviations

CAPM	Capital asset pricing model
CEO	Chief executive officer
China	People's Republic of China
EPO	European Patent Office
ETSI	European Telecommunications Standards Institute
FDI	Foreign direct investment
GDP	Gross domestic product
IC	Intellectual capital
IP	Intellectual property
IPC	International patent classification
IPR	Intellectual property right
JPO	Japan Patent Office
Korea	Republic of Korea ('South Korea')
MC	Marginal cost
MELT	Management, economics, law, and technology
MNC	Multinational corporation
NIC	Newly industrialized country
PCT	Patent Cooperation Treaty
PLC	Product life cycle
PTO	Patent and trademark office
RBT	Resource-based theory
ROI	Return on investment
R&D	Research and development
SIPO	State Intellectual Property Office, China
SME	Small or medium-sized enterprise
TCE	Transaction cost economics
TRIPS	Agreement on Trade-Related Aspects of Intellectual Property Rights
USPTO	United States Patent and Trademark Office
VC	Venture capital
WIPO	World Intellectual Property Organization
WTO	World Trade Organization

1 Introduction

Economic growth and welfare developments are driven by new and useful knowledge. More specifically, developments in technical knowledge (technology) and innovations have been shown to largely impact economic developments and growth. As the interest for the relation between innovations and growth at both firm and national levels has increased, the interest for issues related to intellectual property (IP) and intellectual property rights (IPRs), including patents, has consequently grown. Nations use IPR systems for incentivizing the generation and diffusion of new knowledge, and firms and other actors then use such systems to promote their own interests and increase their competitiveness. IP strategies are thus central for competitiveness at many levels.

Legal and political changes in the US in the 1980s, which essentially strengthened the IP regime, led to what is sometimes called a ‘pro-IP era’ or a ‘pro-patent era’ (Granstrand, 1999). As a result, US patenting increased steeply. That increase spurred the interest for IP issues among practitioners and scholars, and a number of studies investigated the increase in patenting (see e.g. Kortum and Lerner, 1998; Hall and Ziedonis, 2001). More recent trends show a rapid increase of patenting in developing countries, especially in China, as studied by Hu and Jefferson (2009) and Hu (2010).

Related developments are the increasing importance of technological convergence (Rosenberg, 1963; Jantsch, 1967), technological diversification (Kodama, 1986; Granstrand and Sjölander, 1990; Granstrand et al., 1997), and various forms of open innovation (Granstrand and Sjölander, 1990; Chesbrough, 2003, 2006; Chesbrough et al., 2006). Such trends are related (see e.g. Granstrand et al., 1997), and they lead to an increased need for proper management and strategies of IPRs and IP.

This thesis will deal with strategies related to IP and IPRs at the firm, national, and international levels, and the thesis and its four appended papers take on a wide scope of the concept of IP strategies. Paper I reviews the literature related to patent propensity, appropriation strategies and motives for patenting, and presents empirical results on entrepreneurial SMEs. Paper II investigates the causes and consequences of increases and decreases in patenting in Sweden and Swedish firms. Paper III studies global IP-related developments, and especially whether there is a global convergence. Paper IV, finally, relates IP strategies to the dynamics of openness in innovation systems.

This cover paper is outlined as follows. The introductory chapter is followed by a problem description and the purpose in chapter 2. Previous research and the frame of reference are discussed in chapter 3. Based on previous research, the specific research questions are outlined in chapter 4, before the methodology is motivated and described in chapter 5. The methodology is followed by summaries of the appended papers in chapter 6. The answers to the research questions are presented in chapter 7, leading to conclusions and suggestions for future research in chapter 8.

2 Problem and purpose

Intellectual property used to be patents only. Now everyone begins to realize that intellectual property is not only patents, it is actually whole sets of architectures or skill-sets of a technology, or even business models. That moves it into the strategy room with questions like: If we have this intellectual property or these assets, how can we best make use of them? (Leif Johansson, CEO of Volvo Group) [1]

2.1 Background

As described in the introduction, current business trends have led to an increased interest for, focus on and importance of IP and IPRs and proper management of these. In the early 1980s, legal changes in the US, including the creation of the US Court of Appeals for Federal Circuit (CAFC) and the strengthening of enforcement of patent rights, led to what is sometimes referred to an explosion in patenting in the US (see e.g. Hall, 2005) and the 'pro-patent era' (Granstrand, 1999). Since then, US patenting has more than tripled (as seen in Figure 2.2 in section 2.3) and large firms have increased their patenting a lot, exemplified by the top ten patentees[2] in Table 2.1. As globalization is increasing, this change has impacted firms also outside the US, and Asian firms in fact hold a large share of granted US patents. The worldwide patenting has also increased during the same period, albeit with a slightly lower pace, see Figure 2.1.

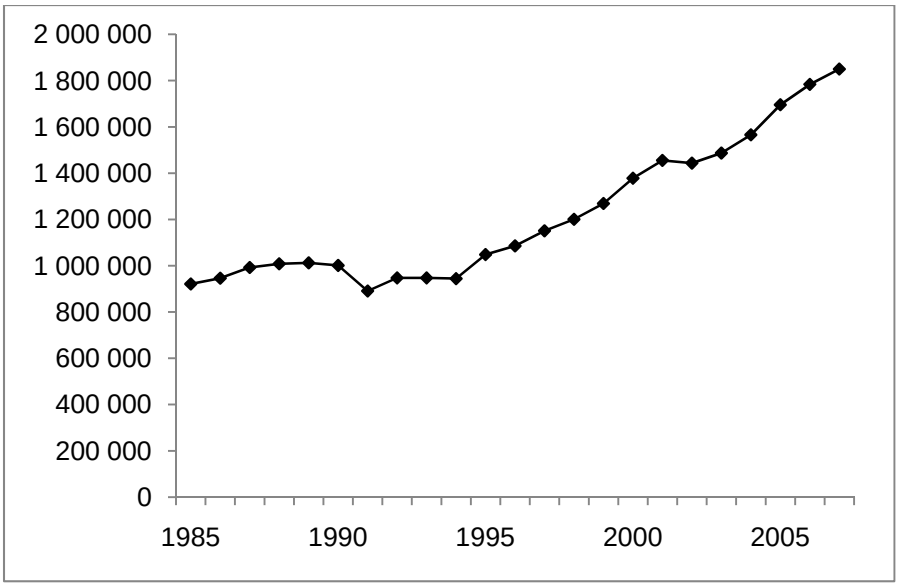
Table 2.1 Top ten patentees in terms of granted US utility patents in 1987, 2000 and 2010

	1987	No.		2000	No.		2010	No.
1	Canon	847	1	IBM	2886	1	IBM	5866
2	Hitachi	845	2	NEC	2021	2	Samsung	4518
3	Toshiba	823	3	Canon	1890	3	Microsoft	3086
4	General Electric	779	4	Samsung	1441	4	Canon	2551
5	US Philips	687	5	Lucent	1411	5	Panasonic	2443
6	Westinghouse	652	6	Sony	1385	6	Toshiba	2212
7	IBM	591	7	Micron Technology	1304	7	Sony	2130
8	Siemens	539	8	Toshiba	1232	8	Intel	1652
9	Mitsubishi Electric	518	9	Motorola	1196	9	LG Electronics	1488
10	RCA	504	10	Fujitsu	1147	10	HP	1480
	Total:	6785		Total:	15913		Total:	27426

Source: Statistics from USPTO for year 2000 and 2010, and Granstrand (1999) for year 1987

[1] This statement was made by the CEO of Volvo Group, Leif Johansson, in a project interview at Volvo Group's headquarters in Gothenburg, 2009-09-16.

[2] The concept 'patentee' denotes the patent applicant, while 'patentor' is the person or actor granting the patent. Similarly 'licensee' denotes a license buyer, while the 'licensor' is the license seller.



Source: Statistics from WIPO

Figure 2.1 Patent applications worldwide per year, 1985-2007

This growth in patenting indicates an increasing importance of IP and increasing relative values of intellectual capital (IC). Granstrand (1999) elaborates upon the notion of intellectual capitalism, a form of capitalism where the traditional dependence upon fixed assets is increasingly replaced with dependence upon intellectual and intangible assets, such as knowledge, competence, patents, trademarks, etc. A number of measures have been used by various scholars to point at the increasing relative value of intellectual capital, although few of them actually provide any clear evidence if scrutinized.[3] However, the fact that the share of

[3] A number of measures of increasing importance of IP and intellectual capitalism that have been used can be questioned. First, looking at increased patenting, the worldwide increase to a large extent stems from increases in patenting in the United States and various countries in Asia, e.g. Japan, Korea, India and China, see e.g. Figure 2.2. Since the rise in Asia might be due to general catching-up effects (see e.g. Abramovitz, 1986) this does not provide proof of increasing intellectual capitalism. Additionally, the industrialization of the world has increased during the same period, which affects the statistics of patent applications. Industrialization in itself is of course related to intellectual capitalism, however.

Second, the value of trademarks is sometimes used as a measure. The sum of the values of the eight most highly valued trademarks in 1992 was 132.6 BUSD (see Granstrand, 1999), while the sum of the values of the eight most highly valued trademarks in 2009 (which is another set of trademarks) was 363.8 BUSD (see Interbrand, 2009). This corresponds to an increase in trademark values of 174% from 1992 to 2009 in nominal terms. Since the most highly valued trademarks are mainly owned by US companies, the value growth can be compared to the increase in GDP for the US from 1992 to 2007 which was 229% in nominal terms (based on OECD Statistics, 2009). Hence, the growth in trademark values has been lower than the growth of GDP in the US. At the same time, comparing growth in trademark values with GDP growth as an indication of intellectual capitalism is misleading, since much of the GDP growth might be driven by intellectual capital and knowledge and this measure therefore might underestimate intellectual capitalism. Nevertheless, the fact that the GDP of the US grows faster than the top values of trademarks could, if anything, be seen as an indicator of decreased intellectual capitalism.

Third, some scholars compare market values of companies with low numbers of employees (e.g. Google) with market values of companies with high numbers of employees (e.g. Ford) to show that the relative value of

people's lives spent on education and learning increases and that the intensity of knowledge and information in products and services rises still indicate that society is becoming increasingly knowledge-based (Granstrand, 1999). Knowledge in general is then of increasing importance for competitiveness of countries, companies, individuals, etc. More specifically, technical knowledge (technology) and technological developments are major factors behind economic developments (Schumpeter, 1942; Solow, 1956, 1957; Rosenberg, 1982; Rosenberg and Birdzell, 1986; Scherer, 1999; Baumol, 2002). Considering the role of IP and IPRs in incentivizing and diffusing technology, innovation and knowledge investments on country level and in corporate and technology management on firm level, it is clear that IP strategies are of pivotal importance for the competitiveness of countries as well as firms.

2.2 Rationale of an IPR and patent system

> *As we have seen, information is a commodity with peculiar attributes, particularly embarrassing for the achievement of optimal allocation. In the first place, any information obtained, say a new method of production, should, from the welfare point of view, be available free of charge (apart from the cost of transmitting information). This insures optimal utilization of the information but of course provides no incentive for investment in research.* (Arrow, 1962, pp. 616-617)

Knowledge has characteristics of a public good, meaning that consumption by one actor does not restrict consumption by others (non-rival) and that it is impossible to exclude actors from using the good (non-excludable). The non-excludability leads to investors in R&D, technology and innovation having problems with appropriating returns from their investments. Teece (1986) showed that the profits from innovation are likely to end up with holders of complementary assets when imitation is easy, rather than with the inventing actor. Arrow (1962) and Mansfield et al. (1977) showed theoretically and empirically, respectively, that underinvestment in R&D and innovation occurs due to this market failure. Considering the importance that technological developments have for economic developments and growth, countries try to incentivize technology and innovation investments by various means. An IPR system in general, and a patent system more specifically, is thus constructed to make knowledge excludable, at least temporarily, and thereby incentivize generation and diffusion of inventions. The role of a patent is thus to temporarily exclude others than the patent holder from commercially using the invention. Other IPRs function similarly. The European Patent Office (EPO) defines (as of 2011) a patent as "a legal title granting its holder the right to

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intellectual capital in the world has risen since companies with only few employees nowadays can outcompete very large organizations in terms of market values. However, such a comparison is also misleading since human capital is an important part of intellectual capital, which is further described in section 3.1.2.

Fourth, the market to book-ratio or Tobin's q can be used, which indicate the relation between a company's market value and the booked value of its assets. Still, the development of Tobin's q over time shows no clear evidence for increased levels of intellectual capital (despite the all time high around year 2000). Part of the reason for this might be more liberal accounting with companies beginning to book more and more intangible assets, leading to a decreased Tobin's q.

prevent third parties from commercially exploiting an invention without authorization". From a national policy perspective a patent system therefore has two main functions:

1. Stimulation of R&D and innovation investments.
2. Stimulation of knowledge disclosure.[4]

An IPR system is one, but not the only, way of incentivizing the generation and diffusion of knowledge and inventions (Scotchmer, 2004; Greenhalgh and Rogers, 2010; Granstrand, 2011a, 2011b), and the patent system has actually received a lot of critique (see e.g. Jaffe and Lerner, 2004) for creating too high transaction costs and monopolistic over-pricing leading to welfare losses, and some have even suggested to abolish the system. The consequences of abandoning the patent system are however impossible to overlook, and the following quote to some extent pervades contemporary views of the patent system:

> *If one does not know whether a system 'as a whole' (in contrast to certain features of it) is good or bad, the safest policy conclusion is to 'muddle through' – either with it, if one has long lived with it, or without it, if one has lived without it. If we did not have a patent system, it would be irresponsible, on the basis of our present knowledge of its economic consequences, to recommend instituting one. But since we have had a patent system for a long time, it would be irresponsible, on the basis of our present knowledge, to recommend abolishing it.* (Machlup, 1958, p. 80)

Alternatives to a patent system, commonly used in a complementary way, include sales tax reductions and subsidies, innovation procurement contracts, R&D tax credits/deductions, innovation prizes, and R&D grants/subsidies (cf. Wright, 1983; David, 1993; Granstrand, 2003; Scotchmer, 2004; Greenhalgh and Rogers, 2010). See Granstrand (2011b) for a more thorough elaboration on this subject.

From a company strategy perspective patents also have two roles, related to the roles on policy level above:

1. *Patent rights are important as competitive means for the protection and commercial exploitation of new technologies.*
2. *Patent information is important as a means for technology and competitor intelligence.* (Granstrand, 1999, p. 71)

A company further needs to weigh the benefits from a patent, or any other IPR, against the costs. Benefits from a patent typically include possibilities to deter competition and employ monopolistic pricing; creation of an identifiable asset that can be used in licensing, financing, cooperation, divestment, etc.; creation of an asset that can be activated on the balance sheet; enabling intra-firm licensing for cross-country transfer of profits; and creation of incentives to invent and measurements of inventive productivity (Granstrand, 1999, 2010). The costs of a patent typically relate to the direct costs of writing (including translating), filing and renewing

[4] A national patent application is typically published 18 months after the filing (priority) date or when the patent is granted, whichever comes first.

the patent; the costs of monitoring and enforcing the patent; and the drawbacks with the related information disclosure.

2.3 IP strategies

IP strategies are here differentiated into two main levels; macro (national) level policies and micro (firm) level strategies, in accordance with the discussion above.[5] At macro level, IP policy problems relate to how to manage the IPR system, while IP strategy problems at micro level relate to how to manage **in** the IPR system.

A number of more or less adjustable parameters are related to an IPR system at macro level, and when managing the system the purpose is ultimately to maximize dynamic competition while sacrificing as little static competition as possible, and in addition commonly to promote domestic firms and inventors (which not necessarily complies with promotion of competition, as described below). A national IPR system typically consists of a range of various IPRs, such as patent rights, trademark rights and design rights (see also section 3.1.3). Each IPR is designed to fulfill one or more purposes. Parameters related to this design include what should be protectable[6], how long should it be protected, how strong should it be protected, where should it be protected, what should be the cost, etc. (for the case of patents, see e.g. Gilbert and Shapiro, 1990; Klemperer, 1990; Merges and Nelson, 1990). A general problem is then that various IPR systems are typically designed in a 'one size fits all' type of way (Thurow, 1997). This becomes a problem since various actors, intangibles and technologies are impacted differently from an IPR system. Technologies with short product life cycles (PLCs) and low investment levels, e.g., have the same maximal protection time by a patent as technologies with long PLCs and high investment levels. The latter typically needs longer market exclusivity to reach positive returns on investments (ROI), whereby also a longer protection time would ideally be given, and vice versa.[7] Further, small and medium sized enterprises (SMEs) have been shown to utilize and benefit from a patent system differently than large firms (Granstrand, 1988; Blind et al., 2006; Leiponen and Byma, 2009; Rassenfosse, 2011; Paper I).

A nation's government has an important role in international competition and for the competitiveness of the nation's firms, and the domestic science and technology policy is important in that context (Porter, 1990). The national IPR system is one way of promoting nationalistic interests and the management of the system is thus of outmost importance for the competitiveness of the nation and its firms. In that context, the competitiveness of the nation's firms relative foreign firms might be more important to promote than creating a well-functioning system promoting dynamic and static competition within the nation. Strong and

[5] In this thesis, 'micro' relates to the level of the firm, or groups of firms, while 'macro' relates to the level of nations (i.e. national and international issues). In accordance with this distinction, macro level IP strategies are primarily denoted 'IP policies'.

[6] 'Patentable subject matter' in the case of the patent system.

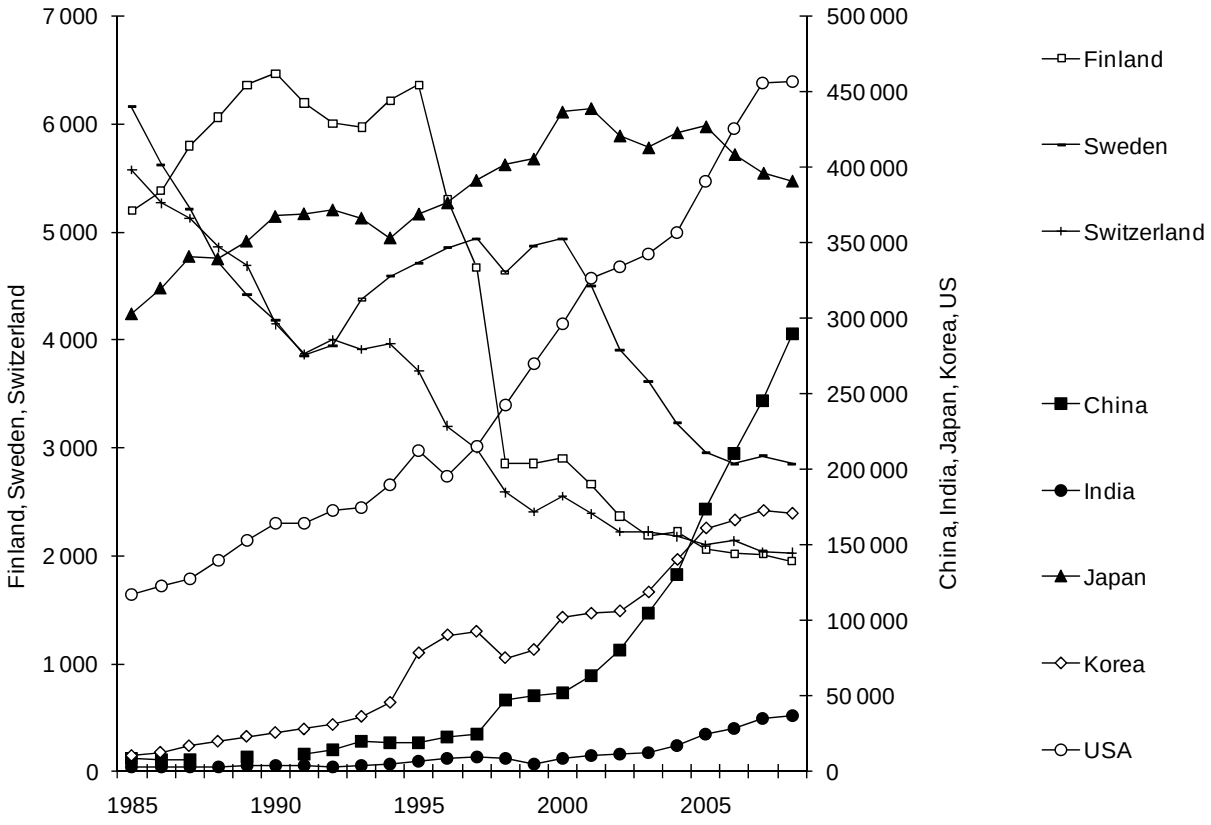
[7] Some flexibility in terms of patent protection time is available in cases of pharmaceutical patents subject to many years of trials before marketing due to government regulations.

weak IP regimes might therefore be of different use throughout the industrialization process of a country (weak IP regimes are then typically useful when catching up while strong IP regimes are typically more beneficial when forging ahead, as discussed in Paper III). An IPR system therefore typically evolves over time and with the level of industrialization in the country. The history of patent-like rights goes back to at least the 14th century (Granstrand, 1999) although what is often referred to as the first formal patent statute was adopted in Venice in 1474 (Guellec and van Pottelsberghe, 2007). China's first patent law came in 1984 (Keupp et al., 2010) which can be compared to 1623 in England, 1790 in the US, and 1819 in Sweden. As the IPR systems around the world have evolved, they have also started to converge, not the least after the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) in 1994, and its enforcement through the World Trade Organization (WTO).[8]

Looking at the development of national patent frequency in various countries it is clear that the development is very different throughout the world, see Figure 2.2. While national patenting increases in the US and in Asia, it decreases in a number of small industrialized European countries, here exemplified with Sweden and some similar small countries in terms of industrial structure. In this connection it is important to note that there are a number of different routes to take when applying for a patent, as described in Paper II, and statistics must therefore be treated with care. Since Swedish patentees can file patent applications not only to the Swedish patent and trademark office (PTO), but also to any other national PTO, to the European Patent Office (EPO), or in the international PCT system, the decline in Swedish national patenting does not necessarily imply a decreased inventive output in Sweden, but could also indicate a strategic change among its inventing actors.

At firm level, IP and IP management is increasingly accepted as strategically important matters that deserves and requires top management focus, as exemplified by the quote in the beginning of this chapter (see also Granstrand, 1999; Reitzig, 2007). Many companies (and products) become increasingly technologically diversified (Kodama, 1986; Pavitt et al., 1989; Granstrand and Oskarsson, 1994). As the diversification increases, the costs of R&D increase (Granstrand and Oskarsson, 1994). Granstrand (1998) suggests that this partly has to do with the coordination and integration work necessary when incorporating multiple technologies in the firm. How to appropriate the returns from R&D investments become increasingly important as R&D costs increase. The use of various means for appropriation as originally studied by Levin et al. (1987), and subsequently by a stream of literature reviewed in section 3.5 and Paper I, is therefore of interest. Such means include IPRs, but also other means such as market lead times, marketing efforts, switching costs, and cost reductions in production.

[8] See also National Resource Council (1993) for a discussion on harmonization and differentiation of IPR systems.



Source: Statistics from WIPO and national PTOs

Figure 2.2 National patent applications in selected countries per year, 1985-2008

In addition, as more diverse technologies are included in products and companies, external technology acquisition and sourcing and different forms of open innovation becomes increasingly important, putting new and increased demands on IP management. Before marketing a new technology (in form of a product or a process), all necessary IPRs need to be collected, e.g. by using licensing agreements, to ensure freedom to operate. The problem of collecting all necessary rights is sometimes called the IP assembly problem (Granstrand, 2010), and firms without IPRs to cross-license risk to pay large royalties due to vast amounts of IPRs spread across stakeholders, a phenomenon referred to as royalty stacking (Lemley and Shapiro, 2007; Paper IV). However, industrial developments have pointed not only at the problem of assembling IPRs, but also at the problem of disassembling the rights in cases of divestments. A recent example is the different consolidation efforts in the automobile industry, e.g. GM's purchase of SAAB Automobile (1990) and Ford's purchase of Volvo Car Corporation (1999), whereby extensive IPRs were collected and merged in joint developments. In 2010 (after a global financial crisis) when both GM and Ford were to divest SAAB Automobile and Volvo Car Corporation, respectively, one of the main issues to solve was how to divide the IPRs (raising interest and involvement from financiers as well as from the Swedish government, besides the involved firms).

Related to assembling and disassembling IPRs are technology acquisition and exploitation strategies in general (Granstrand, 1982; Granstrand and Sjölander, 1990). The dichotomy of acquisition and exploitation (originating from the works on innovation of Schumpeter, 1934)

is then fairly interchangeable with similar dichotomies like exploration and exploitation (see e.g. March, 1991), and inbound and outbound innovation (see e.g. Chesbrough and Crowther, 2006; Dahlander and Gann, 2010). Patents and other IPRs play an important role here as they enable technology and knowledge trade (Arora et al., 2004; Granstrand, 2004), e.g. by various forms of licensing (Bogers et al., 2011), which would otherwise be hampered due to the nature of information which needs to be revealed before traded (Arrow, 1962), often referred to as the information paradox.

Since an IPR system at macro level is designed for promoting generation and diffusion of knowledge and ideas at micro level, there are obviously interactions between the strategies and actions at macro level and the strategies and actions at micro level, and vice versa. Such interactions therefore need to be taken into account when studying IP strategies. IP strategies further include managerial, economical, legal, and technological aspects, and IP strategies at both macro and micro levels are to large extent part of an international rather than national context, which also must be addressed. Hence, when studying IP strategies it is important to apply a multinational and interdisciplinary approach (see e.g. Granstrand, 2003).

2.4 Purpose and scope

The general purpose of the thesis is to explore and explain the causes and consequences of intellectual property (IP) strategies and policies at firm, national, and international levels in different industrial contexts with different types and degrees of openness in innovation.

The thesis focuses mainly on technology-based firms, technology-based competition and technology-related strategies. Therefore, the thesis also focuses, albeit in a non-exclusive way, on technical inventions. Many types of IPRs can be used to protect technology-based competitiveness, including patent rights, trademark rights, and trade secret rights. However, most emphasis will be on patents in this thesis, since it is the IPR specifically designed to protect and promote technical innovations.

3 Frame of reference and previous research

This chapter starts with defining some of the key concepts for the thesis, leading to a discussion on microeconomic theory and open innovation. This is followed by previous research on various issues related to IP strategies. The literature review is not exhaustively complete, but focuses on the literature streams of most importance for the outline of research questions in the following chapter.

3.1 Key concepts

There are a number of concepts important to this thesis, mainly related to innovation and intellectual property. The main ones are here described, and the descriptions of the concepts are grouped into concept families.

3.1.1 Discoveries, inventions, innovations and imitations

A first concept family is that of discoveries, ideas, inventions, innovations and imitations. Discovery, to start with, is a finding of some pre-existing feature of nature (Granstrand, 1999). This may e.g. be a law of nature.

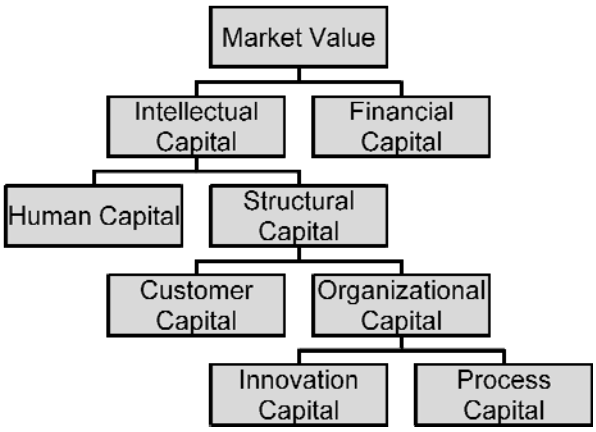
Many definitions of an invention exist. One example is “The first idea, sketch or contrivance of a new-to-the-world product, process or system, which may or may not be patented” (Freeman et al., 1982, p. 201). However, an invention is most often distinguished from an idea in that the invention is the technical application of the idea. An invention differs from a discovery in that it is invented by man – hence not existent before being invented. An imitation is defined as a close reproduction, copy or duplication of something once perceived as an invention.

An innovation is commonly defined as something new that has come to some sort of use, following the works of Schumpeter (1934). Granstrand (1999) defines an innovation as a “change in ideas, practices or objects involving some degree of (i) novelty or creation based on human ingenuity and (ii) success in application” (p. 58). Notice now that it is mainly the second part of this definition that separates the definition of an innovation from the definition of an invention. Hence, an invention is turned into an innovation when the invention comes to its first use, e.g. by being sold the first time (in the case of a product invention) or by being applied in production (in the case of a process invention). Common terms for these two parts of the innovation concept are exploration and exploitation (see e.g. March, 1991) and acquisition and exploitation (Granstrand, 1982; Granstrand and Sjölander, 1990). Studies have shown that, while firms struggle with combining the two activities, the ones who succeed increase their sales growth (He and Wong, 2004). Dichotomies of the size of innovations or changes typically distinguish between incremental (minor/continuous/evolutionary) and radical (major/discontinuous/revolutionary) innovations and changes. The ability in an organization to implement both types of change is commonly called ambidexterity (Tushman and O’Reilly, 1996), although this concept has also been used as the ability of combining exploration and exploitation (see e.g. He and Wong, 2004), which is not necessarily the same thing.

3.1.2 Intellectual capital, assets, property and property rights[9]

The concepts in the family of intellectual property, intellectual capital, intellectual assets and intellectual property rights have not yet been fully established and homogenously defined in academia and practice, which is described e.g. by Marr et al. (2004). Further, it is difficult to account for the values of intellectual property, assets, etc. since there are no exchange value related to them (Hall, 1989). Hall (1989) also describes intellectual assets as difficult to accumulate and acquire, as capable of simultaneous multiple use and as both inputs or outputs in business processes.

One of the early frameworks of intellectual capital was developed within the Swedish insurance company Skandia by Edvinsson (1997) and is illustrated in Figure 3.1. One of the drivers behind the development of this model was a perceived need for better valuation of companies and accounting measures more linked to the actual market value. The use of these new accounting procedures later led to a bubble in Skandia's stock value which enabled the top management of the company to collect large bonuses. This resulted in what was probably the largest corporate scandal in Sweden during the first decade of the 21st century, in turn staining the concept of intellectual capital to some extent among investors.



Source: Edvinsson (1997)

Figure 3.1 Skandia intellectual capital framework

There are a variety of other frameworks of intellectual capital available, but most frameworks have emerged to include three general building blocks (Marr and Adams, 2004), see e.g. McConnachie (1997), Roos et al. (1997), Sveiby (1997), Lev (2001), and Bontis (2002). The first building block is human capital (by some authors called individual capital, human resources or human resource intangibles) which relates to the knowledge, skills, experience, etc. related to specific employees. The second block is the structural capital (internal structure, organization resources, structural resources or organizational intangibles) and it

[9] Notice that the word intellectual is commonly exchanged for intangible and immaterial. Intangibles is e.g. often used with the same meaning as intellectual or immaterial assets.

mainly relates to the organization, management, attitudes, R&D, software, etc. The final building block is the relational capital (external structure, relationships resources, customer capital or stakeholder relationship) which refers to the relationships with all different stakeholders, including customers and suppliers. A general framework for intellectual capital and intangible assets, based on the above discussion, is illustrated in Figure 3.2. However, intellectual capital is distinguished from intangible assets by having some kind of assignable capitalized value. Intangible assets can therefore be seen as a slightly broader concept, since the intellectual capital is the part of these assets with "some kind of assignable capitalized value".

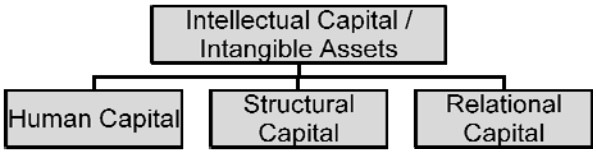


Figure 3.2 Framework for intellectual capital and intangible assets

Moving on to IP, what is the difference between an asset and a property? Encyclopædia Britannica defines property as "an object of legal rights, which embraces possessions or wealth collectively, frequently with strong connotations of individual ownership. In law the term refers to the complex of jural relationships between and among persons with respect to things. The things may be tangible, such as land or goods, or intangible, such as stocks and bonds, a patent, or a copyright" (Encyclopædia Britannica, 2009). However, the actual difference between an intellectual property and an intangible asset is not entirely clear. Granstrand (1999, p. 18) makes the following distinctions which will be used in the thesis:

> *In common language, the term 'property' usually refers to resources (or assets) of some sort, physical (tangible, material) or otherwise over which somebody can exercise some justified control. In a broad sense, intellectual property (IP) can be taken to mean the opposite of physical or material or tangible property, and thus becomes synonymous with immaterial property. The term 'property right' refers to a right (or bundle of rights) that has evolved in society as recognized enforceable claims to some benefits or use of the resource. The rights may be transferable and may be treated as property or resources in themselves. Thus, property right is a social construct to be distinguished from the underlying resource. To emphasize this distinction, the fuller expressions 'property rights' and 'intellectual property rights' (IPR) are used. Intellectual property rights are typically comprised of patent rights, copyrights, design rights, trademark rights, trade secret rights and a few other special property rights as items in contemporary law. Intellectual capital in turn essentially comprises all immaterial resources that could be considered as assets with some kind of assignable capitalized value.*

Following the reasoning above, IPRs will be distinguished from IP. IP will be used as a broad concept for intangible assets with ownership assigned to them, whilst IPRs are the legal rights protecting the ownership of the asset.

3.1.3 Intellectual property rights

There are a number of (legal, economic, management, engineering, etc.) textbooks describing the different IPRs and the legal and practical aspects around them, see e.g. Koktvedgaard and Levin (2004), Rockman (2004), and Spence (2007). Rockman (2004) takes his standpoint in US law and divides the IPRs into patents, trademarks/service marks, copyrights and trade secrets. Patents protect novel, useful and non-obvious inventions. In the US, designs can be protected by a design patent (different from the utility patent protecting inventions). Copyrights "cover the creative works of authors, composers, software developers, artists and the like" (Rockman, 2004, p. 5). Trademarks and service marks protect the "source identity" of products and services. Examples of source identities are logos and names. Trade secrets protect from misappropriation of valuable secrets that are not generally known. However, a trade secret does not protect from others inventing the same thing independently or from reverse engineering. Hence, trade secrets are most suitable for secrets that are difficult to discover or reverse engineer.[10] Notice also that e.g. patents and copyrights expire after a certain time[11] while there is no legally codified end to trade secret rights.

Spence (2007) bases his description on the UK situation and divides the IPRs into copyrights, patents, trademarks and database rights. The database right protects a collection of "independent works, data or other materials which are systematically arranged and individually accessible" (Spence, 2007, pp. 11-12).

Koktvedgaard and Levin (2004), finally, describe IPRs from the Scandinavian legal point of view and divide them into copyrights, patents, design rights and trademarks. Hence, trade secret rights are not included in this description even though trade secrets are protectable by law in Sweden.

The national differences which can be identified in the descriptions of IPRs above will at this point be left without further comments. Notice however that the IPRs in general only offer a national protection. If e.g. an invention is patented in Germany it offers only legal protection in Germany. This does not give the owner right to prevent others from using the invention in e.g. France. Copyrights, in contrast, commonly protect the owner internationally, at least in practice (Koktvedgaard and Levin, 2004).

Worth noticing is that a patent in itself does not give the owner any freedom to use the invention commercially, it might in fact be hindered by other patents. Consider a case where a basic invention is patented by company A. Company B then improves the basic invention and patents this improvement. Then company B needs a license from company A on the basic invention before having the right to produce its product (based on both inventions). The patent

[10] Rockman (2004) also describes mask works for semiconductors as an IPR, but due to its limited importance for this thesis it is not further discussed here. Interested readers are referred to the original reference.

[11] The length of a copyright varies in different jurisdictions. In the US and in Sweden, a copyright lasts for 70 years after the death of the creator of the copyrighted work. A patent typically lasts for 20 years after the filing of the application as long as the renewal fees are being paid. See also Greenhalgh and Rogers (2010) for a description of the length, breadth and coverage of various intellectual property rights.

does only give the owner a right to prevent others from using the patented invention commercially (Spence, 2007), not a right for the owner to commercialize it him-/herself.

Even though no commonly accepted general division into different IPRs can be identified in the literature (which is not surprising due to differences in national laws) the following non-exclusive division will be used here:

- Copyrights
- Design rights
- Patent rights
- Trademark rights
- Trade secret rights

This list of IPRs is by no means exhaustively complete. A number of other rights are also available in various jurisdictions, including database rights, mask work rights, plant breeder's rights / plant variety rights, etc.

3.1.4 Strategy

Strategy is an essential concept in the thesis. Strategy is originally a military concept referring to "the science or art of employing all the military, economic, political, and other resources of a country to achieve the objects of war" (Encyclopedia Britannica, 2010). Porter describes competitive strategy as "taking offensive or defensive actions to create a defendable position in an industry…and thereby yield a superior return on investment for the firm" (1980, p. 34). In a resource-based view of the firm a strategy can be described as the resource allocation that facilitates a maintained or improved performance (Barney, 1997).

Mintzberg defines a strategy as "a pattern in a stream of decisions" (Mintzberg, 1978, p. 934), and Mintzberg and Waters (1985) emphasize that strategies typically lie on a continuum between deliberate and emergent strategies. Deliberate strategies are patterns of decisions realized as intended, while emergent strategies are patterns of decisions realized despite or without intentions. Hence, Mintzberg and Waters recognize that on one hand are strategies not always deliberate, and on the other hand does a deliberate plan not always lead to a pattern of decisions according to the plan.

The strategy concept is commonly used at different levels. Corporate strategy e.g. refers to an entire corporation's strategy while business strategy often refers to a business unit's strategy or a company's strategy on a specific market. A nation's strategy, often referred to as policy, typically denotes the strategy of a nation or country in improving competitiveness of the nation and its firms. Science and technology policies are an important means for governments in promoting their country's competitiveness (Porter, 1990) and IPR policies are an important part of such policies.

3.2 Microeconomic theory

Although no contributions to microeconomic theory are being made in this thesis, this section presents a general background to increase the understanding of various arguments made. In addition, Paper IV is to a large extent related to theories of the firm, which motivates a short

introduction.[12] Three streams of microeconomic theory, mainly focusing on theory of the firm, are essential to this thesis.[13]

First, neoclassical economic theory in the footsteps of Marshall (1890) and others is commonly used when dealing with the economics and rationale of IPRs (see e.g. Granstrand, 1999, 2010; Scotchmer, 2004; Greenhalgh and Rogers, 2010). When a firm receives a patent on a product technology, the society as a whole makes a temporary welfare loss (deadweight loss) due to monopolistic pricing above the marginal cost (MC), while the firm can make a profit (enabling a positive ROI). This is a sacrifice made from society's point of view in order to create incentives for firms to invest in R&D in the first place. However, since the patent protection is temporary the pricing will essentially fall to the MC, leading to increased welfare for society at large. Since products are typically based on more than one patented invention, and since there might be supplementary products and inventions, reality is of course seldom as simple as this economic model. This does not mean that the model is of no use, however. The neoclassical theory of the firm builds on an assumption of profit maximization, and that a firm should expand its output whenever profitable, i.e. whenever the benefits are greater than the costs (see e.g. Frank, 2006).

Second, transaction cost economics (TCE) of the firm as pioneered by Coase (1937) and Williamson (1975, 1985, 1996) is pivotal to the thesis. Contractual relationships are central in TCE, making it especially useful when studying IP strategies, but also when studying e.g. open innovation. The theory emphasizes the interaction between the cost of organizing transactions within an organization and the cost related to transactions on the market (between actors) using a price mechanism. Coase argues that a firm is created when the internal transaction cost is lower than the transaction cost on the market. The transaction costs on the market typically relates to the costs of discovering the relevant price, negotiating, contracting, etc. Coase (1937, p. 392) summarizes:

> *We may sum up this section of the argument by saying that the operation of a market costs something and by forming an organization and allowing some authority (an "entrepreneur") to direct the resources, certain marketing costs are saved.*

Williamson (1975) distinguishes between transactions on the market and within the hierarchy (within the organization). Like Coase, Williamson thereby sees markets and firms as "alternative instruments for completing a related set of transactions" and further that "whether a set of transactions ought to be executed across markets or within a firm depends on the relative efficiency of each mode" (Williamson, 1975, p. 8). He includes the concept of atmosphere in his transaction cost theory to emphasize the importance of 'attitudinal interactions' that might occur and that the exchange process in itself thereby might be assigned a value. Asset specificity is central in TCE (see e.g. Williamson, 1983, 1985), a concept which relates to resources' values being dependent on a specific transaction. Hence,

[12] Further advancements will also be made in this area when developing this Licentiate thesis into a PhD thesis.

[13] Notice that macroeconomic theory is also related to this thesis, e.g. the role of technological developments for economic growth.

asset specificity leads to the parties being tied to the transaction and each other. Another important concept in TCE is information impactedness which exists when "true underlying circumstances relevant to the transaction, or related set of transactions, are known to one or more parties but cannot be costlessly discerned by or displayed for others" (Williamson, 1975, p. 31).

Third, the resource-based theory (RBT) of the firm as put forward by Penrose (1959) emphasizes the resources of a firm, and the services rendered by such resources. In a similar way as in TCE, RBT distinguishes between the firm and the market in that the "essential difference between economic activity inside the firm and economic activity in the 'market' is that the former is carried on within an administrative organization, while the latter is not" (Penrose, 1959, p. 13). Penrose also emphasizes the ambiguous concept of the firm:

> *A 'firm' is by no means an unambiguous clear-cut entity; it is not an observable object physically separable from other objects, and it is difficult to define except with reference to what it does or what is done within it.* (Penrose, 1959, p. 9)

A number of strategy scholars have followed in the footsteps of Penrose, developing what is commonly called the resource-based view. The works by Wernerfelt (1984) and Barney (1991) are central in this stream of literature, and the work of Prahalad and Hamel (1990) on core competencies is also important. Barney defines (after some critique from Priem and Butler, 2001) resources as "the tangible and intangible assets a firm uses to choose and implement its strategies" (2001, p. 54). A competitive advantage is defined to exist when a value creating strategy is implemented by a firm without "simultaneously being implemented by any current or potential competitors" (Barney, 1991, p. 102). A sustained competitive advantage, finally, is a competitive advantage that the current or potential competitors are unable to duplicate (Barney, 1991). The competitive implications of a resource can be assessed by the VRIO framework, analyzing the resource's **v**alue, **r**areness, **c**ost to imitate, and exploitability by the **o**rganization (see e.g. Barney and Hesterly, 2005). Intellectual property strategies have major impact on all parts of this framework. Teece et al.'s (1997) work on dynamic capabilities (partly building on Nelson and Winter, 1982) should also be mentioned here. They emphasize the importance of identifying and embracing new opportunities effectively and efficiently rather than focusing on blocking and raising costs for competitors and new entrants.

Most theories of the firm are compatible with each other (Granstrand, 1998), and the complementarities between TCE and RBT have been increasingly recognized (see e.g. Jacobides and Winter, 2005). As various microeconomic theories see the (complex) world from various points of view, it is often beneficiary to employ multiple theories, although with care:

> *Given the complexity of the phenomena under review, transaction cost economics should often be used in addition to, rather than to the exclusion of, alternative approaches. Not every approach is equally instructive, however, and they are sometimes rival rather than complementary.* (Williamson, 1985, p. 18)

Both TCE and RBT are useful when studying contractual relations and boundaries of the firm. In TCE, various forms of contractual relations are included, emphasizing various degrees of integration. Penrose to some extent also discusses this issue:

> *The concept of the firm developed above does not depend on the ramification of stock ownership or the mere existence of the power to control … On the other hand, long-term contracts, leases, and patent license agreements may give an equally effective control … If a corporation is controlled by … a larger corporation, it is part of the larger firm only if there is evidence of an administrative co-ordination of the two corporations … Thus, although many industrial firms are more or less loosely bound together by a common source of finance or a strong element of common ownership, the mere existence of such connections is not of itself sufficient evidence that administrative co-ordination is effective and adequate enough to justify calling such a grouping a firm.* (Penrose, 1959, pp. 18-19)

The distinction between a firm and a market is thus not clear-cut, and there are various degrees of hierarchy, depending on the concentration of responsibility (Williamson, 1985). In fact, quasi-integrated forms of organizations have been argued to be most conducive to technological innovation and that they will therefore become more common as a result of market and organization failures and managerial and technological innovations (Granstrand, 1982). Technology and technological developments have however not been sufficiently accounted for in received theories of the firm, as described by e.g. Granstrand (1998), and including them is not easily done, since innovation processes should be viewed as "changes in a complete system of not only hardware, but also market environment, production facilities and knowledge, and the social contexts of the innovating organization" (Kline and Rosenberg, 1986, p. 304).

3.3 Open innovation

Research on open innovation has been increasing since the work of Chesbrough (2003), where the concept of open innovation was coined: "Open Innovation is a paradigm that assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as the firms look to advance their technology" (Chesbrough, 2003, p. xxiv). Research and practice of open innovation span a much longer time horizon, however (Trott and Hartmann, 2009; Bogers et al., 2010; Dahlander and Gann, 2010). See e.g. the works of Allen (1977) on gatekeepers, Granstrand (1982) on quasi-integrated organizations for technology development, and von Hippel (1988, 2005) on various sources of innovation.

Granstrand (1982), Granstrand and Sjölander (1990), and Granstrand et al. (1992) present a framework of technology procurement/acquisition and exploitation, based on various strategies for acquiring and exploiting the technology base of a firm. These are ranked in order of the contractual relationships in a TCE inspired way, i.e. in order of the organizational

integration as described above, essentially ranging from closed to open ways of acquiring[14] and exploiting[15] the technology base. Dahlander and Gann (2010) present a similar generic framework, based on previous research, with two dimensions of open innovation, namely (1) inbound and outbound, and (2) pecuniary and non-pecuniary. Empirical studies have shown that there are complementarities between open and closed forms of innovation (see e.g. Cassiman and Veugelers, 2006), especially in that internal R&D increases a firm's absorptive capacity, i.e. the ability to recognize, assimilate and apply external knowledge commercially (Cohen and Levinthal, 1990). It has also been shown that inbound openness is related with costs, and at some point the search for external ideas renders more costs than benefits (Laursen and Salter, 2006)

Discussing openness implies some form of boundary, and the discussion of the theory and boundaries of the firm in section 3.2 and elsewhere thus become essential (see also Paper IV). Depending on which level of boundary one refers to, and the degree of openness of that boundary, different types and different degrees of openness can be identified. An open, collaborative atmosphere between two firms does not necessarily mean that these firms are very open in general. If they have a joint venture, which in turn is very closed (in some sense) to the outside, the joint venture could in turn be regarded as one closed actor, containing two firms with boundaries that are open to a limited part of the external environment. Hence, openness is a fairly complex issue where a lot of conceptual and theoretical work remains to be done (see Penrose, 1959, for a discussion of what should/could be regarded a firm and not).

IP issues are central in open innovation, and there are many (interrelated) functions of IPRs related to open innovation. In fact, one of the main purposes of an IPR system is to stimulate the disclosure and diffusion of new knowledge among various actors, as described in section 2.2. Patent information is a rich source of technological solutions, and technological intelligence (technology scanning), e.g. by studying patent information, could be seen as one form of open innovation (see e.g. Granstrand and Sjölander, 1990). IPRs further enable technology trade of various forms and IPRs can be used as means for governance of open and collaborative innovation. Licensing and technology trade have been extensively studied (see e.g. Arora, 1997; Arora et al., 2004; Granstrand, 2004; Lichtenthaler, 2010). Although standard-related issues have attracted some interest (see e.g. Swann, 2000; Blind and Thumm, 2004; Paper IV), few studies of the role of IPRs in governing open innovation more generally have so far been undertaken (for an exception, see e.g. Foray and Steinmueller, 2003).

[14] These include internal R&D (including recruitment and training), acquisition of innovative projects or firms (units), joint technology ventures, technology purchasing (contract R&D, licensing in, etc.), and technology scanning. See also Granstrand and Sjölander (1990).

[15] These include internal exploitation (direct investments in production and/or marketing of products), creation of innovative projects or firms (units), joint ventures, technology selling (performing contract R&D, licensing out, etc.), divestment, and storage, dissemination and leakage. See also Granstrand and Sjölander (1990).

3.4 Propensity to patent and patent frequency

There is a difference between patent frequency (number of patents per time unit) and patent propensity; the latter being defined as the propensity to patent a patentable invention (Mansfield, 1986) or innovation (Arundel and Kabla, 1998). When discussing propensity to patent, it is therefore important to distinguish between the patent per R&D cost ratio and the propensity to patent a patentable invention or innovation. Between the R&D variable and the patent variable is an intermediate variable, namely the number of patentable inventions per R&D cost (R&D yield). Somewhat simplified, and without taking uncertainties and time lags into account, the relations between different variables can be expressed with the following formula: Number of patents = R&D × R&D yield × Patent propensity.

Early empirical studies by Scherer (1965, 1983) showed that US firms' patent frequency was mainly related to their R&D outlays, and most commonly linearly so in regressions, but with varying coefficients over industries. There was in most industries no significant departure from constant returns (59.7%), and deviations from constant returns were more commonly towards diminishing returns (25.0%) than increasing returns (15.3%).

Patent propensity varies with industry and firm characteristics. The results of Scherer (1983) further showed that the patent per R&D ratio varied over industries, and later results have shown that also the patent propensity varies over industries (see e.g. Mansfield, 1986; Arundel and Kabla, 1998; Brouwer and Kleinknecht, 1999). Firms with R&D collaboration agreements have been found to be more likely to patent than others. A conclusion is that patents help formalizing R&D collaborations (Brouwer and Kleinknecht, 1999).

Further, SMEs have lower propensities to patent than large firms (Mansfield, 1986; Arundel and Kabla, 1998; Brouwer and Kleinknecht, 1999; Chabchoub and Niosi, 2005), while they at the same time have higher patent per R&D ratios than large firms (Bound et al., 1984; Granstrand, 1988). An important fact here is however that innovation activities in SMEs are underestimated when measured by R&D statistics while innovation activities in large firms are underestimated when measured by patent statistics (Pavitt, 1982).

The decline and then rise in US patenting in the 1970s and 1980s, respectively, have raised interest about patent propensity and patent frequency from researchers. Griliches (1988) explained the decrease during the 1970s with business cycle reasons and two oil price shocks. Regarding the increase in the 1980s, Kortum and Lerner (1998) found that the rise in patenting was driven by changes in R&D management and increases in innovative activities with more applied R&D. However, the strengthening of enforcement of patent rights and the creation of CAFC, leading to higher propensities to patent, have most commonly been used as an explanation behind the increase (see e.g. Granstrand, 1999; Hall and Ziedonis, 2001). Similarly, the recent rise in Chinese patenting has been explained by strengthened legislation, foreign direct investments (FDIs), entry of non-state enterprises with more IPR awareness, and increased R&D intensity. For a more thorough review of this literature, see Paper I and Paper II.

3.5 Appropriation and IP strategies

The ability to capture returns from R&D investments is commonly denoted appropriability (Teece, 1986, Levin et al., 1987). A number of studies have studied the relative effectiveness and importance of various means and strategies of protecting the competitiveness of new products and processes. Similarly as for patent propensity, the effectiveness of different means varies widely over various industries (Levin et al., 1987; Granstrand, 1999). Patents are typically more effective for product innovations than for process innovations (Levin et al., 1987; Granstrand, 1999). Patents have however been shown to be one of the least effective means for appropriation in numerous studies (Levin et al., 1987; Harabi, 1995; Kitching and Blackburn, 1998; Brouwer and Kleinknecht, 1999; Granstrand, 1999; Cohen et al., 2000; Leiponen and Byma, 2009). Instead, firms typically rate informal means of appropriation more effective, such as sales or service efforts, market lead times, learning/cost reductions, secrecy, and switching costs. The only exception is found among Japanese firms, where patents have been rated the most effective means (Granstrand, 1999). The main perceived drawbacks with patenting are the possibility for competitors to legally invent around patents and the information disclosure related to patenting (Levin et al., 1987; Harabi, 1995), as well as the high economic and non-economic costs of patenting (Kicthing and Blackburn, 1998; Cohen et al., 2000). Despite these drawbacks and the perceived relative low effectiveness of patenting, firms seem to make use of them frequently. In industries where patents were rated unimportant, roughly 60% of patentable inventions were still patented (Mansfield, 1986). This is sometimes referred to as the patenting paradox. The patent propensity is however higher among firms where patents are rated more important for appropriation (Arundel and Kabla, 1998; Arora and Ceccagnoli, 2004).

In this connection it is important to note that various appropriation means are not mutually exclusive, as is, at least implicitly, assumed in some of the abovementioned studies. Patents are e.g. one way of increasing market lead time, as is secrecy. In addition, various means are complements rather than substitutes. For a further discussion on this stream of literature, see Paper I.

3.6 Motives for patenting

Previous research on patent propensity and appropriation means indicates that while patents are rated with low effectiveness in protecting new products and processes, inventions and innovations are frequently patented (see e.g. Mansfield, 1986). This patenting paradox leads to the question: Why do firms patent? This question has rendered a number of studies. Despite the fact that patents have been shown to have little effectiveness in appropriation, the main motive for patenting is undisputedly to protect innovations and thereby prevent imitation (Arundel et al., 1995; Duguet and Kabla, 1998; Granstrand, 1999; Cohen et al., 2000; Thumm, 2004; Blind et al., 2006; Giuri et al., 2007). Other important motives are to avoid trials and to reach a strong position in negotiations (Arundel et al., 1995; Duguet and Kabla, 1998; Granstrand, 1999) and to block other firms' R&D and patenting efforts (Cohen et al., 2000). Additionally, in industries where standards are of importance, e.g. in telecommunications, the possibility to reach a strong position in the standard by patenting essential inventions is an important motive to patent (Granstrand, 1999; Bekkers et al., 2002).

SMEs have been found to, more than large firms, emphasize reputation motives behind patenting, i.e. to improve technological image and company value (Blind et al., 2006). In addition, SMEs more than large firms patent to license or to convince investors and banks about the value of an invention (Granstrand, 1988; Rassefosse, 2011). Other studies have also addressed patents' function as a value signal to investors (Lemley, 2000; Hsu and Ziedonis, 2008; Haeussler et al., 2009), and SMEs in general are more likely to need venture capital. See Paper I for more information on this topic.

3.7 Value of IPRs and patents

Some IPRs can be extremely valuable, while most have low or no value. The list of the world's most highly valued trademarks in 2009, and the corresponding values in 2007 and 2001, is presented in Table 3.1 (see also Interbrand, 2009). Such values must of course be treated with care, since they are extremely difficult to measure considering the lack of a market to value them. Despite this, they give an indication of the high values of the top trademarks. Simultaneously, the world is full of trademarks with extremely low values.

Table 3.1 The world's most highly valued trademarks

2009 Rank	Trademark	2009 Value (BUSD)	2007 Rank	2007 Value (BUSD)	2001 Rank	2001 Value (BUSD)
1	Coca-Cola	68.7	1	65.3	1	68.9
2	IBM	60.2	3	57.1	3	52.8
3	Microsoft	56.6	2	58.7	2	65.1
4	GE	47.8	4	51.6	4	42.4
5	Nokia	34.9	5	33.7	5	35.0
6	McDonald's	32.3	8	29.4	9	25.3
7	Google	32.0	20	17.8	>100	-
8	Toyota	31.3	6	32.1	14	18.6

Source: Interbrand (2009)

Copyrights can also be very valuable. This is exemplified by the massive profits some copyright holders can make, but also by the severe decrease in revenue that the music and movie industries experienced as more or less legal/illegal internet-based distribution channels started to take off in the early 2000s, to various extents infringing on copyrighted material. However, most copyrights are again of low or no value.

Similarly as for other IPRs, patent value distributions are extremely skewed, as reported by Lanjouw et al. (1996), Scherer (1999), and Harhoff et al. (2003). In fact, they are so skewed that an infinite variance of patent values cannot be ruled out. This means firstly that in such cases the capital asset pricing model (CAPM) cannot be unreservedly used when valuing patent assets (Granstrand, 2003), and secondly that portfolio strategies do not guarantee that average values will reach a stable mean (Scherer, 1999). In general, patents and other IPRs

are very difficult to value, even ex post, due to the difficulty in assessing the related cash flows.[16]

[16] See e.g. Copeland et al. (2005) and Damodaran (2002) for general valuation principles and Mun (2006) for a real options approach in valuing patents and other assets.

4 Research questions

The general purpose of the thesis is to explore and explain the causes and consequences of intellectual property (IP) strategies and policies at firm, national, and international levels in different industrial contexts with different types and degrees of openness in innovation. This purpose will be addressed by a number of different research questions that are outlined here, based on previous research and observations.

The literature review indicates a low relative importance of patenting in appropriating returns from R&D but a high although varying propensity to patent. Previous studies also indicate that there are differences between large firms and SMEs in terms of patent propensity, appropriation strategies and motives for patenting. Therefore, the following micro level questions are outlined:

RQ1a: *What are the importance and role of patenting for growth in entrepreneurial SMEs?*

RQ1b: *What are the motives for and against using patenting among entrepreneurial SMEs?*

Further, previous research has studied both negative and positive growths in US patenting. Recent patent statistics (see e.g. Figure 2.2) show that patenting in small countries, including Sweden, decreases, a trend that has not yet been explained. Therefore the next research question is:

RQ2: *What are the causes and consequences (at both micro and macro level) of positive and negative growths of patenting in Sweden?*

The results from studying this question show that large Swedish firms have changed their patenting strategies with a more selective and international focus. This leads to the question whether firms in other countries increasingly develop similar strategies and behavior. If so, and if similar markets are chosen for patent applications, there should be signs of global convergence in terms of preferred markets for patenting from firms and inventors in various countries (market convergence). If there is a convergence of preferred markets, a related question is whether there is also a convergence of the set of prioritized technologies (technology convergence[17]) in various countries, or whether technological specialization still dominates.[18] Related to this is the question whether various nations' legal IPR systems (macro level policies) become increasingly similar (legal convergence). This leads to the following set of research questions:

RQ3a: *Is there market convergence?*

RQ3b: *Is there technology convergence?*

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[17] Notice that technology convergence is distinguished from technological convergence, as studied by e.g. Rosenberg (1963); technological convergence then meaning that two or more technologies are increasingly jointly developed or combined. See Paper III for more details.

[18] For studies of technological specialization, see Soete (1981, 1987), Patel and Pavitt (1987, 1991), Cantwell (1989, 1991), Dosi et al. (1990), Archibugi and Pianta (1992, 1994), Gambardella and Torrisi (1998), and Cantwell and Vertova (2004).

RQ3c: *Is there IPR legal convergence?*

A related question, to some extent addressed in Paper III, is whether there is a convergence of international management practices. An example of an increasingly important phenomenon worldwide is the management of innovation in an open and collaborative way over firm boundaries. Despite the fact that IP strategies are crucial in open innovation, little research has yet been performed on the interrelation between IP strategies and open innovation. The final research question is therefore:

RQ4: *How are IP strategies impacting openness in innovation and vice versa?*

These research questions are part of a broader context, with subsequent research leading on to the final PhD thesis. The general purpose will therefore not be entirely and ultimately scrutinized in this licentiate thesis. The appended papers are numbered in accordance with the related research questions. Paper I focuses on RQ1a-b, Paper II focuses on RQ2, Paper III focuses on RQ3a-c, and Paper IV focuses on RQ4.

5 Methodology

The methods applied are described in detail in the appended papers. A short overview of the overall methodology and the basic assumptions employed is however given here. The chapter also includes some contextual background to the conducted research.

5.1 Research projects

The research underlying this thesis has been performed in two projects; Patents and Innovations for Growth and Welfare[19] (financed by the Swedish government) and Management, Economics and IP Law of Open Distributed Innovation Processes (financed by Vinnova). Both projects have been conducted within the Industrial Management and Economics research group at Department of Technology Management and Economics at Chalmers University of Technology.

While the first research project is more policy and macro level oriented, the second is more management and micro level oriented. However, large overlaps and interactions between the micro and macro levels have been found, as described and argued for in this thesis, and the two projects have therefore turned out to have major synergies, especially regarding the relation between micro and macro levels.

The nature of IP issues requires an interdisciplinary approach when studying them, which has been addressed in both of the abovementioned research projects. More specifically, the need for taking managerial, economical, legal, and technological (MELT) factors into account have been identified in the projects, and the research teams have thus been designed to include such skills.[20] Being educated in management, economics, and engineering, those perspectives are the main ones in this thesis. This has been complemented by input from other scholars within and outside the research teams, especially regarding legal issues.

5.2 Basic assumptions and research strategy

Before describing the research methods used, it is of importance to describe the point of departure of the study in terms of epistemological and ontological assumptions, since these naturally guide the choice of methods. The basic assumptions of this thesis can probably most closely be described as critical realism (see Bhaskar, 1989). In critical realism, social phenomena are assumed to be "produced by mechanisms that are real, but that are not directly accessible to observation and are discernible only through their effects" (Bryman and Bell, 2007, p. 628).[21] Hence, in terms of ontology (the nature of existence), the critical realist approach accepts neither pure objectivism nor pure constructionism. Regarding epistemology (the nature of knowledge), critical realism implies two things:

[19] See SOU (2006).

[20] Other disciplines, such as sociology, behavioral science, political science, and history (technological, economical, and general) are also of importance.

[21] For a description of social structures and social mechanisms, see e.g. Bhaskar (1989) or Smith (1998).

> *First, it implies that, whereas positivists take the view that the scientist's conceptualization of reality actually directly reflects that reality, realists argue that the scientist's conceptualization is simply a way of knowing that reality … Secondly, by implication, critical realists unlike positivists are perfectly content to admit into their explanations theoretical terms that are not directly amenable to observation. As a result, hypothetical entities to account for regularities in the natural or social orders (the 'generative mechanisms' to which Bhaskar refers) are perfectly admissible for realists, but not for positivists.* (Bryman and Bell, 2007, p. 18)

Critical realism has been argued to constitute more accurate assumptions than the prevailing positivist approach when studying the interplay between micro and macro levels in economics, as argued by e.g. Lawson (1997, 2003). This has come as a reaction to the mathematical modeling and pure deductive approach otherwise commonly used in mainstream economics:

> *It seems to be the case, however, that the ontological presuppositions of the methods of mathematical modeling used by economists are rarely questioned or even acknowledged, at least not in any systematic or sustained way. As a result, the possibility of a lack of ontological fit … is not considered … And my assessment, simply stated … is that these preconditions of mathematical-deductivist methods appear not to arise very often in the social realm.* (Lawson, 2003, p. 12)

The critique of mainstream economics above does however not mean that mathematical methods and models, and the related clarity, rigor and consistency, should be abandoned, but they should be complemented with other methods. As Lawson (2003, p. 21) puts it: "I do though insist that these attributes are not enough, that ability to illuminate the social realm counts as well."

Drawing upon the arguments above, both inductive and deductive research strategies are used in the research underlying this thesis. These are seldom pure forms of methodologies, since deductive studies typically include an element of induction and vice versa. The combination of induction and deduction means that this study can be categorized as an iterative study in which data and theory are simultaneously (or iteratively) developed and analyzed (Bryman and Bell, 2007). Also drawing upon the arguments above, both qualitative and quantitative research methods are iteratively used. This is further discussed below.

5.3 Research methods and data sources

The IPR field is an area where a lot of quantitative data sources are available. These are very useful, but sole reliance upon these data sources would probably not give as valuable and interesting results as if complementing with other data sources. In fact, numerous authors have advocated the use of multiple methods, commonly denoted triangulation[22], in order to increase validity (Jick, 1979; Bryman and Bell, 2007; Flick, 2009). Multiple methods can

[22] Notice that the exact definition of triangulation varies slightly in various literatures on research methods.

however do more than only increase validity, especially when combining quantitative and qualitative methods:

> *That is, beyond the analysis of overlapping variance, the use of multiple measures may also uncover some unique variance which otherwise may have been neglected by single methods. It is here that qualitative methods, in particular, can play an especially prominent role by eliciting data and suggesting conclusions to which other methods would be blind. Elements of the context are illuminated. In this sense, triangulation may be used not only to examine the same phenomenon from multiple perspectives but also to enrich our understanding by allowing for new or deeper dimensions to emerge*. (Jick, 1979, pp. 603-604)

This study has therefore employed various data collection methods, including interviews, questionnaires surveys, public statistics, and document studies, in a complementary way. These methods are described more in depth in the various papers, and they are summarized in Table 5.1. Besides the data sources specifically described in the papers, a number of interviews framing the research in an industrial and international context have been undertaken. The reason for this has essentially been to further increase the number of perspectives and to enrich the understanding of the subject, as argued by Jick (1979). The most important of those 'contextualizing' interviews are presented in Table 5.2. In addition, meetings with practitioners and scholars at various conferences have also provided important input to the study.

Table 5.1 Data collection methods in the different papers

	Public statistics	**Questionnaires**	**Interviews**	**Document studies[1)]**
Paper I		X	X	
Paper II	X	X[2)]	X[3)]	
Paper III	X		X	X
Paper IV	X		X	X

Notes: 1) This category emphasizes the use of document studies for empirical data collection. Notice that all studies contain some form of document study when designing and framing the study based on previous research.
2) The author of this thesis did not take part in the questionnaire and sample design.
3) The author of this thesis did not take part in the interviews.

Paper I presents a literature review and empirical material collected in interviews in three samples of entrepreneurial SMEs. The concept of entrepreneurial firms is in this case used on one hand to denote firms based on new technologies and on the other hand firms with new or improved commercialization.[23] In addition to the interviews, a small questionnaire was used to collect additional information on patents. The primary data source in Paper I is however 26

[23] See Gartner (1990) for a discussion on the concept of entrepreneurship.

semi-structured interviews. Non-probability sampling was used when selecting the firms, focusing on the tail of firms in various variables. The first interview sample consisted of eight firms with high sales growth, the second sample consisted of twelve hi-tech firms, and the third sample consisted of six firms in a Swedish region, 'Gnosjöregionen', recognized for its entrepreneurial spirit (Wigren, 2003). See Paper I for more details.

Paper II is based primarily on patent statistics and questionnaire surveys, but to some extent also on interviews. The sources for patent statistics were primarily the Swedish PTO, USPTO, and WIPO. A questionnaire survey was performed among three samples of firms; large patentees, SMEs, and patent consultancy firms. Again, tail sampling was found most suitable. On one hand, the use of tail sampling could limit the generalizability of the results, but on the other hand there is a large benefit in the fact that the results then do actually explain a major part of the fluctuations on national level (cf. RQ2). Thus, in this case tail sampling is expected to increase the validity of the explanatory factors behind the fluctuations. The large patentees were essentially sampled among the largest Swedish firms with the highest patenting frequency, in order to explain as much of patenting fluctuations on national level as possible. 38 out of 73 firms responded (52%). The sample of SMEs focused on smaller patentees with a decrease in patent frequency. 20 out of 51 firms responded (39%). The final sample consisted of the largest patent consultancy firms in Sweden. The 12 out of 14 responding firms (86%) jointly corresponded to about 83% of the total sales of the patent consultancy industry in Sweden.[24]

Paper III is mainly based on public statistics, but also to some degree on interviews (including some of the ones in Table 5.2) and documents. The statistics were collected from WIPO and USPTO. Paper III focuses on global convergence, and convergence is then defined as a decrease in difference. Three difference indices, based on patent statistics, were constructed for market convergence and technology convergence, respectively, i.e. six difference indices in total.[25] All pairs of countries were compared in terms of patent market shares and technology shares, and related measures, essentially resulting in $\frac{N^2}{2} - N$ unique difference indices, for each type of index, with N number of countries (although missing data for some countries led to fewer unique indices in practice). Convergence was then measured as a decrease in difference indices. See Paper III for a more elaborate description of index constructions and statistical tests.

Paper IV, finally, includes a longitudinal case study of technology development in mobile telecommunications, and it is based on interviews, document studies and patent statistics. The work with Paper IV is still in progress, and a number of interviews remain to be conducted to

[24] Notice that due to lack of data the sampling of large patentees and SMEs had to be done in a sequence of steps. See Paper II for more information. Also notice that the author of this thesis did not take part in the questionnaire and sample design for Paper II.

[25] These indices are partly based on the work of Balassa (1965) on revealed comparative advantage. Technology convergence further relates to the works on technological specialization by Soete (1981, 1987), Patel and Pavitt (1987, 1991), and others.

update the case material. Paper IV partly rests on quantitative data on essential patents in the different telecommunication standards (1G, 2G, 3G, and 4G), reported to the European Telecommunications Standards Institute (ETSI). The patent data is partly used to measure how concentrated among actors the technological development is in various generations of standards. However, since the essential patents are self-reported to ETSI, and since extensive over-reporting is likely due to the importance of holding a strong patent position in standard setting and licensing agreements, the reported essential patents need to be evaluated before treating them as essential patents to ensure measurement validity. Such evaluations have been made in various studies, among only a few are publicly available. The results from the studies conducted by Fairfield Resources International (2005, 2007, 2009a, 2009b) are used in this study.

Table 5.2 List of the most important contextualizing interviews

Company/organization	Country	Interviewee(s)
E.ON	Sweden	Head of Innovation and Environment R&D Coordinator
Ericsson	Sweden	Vice President of Patent Strategies and Portfolio Management
EU-China IPR2	China	Team Leader
Huawei	China	IP Deputy Director
IBM	UK	IP Law Counsel
IBM	Japan	Senior Counsel, IP Law
Japan Intellectual Property Association	Japan	Executive Managing Director
Japan Management of Technology Association	Japan	Senior Executive Director Secretary General
Korean Intellectual Property Office (KIPO)	Korea	Director, International Cooperation Division
Ministry of Science and Technology	China	Director
NanoCarrier	Japan	Senior Advisor
Nokia	UK	Director of IPR, Regulatory Affairs
State Intellectual Property Office (SIPO)	China	Hearing
Tokyo Small and Medium Business Investment & Consultation	Japan	President and CEO (Former director of IP Strategy Headquarters in Japan)
Volvo Group	Sweden	President and CEO
Volvo Technology Transfer	Sweden	CEO

Patent statistics provide a reliable source of information about the number of patent applications in different countries, by different firms, in different patent classes, etc., and have therefore partly been used in the research behind this thesis. Using patent statistics also ensures a high degree of replicability in the studies. Patents are however commonly used to measure the inventive productivity of firms and nations. The results of this study contain a

number of reasons to question the construct validity of this measure (measurement validity). There is indeed a relation between invention production and the number of patents, but due to differences in patenting strategies over nations, industries, firms, and time, this relation is not easy to assess. Any results obtained from patent data must therefore be analyzed with care.

6 Summaries of appended papers

This chapter presents the summaries of the appended papers. These summaries leave little room for methodological, theoretical, and empirical details. Therefore, readers are referred to the appended papers for more information.

6.1 Paper I

Patent propensity, appropriation and motives for patenting innovations: A literature review and an empirical study of entrepreneurial SMEs

This paper starts with reviewing previous research on patent propensity, appropriation and motives for patenting innovations. Research on these issues has mainly focused on large firms and there is a need for research on SMEs, which differ from large firms according to earlier studies. To this end 26 interviews were performed among three samples of entrepreneurial SMEs in Sweden (high/top growth SMEs, hi-tech SMEs, and SMEs within a highly entrepreneurial region), to explore the importance and role of patenting, and the motives for and against using patents. The patent knowledge was low among the studied SMEs, and internal patent competence was found to be a prerequisite for effective and efficient use of the patent system, indicating that there is a critical size and/or profitability at which SMEs can afford to acquire the competencies necessary to benefit from the patent system. A low importance of patents for deterring imitation relates to limited resources within SMEs for monitoring and enforcing their rights. It is found that various motives for patenting impact patent propensity and that different appropriation means are complements rather than supplements. While of limited perceived importance for protecting inventions, patents were instead used to attract customers and investors. Patents can function as a governance mechanism for investors and financiers, and patents have both venture capital qualifying and winning characteristics.

6.2 Paper II

The anatomy of rise and fall of patenting and propensity to patent: The case of Sweden

Fluctuations in patenting frequency and propensity to patent have caught increasing interest since the productivity and patenting slowdown in the US in the 1970s and then especially since the US switch to a stronger IP regime in the 1980s, triggering the emergence of a worldwide pro-patent era. In this paper fluctuations in Swedish patent frequency from 1990 to 2006 are described and analyzed, based on statistics, questionnaire survey studies among large and small patentees as well as IP consultancy firms, and an interview-based case. The results confirm previous research about the importance of size of R&D and size of patenting resources for both large and small firms across industries and for both positive and negative growth of patenting, as well as the importance of business cycles. In addition, a more quality-oriented approach in patenting with more selective patenting led to decreased patenting frequency (especially among large firms), while a decreased importance of patents for financing R&D, related to a decline in the supply of venture capital following the business downturn in the early 2000s, led to decreased patenting frequency among small patentees. As to propensity to patent using different routes, national first filings are declining in the longer

run on average for small countries like Sweden and Finland, as especially large companies internationalize their IP operations and increasingly use the PCT route. This trend has serious implications for national patent policies and patent offices in small countries.

6.3 Paper III

Managing multinational technology and intellectual property (IP) – Is there global convergence?

This paper addresses various hypotheses about global convergence – economic, management, market, technology and legal convergence – by analyzing international patenting and intellectual property (IP) conditions. The empirical base is worldwide patent statistics and interviews in Asia, Europe and US. A mixed picture of convergence emerges with signs of market and IP legal convergence, partial economic and technology convergence, and anecdotal evidence of technology and IP management convergence. Asian NICs have significantly increased their international patenting and supply of patented inventions, and strengthened their IP regimes. Switching from weak to strong IP regimes in the technological catch-up process has traditionally attracted inward FDIs, technology transfer and R&D. However, recent IP developments, especially in China, may imply strong but protectionist IP regimes that could reverse this behavior among MNCs in other countries. Such policy changes will have profound impact on R&D, technology and innovation management in developed as well as developing countries.

6.4 Paper IV

The dynamics of multi-layered openness in innovation systems: The role of distributed knowledge and intellectual property

This paper aims at clarifying some underpinnings of open innovation by exploring the dynamics of openness of innovation and intellectual property (IP) at different levels of organizational boundaries using the case of a series of overlapping generations of mobile communications standards.

The empirical analysis shows how companies in a network (or community) pool their technologies in a collaborative development of new generations of mobile communication standards. Initially fairly discrete generational shifts have become more incremental and frequent due to increasing technological overlaps, leading to a more continuous dynamics with an increasing amount of transitional sub-generations (gap-fillers or turbo versions), such as GPRS (2.5G) and HSPA (3.5G and 3.75G). At the same time the number of technologies and the number of intellectual property right (IPR) holders have increased.

The continued analysis extracts two main dimensions of innovation openness, namely organizational openness and IPR openness, related to the knowledge distribution and knowledge accessibility within the innovation system, respectively. These dimensions represent different but related conceptualizations of open innovation. The case shows that organizational openness in general does not imply IPR openness, or vice versa. Moreover, the cross-correlation between these two distinct dimensions changes in size and sign over time.

Thus, IPR openness and weak IP regimes do not necessarily promote organizational openness and innovation performance.

The paper concludes that in managing innovation, there is a need to consider different types and levels of openness in order to create and sustain an efficient innovation system, i.e. openness in innovation systems is multi-layered and multi-dimensional, and in addition dynamic. Thus, any notion of the existence of a stable level of optimal openness in innovation is overly simplistic and likely to mislead managerial and policy decisions. In particular, firms need to dynamically manage their cross-boundary activities with more skillful IP management.

7 Main results

This chapter will answer the research questions outlined in chapter 4, based on the results in the various papers (see also chapter 6). This chapter focuses on the results specifically related to the research questions, and the reader is therefore referred to the appended papers for further results and more elaborate descriptions and discussions of the results. The first set of research questions were generated from identified differences between large firms and SMEs in terms of patent propensity, appropriation strategies, and motives for patenting. The following research questions were developed:

RQ1a: *What are the importance and role of patenting for growth in entrepreneurial SMEs?*

RQ1b: *What are the motives for and against using patenting among entrepreneurial SMEs?*

The results of Paper I indicate that patents were of little perceived importance for appropriating returns from R&D in the studied entrepreneurial SMEs, and the studied firms had low trust in general for patents' ability to deter imitation. This was essentially due to SMEs having limited resources for monitoring and enforcing their patent rights. Other reasons were the information disclosure related to patent protection and the possibility for competitors to legally invent around the patent protection (these reasons have previously been addressed by e.g. Levin et al., 1987, and Harabi, 1995). In fact, when patenting, the motive among the studied SMEs was not mainly to deter imitation (contrasting the results of a number of previous studies, see e.g. Arundel et al., 1995; Duguet and Kabla, 1998; Granstrand, 1999; Cohen et al., 2000; Thumm, 2004; Blind et al., 2006). Instead, patents were mainly used for attracting customers and capital (both of which in fact have large impact on firm growth), again contrasting previous results (see e.g. Thumm, 2004). This should be analyzed in light of the fact that many of the studied firms, at least the entrepreneurial hi-tech SMEs, were young, and securing financing is a crucial activity in young hi-tech firms. Thus, it is possible, and likely, that the role of and motive for patenting changes as these firms mature. The fact that investors seem to require patents before making venture capital (VC) investments is interesting, and it is in Paper I argued that patents provide a governance mechanism in VC financing that complements e.g. employment contracts.

The next research question to be answered was a result of a recent decrease in patenting in Sweden at the national level. Therefore the following research question was formulated:

RQ2: *What are the causes and consequences (at both micro and macro level) of positive and negative growths of patenting in Sweden?*

The results of Paper II show that changes in R&D and patenting resources impact patenting frequency, and so does business cycles, confirming previous results by e.g. Scherer (1983) and Griliches (1988). In addition, a rise in the importance of patents during the 1990s led to increased patenting, while the decrease in national patenting during the early 2000s was explained by more selective and more quality-oriented patenting, especially among large firms. SMEs on the other hand rated a decreased importance of patents for financing R&D highly as a factor behind a decrease in patenting (cf. Paper I). The latter is related to a decline in the supply of VC in general in Sweden after the business downturn around year 2000. Further, a decrease in national patenting in Sweden is partly explained by an increased use of

international routes to apply for patents, especially the use of the PCT system. This has implications for the Swedish PTO, as well as for PTOs in other small countries where a similar internationalization of the domestic firms' IP behavior is taking place, in turn decreasing the importance of the national patent application route. It also has implications for the patent consultancy industries in these countries, since they are typically oriented towards the national patent offices regarding language preferences etc.

The increasing internationalization described above, and the general globalization, leads to the question whether firms worldwide increasingly develop similar strategies and behavior. The third set of research questions were thus developed around the theme of convergence; whether preferred output markets for patenting from firms and inventors in various countries become increasingly similar (market convergence), whether the set of prioritized technologies in various countries become increasingly similar (technology convergence), and finally whether various nations' legal IPR systems (macro level policies) become increasingly similar (legal convergence):

RQ3a: *Is there market convergence?*

RQ3b: *Is there technology convergence?*

RQ3c: *Is there IPR legal convergence?*

The results of Paper III indicate that there is a market convergence; all three difference indices used in the paper show statistically significant decreases over time. There is not as clear results regarding technology convergence, however, since the changes of the different indices are not consistent in sign. The varying results regarding technology convergence could be explained by similar technological fields becoming increasingly important in various countries, but at the same time that the differences in relative technological specialization[26] in the various fields are increasing. Previous studies have in general indicated increasing national specialization, and the specialization-related measures in this study also indicate increasing differences between nations, which is an indication of increasing technological specialization in line with the results by e.g. Cantwell and Vertova (2004). It should also be noted that market convergence and technology convergence could be negatively correlated if globalization leads to a general convergence of consumer needs (cf. Paper III for details).

An IPR legal convergence is identified, especially regarding patent law, partly driven by the TRIPS agreement and its enforcement through the WTO. This has in general led to a strengthening of otherwise commonly weak IP regimes in developing countries. Developing countries then typically switch from a weak to a strong IP regime at a point in time when the mainly innovative benefits from a strong regime outweigh the mainly imitative benefits of a weak regime. It should be noted, however, that the industrial sectors in developing countries

[26] A nation is specialized in a technological area if the share of their total number of patents that belongs to that area is larger than the share out of all nations' patents that belongs to the area. See also Soete (1981, 1987), Patel and Pavitt (1987, 1991), Cantwell (1989, 1991), Dosi et al. (1990), Archibugi and Pianta (1992, 1994), Gambardella and Torrisi (1998), and Cantwell and Vertova (2004).

are typically at various development stages, with both leading and lagging sectors, and the optimal timing of a switch is therefore difficult to assess.

The final research question is developed based on an increasing interest for and use of various forms of open innovation. This is intriguing from an IP perspective, since open innovation puts increasing demand on proper and new forms of IP management and IP strategies. Many relevant questions in this field remain to be answered, and the final research question in this thesis was:

RQ4: *How are IP strategies impacting openness in innovation and vice versa?*

Paper IV is based on a case of four generations of mobile communications systems. The preliminary results show that open and collaborative innovation can be organized in innovation systems with both open/lax and closed/strong internal IP regimes. However, an open regime is not stable if one or more actors choose to change strategies to more aggressive ones. This was essentially what happened during the second generation of mobile communications, and the number of reported essential patents for the different generations of mobile communications has increased steeply since then. The case also indicates that there is innovation openness of different types and on different levels, each with different degrees of openness. IPRs and various related contracts (including licensing contracts) can be used for governance of the different types, levels, and degrees of openness. Paper IV particularly argues that firms need to manage cross-boundary activities in a dynamic way, where skillful IP management is of pivotal importance.

8 Conclusions

The general purpose of this thesis has been to explore and explain the causes and consequences of intellectual property (IP) strategies and policies at firm, national, and international levels in different industrial contexts with different types and degrees of openness in innovation. Besides the answers to the specific research questions given in chapter 7, the results of this thesis all in all indicate a dynamic interplay between IP strategies and policies at different micro and macro levels. More specifically, the thesis has shown that due to policy developments at macro level, including the emergence of the pro-patent era, large firms developed their IP strategies and especially their patent strategies. Initially, the patenting increased as a result of rising value and strategic importance of patents. Subsequently, large firms started to focus more on selective and quality-oriented patenting, leading to a slowdown of national patenting, in turn impacting national policies. As globalization continues and firms become increasingly internationalized, there is a convergence of preferred national output markets for patent applications, again impacting macro level developments, and especially national patent offices in small countries. Further, national legal IPR systems converge towards a strong IP regime, partly as a result of pressure on developing and newly industrialized countries (NICs) from developed countries[27] (and their major firms) and partly as a result from innovative benefits from strong regimes outweighing the benefits from weak ones. This impacts the IP strategies of firms in NICs, e.g. in China, and their leading multinational corporations (MNCs) seem to quickly adjust and become frequent patentees internationally, in turn creating reactions from competing firms in developed countries. In corporate innovation systems with various types and degrees of openness, a change to an aggressive IP strategy from one actor typically leads to reactions in form of aggressive strategies also from other actors. Such a change is then difficult to rewind, especially in cases of cumulative and complex technologies. This does not necessarily lead to a closed innovation system, but rather that new forms of governance of open innovation is necessary (including various licensing schemes[28]) in turn leading to a different type of openness. It is still an open question how transaction costs are affected by such a change, but it does put new demands on IP valuation and pricing skills, as fair (in some sense) licensing deals need to be outlined.

This thesis has made a number of empirical contributions; describing the role of and motive for patenting in SMEs (Paper I), explaining fluctuations in Swedish patenting (Paper II), showing signs of various forms of global convergence (Paper III), and describing the longitudinal development of mobile communications standards and the role of IP (Paper IV). Methodologically, the development of market and technology difference indices in Paper III and the related matrices of two by two country comparisons is probably the most important contribution. The main theoretical contribution of the thesis is outlined in Paper IV (and is

[27] In this context the debate about the patent protection of pharmaceuticals in third world countries deserves to be mentioned, see e.g. Scherer (2004).

[28] See e.g. Bogers et al. (2011) for descriptions of various generic types of licenses.

thus still work in progress), and relates to the concept of innovation openness, and various degrees, types, and levels of openness. This is closely related to various theories of the firm, and more specifically to the boundaries of firms.

Future studies are suggested to further elaborate upon the concept of open innovation. In the light of presumed benefits of opening up firms' innovation processes, it is also of interest to investigate theoretical predictions of such benefits.[29] Additional research on the relation between IP issues and open innovation is also needed. In this connection, IP valuation and pricing issues need to be addressed as well as the role of IP in governance of financing and of technological collaborations. Future studies using patent statistics should consider the fact that patent propensity varies over time due to changes in patent strategies, and it is most likely that patent and IP strategies will continue to develop as industries are becoming increasingly knowledge- and IP-based. After all, "future competition in the world is IP competition" (Chinese Prime Minister Wen Jiabao, 2004, as cited in SOU, 2006, p. 101).

[29] One such prediction could be based on Penrose's (1959) argument of using excess resources at zero marginal cost, but in this case more specifically using excess technological resources externally.

List of references

Abramovitz, M., 1986. Catching up, forging ahead and falling behind. *Journal of Economic History*, 46(2), pp.385-406.

Allen, T.J., 1977. *Managing the Flow of Technology*. Cambridge, MA: MIT Press.

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

Archibugi, D. & Pianta, M., 1994. Aggregate convergence and sectoral specialization in innovation. *Journal of Evolutionary Economics*, 4, pp.17-33.

Arora, A., 1997. Patents, licensing, and market structure in the chemical industry. *Research Policy*, 26, pp.391-403.

Arora, A. & Ceccagnoli, M., 2004. *Patent Protection, Complementary Assets, and Firms' Incentives for Technology Licensing*. Working Paper Series. Social Science Research Network.

Arora, A., Fosfuri, A. & Gambardella, A., 2004. *Markets for Technology: The Economics of Innovation and Corporate Strategy*. Cambridge, MA: The MIT Press.

Arrow, K.J., 1962. Economic welfare and the allocation of resources for invention. In R.R. Nelson, ed. *The Rate and Direction of Inventive Activity: Economic and Social Factors*. Princeton: Princeton University Press. pp.609-25.

Arundel, A. & Kabla, I., 1998. What percentage of innovations are patented? Empirical estimates for European firms. *Research Policy*, 27, pp.127-41.

Arundel, A., van de Paal, G. & Soete, L., 1995. *Innovation Strategies of Europe's Largest Industrial Firms. Results of the PACE Survey for Information Sources, Public Research, Protection of Innovations and Government Programmes.* Maastricht: MERIT.

Balassa, B., 1965. Trade liberalization and "revealed" comparative advantage. *The Manchester School o Economic and Social Studies*, 33(June).

Barney, J.B., 1991. Firm resources and sustained competitive advantage. *Journal of Management*, 17(1), pp.99-120.

Barney, J.B., 1997. *Gaining and Sustaining Competitive Advantage*. Addison-Wesley.

Barney, J.B., 2001. Is the resource-based "view" a useful perspective for strategic management research? Yes. *Academy of Management Review*, 26(1), pp.41-56.

Barney, J.B. & Hesterly, W.S., 2005. *Strategic Management and Competitive Advantage: Concepts*. New Jersey: Pearson Education.

Baumol, W.J., 2002. *The Free-Market Innovation Machine*. Princeton, NJ: Princeton University Press.

Bekkers, R., Duysters, G. & Verspagen, B., 2002. Intellectual property rights, strategic technology agreements and market structure - The case of GSM. *Research Policy*, 31, pp.1141-61.

Bhaskar, R., 1989. *Reclaiming Reality: A Critical Introduction to Contemporary Philosophy*. London: Verso.

Blind, K., Edler, J., Frietsch, R. & Schmoch, U., 2006. Motives to patent: Empirical evidence from Germany. *Research Policy*, 35, pp.655-72.

Blind, K. & Thumm, N., 2004. Interrelation between patenting and standardisation strategies: Empirical evidence and policy implications. *Research Policy*, 33(10), pp.1583-98.

Bogers, M., Afuah, A. & Bastian, B., 2010. Users as innovators: A review, critique, and future research directions. *Journal of Management*, 36(4), pp.857-75.

Bogers, M., Bekkers, R. & Granstrand, O., 2011 (forthcoming). Intellectual property and licensing strategies in open collaborative innovation. In C. de Pablos Heredero, ed. *Open Innovation at Firms and Public Administrators: Technologies for Value Creation*. Hershey, PA: IGI Global.

Bontis, N., 2002. *World Congress on Intellectual Capital Reading*. Boston: Butterworth Heinemann.

Bound, J. et al., 1984. Who does R&D and who patents? In Z. Griliches, ed. *R&D, Patents, and Productivity*. Chicago: University of Chicago Press. pp.21-54.

Brouwer, E. & Kleinknecht, A., 1999. Innovative output, and a firm's propensity to patent. An exploration of CIS micro data. *Research Policy*, 28, pp.615-24.

Bryman, A. & Bell, E., 2007. *Business Research Methods*. 2nd ed. Oxford, NY: Oxford University Press.

Cantwell, J., 1989. *Technological Innovation and Multinational Corporations*. Oxford: Blackwell.

Cantwell, J., 1991. Historical trends in international patterns of technological innovation. In J. Foreman-Peck, ed. *New Perspectives on the Late Victorian Economy*. Cambridge: Cambridge University Press. pp.37-72.

Cantwell, J. & Vertova, G., 2004. Historical evolution of technological diversification. *Research Policy*, 33, pp.511-29.

Cassiman, B. & Veugelers, R., 2006. In search of complementarity in innovation strategy: Internal R&D and external knowledge acquisition. *Management Science*, 52(1), pp.68-82.

Chabchoub, N. & Niosi, J., 2005. Explaining the propensity to patent computer software. *Technovation*, 25, pp.971-78.

Chesbrough, H.W., 2003. *Open Innovation: The New Imperative for Creating and Profiting from Technology*. Boston: Harvard Business School Press.

Chesbrough, H.W., 2006. *Open Business Models: How to Thrive in the New Innovation Landscape*. Boston: Harvard Business School Press.

Chesbrough, H. & Crowther, A.K., 2006. Beyond high tech: Early adopters of open innovation in other industries. *R&D Management*, 36(3), pp.229-36.

Chesbrough, H.W., Vanhaverbeke, W. & West, J., eds., 2006. *Open Innovation: Researching a New Paradigm*. Oxford: Oxford University Press.

Coase, R.H., 1937. The Nature of the Firm. *Economica*, 4(16), pp.386-405.

Cohen, W.M. & Levinthal, D.A., 1990. Absorptive capacity: A new perspective on learning and innovation. *Administrative Science Quarterly*, 35(1), pp.128-52.

Cohen, W.M., Nelson, R.R. & Walsh, J.P., 2000. *Protecting Their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (or Not)*. Cambridge, MA: NBER Working Paper Series.

Copeland, T.E., Weston, J.F. & Shastri, K., 2005. *Financial Theory and Corporate Policy*. 4th ed. Pearson Addison Wesley.

Dahlander, L. & Gann, D.M., 2010. How open is innovation? *Research Policy*, 39(6), pp.699-709.

Damodaran, A., 2002. *Investment Valuation: Tools and Techniques for Determining the Value of Any Asset*. 2nd ed. New York: John Wiley & Sons.

David, P.A., 1993. Intellectual property institutions and the panda's thumb: Patents, copyrights, and trade secrets in economic theory and history. In M.B. Wallerstein, M.E. Mogee & R.A. Schoen, eds. *Global Dimensions of Intellectual Property Rights in Science and Technology*. Washington, DC: National Academy Press. pp.19-61.

Dosi, G., Pavitt, K.L.R. & Soete, L.L.G., 1990. *The Economics of Technical Change and International Trade*. New York: Harvester Wheatsheaf.

Duguet, E. & Kabla, I., 1998. Appropriation strategy and the motivations to use the patent system: An econometric analysis at the firm level in French manufacturing. *Annals of Economics and Statistics*, pp.289-327.

Edvinsson, L., 1997. Developing intellectual capital at Skandia. *Long Range Planning*, 8(3), pp.366-73.

Encyclopædia Britannica, 2009. *Property*. [Online] Available at: http://search.eb.com/eb/article-9061557 [Accessed 3 November 2009].

Encyclopedia Britannica, 2010. *Strategy*. [Online] Available at: http://search.eb.com/eb/article-9110191 [Accessed 16 February 2010].

Fairfield Resources International, 2005. *3G Cellular Standards and Patents*. Available for download at company website.

Fairfield Resources International, 2007. *Analysis of Patents Declared as Essential to GSM as of June 6, 2007*. Available for download at company website.

Fairfield Resources International, 2009a. *Review of Patents Declared as Essential to LTE and SAE (4G Wireless Standards) Through June 30, 2009*. Available for download at company website.

Fairfield Resources International, 2009b. *Review of Patents Declared as Essential to WCDMA Through December, 2008*. Available for download at company website.

Flick, U., 2009. *An Introduction to Qualitative Research*. 4th ed. London: SAGE Publications Ltd.

Foray, D. & Steinmueller, W.E., 2003. On the economics of R&D and technological collaborations: Insights and results from the project Colline. *Economics of Innovation and New Technology*, 12(1), pp.77-91.

Frank, R.H., 2006. *Microeconomics and Behavior*. 6th ed. New York, NY: McGraw-Hill.

Freeman, C., Clarc, J. & Soete, L., 1982. *Unemployment and Technical Innovation*. London: Pinter.

Gambardella, A. & Torrisi, S., 1998. Does technological convergence imply convergence in markets? Evidence from the electronics industry. *Research Policy*, 27(5), pp.447-65.

Gartner, W.B., 1990. What are we talking about when we talk about entrepreneurship? *Journal of Business Venturing*, 5(1), pp.15-28.

Gilbert, R. & Shapiro, C., 1990. Optimal patent length and breadth. *RAND Journal of Economics*, 21(1), pp.106-12.

Giuri, P. et al., 2007. Inventors and invention processes in Europe: Results from the PatVal-EU survey. *Research Policy*, 36, pp.1107-27.

Granstrand, O., 1982. *Technology, Management and Markets*. London: Frances Pinter.

Granstrand, O., 1988. *Patents and Innovation - A Study of Patenting Practices and Trends in Sweden with a Brief Outlook on the US*. CIM Working Paper 1988:04. Gothenburg: Department of Industrial Management and Economics, Chalmers University of Technology.

Granstrand, O., 1998. Towards a theory of the technology-based firm. *Research Policy*, 27, pp.465-89.

Granstrand, O., 1999. *The Economics and Management of Intellectual Property: Towards Intellectual Capitalism*. Cheltenham: Edward Elgar Publishing.

Granstrand, O., ed., 2003. *Economics, Law and Intellectual Property: Seeking Strategies for Research and Teaching in a Developing Field*. Boston: Kluwer Academic Publishers.

Granstrand, O., 2004. The economics and management of technology trade: towards a pro-licensing era? *International Journal of Technology Management*, 27(2/3), pp.209-40.

Granstrand, O., 2010. *Industrial Innovation Economics and Intellectual Property*. 5th ed. Gothenburg: Svenska Kulturkompaniet.

Granstrand, O., 2011a (forthcoming). *Patents and Innovations for Growth and Welfare*. Cheltenham: Edward Elgar Publishing.

Granstrand, O., 2011b. *The economics of IP in the context of a shifting innovation paradigm*. Unpublished manuscript.

Granstrand, O., Bohlin, E., Oskarsson, C. & Sjöberg, N., 1992. External technology acquisition in large multi-technology corporations. *R&D Management*, 22(2).

Granstrand, O. & Oskarsson, C., 1994. Technology diversification in "MUL-TECH" corporations. *IEEE Transactions on Engineering Management*, 41(4), pp.355-64.

Granstrand, O., Patel, P. & Pavitt, K., 1997. Multi-technology corporations: Why they have "distributed" rather than "distinctive core" competencies. *California Management Review*, 39(4), pp.8-25.

Granstrand, O. & Sjölander, S., 1990. Managing innovation in multi-technology corporations. *Research Policy*, 19(1).

Greenhalgh, C. & Rogers, M., 2010. *Innovation, Intellectual Property, and Economic Growth*. Princeton, NJ: Princeton University Press.

Griliches, Z., 1988. Productivity puzzles and R&D: Another nonexplanation. *The Journal of Economic Perspectives*, 2(4), pp.9-21.

Guellec, D. & van Pottelsberghe de la Potterie, B., 2007. *The Economics of the European Patent System*. Oxford: Oxford University Press.

Haeussler, C., Harhoff, D. & Mueller, E., 2009. *To be Financed or Not. - The Role of Patents for Venture Capital Financing*. Discussion Paper 7115. London: Center for Economic Policy Research (CEPR).

Hall, R., 1989. The management of intellectual assets: a new corporate perspective. *Journal of General Management*, 15(1), pp.53-68.

Hall, B.H., 2005. Exploring the patent explosion. *Journal of Technology Transfer*, 30(1/2), pp.35-48.

Hall, B.H. & Ziedonis, R.H., 2001. The patent paradox revisited: an empirical study of patenting in the U.S. semiconductor industry, 1979-1995. *RAND Journal of Economics*, 32(1), pp.101-28.

Harabi, N., 1995. Appropriability of technical innovations: An empirical analysis. *Research Policy*, 24, pp.981-92.

Harhoff, D., Scherer, F.M. & Vopel, K., 2003. Exploring the tail of patented invention value distributions. In O. Granstrand, ed. *Economics, Law and Intellectual Property*. Dordrecht: Kluwer Academic Publishers. pp.279-309.

He, Z. & Wong, P., 2004. Exploration vs. exploitation: An empirical test of the ambidexterity hypothesis. *Organization Science*, 15(4), pp.481-94.

Hsu, D. & Ziedonis, R., 2008. Patents as quality signals for entrepreneurial ventures. In *Academy of Management Best Paper Proceedings*., 2008.

Hu, A.G., 2010. Propensity to patent, competition and China's foreign patenting surge. *Research Policy*, 39(7), pp.985-93.

Hu, A.G. & Jefferson, G.H., 2009. A great wall of patents: What is behind China's recent patent explosion. *Journal of Development Economics*, 90, pp.57-68.

Interbrand, 2009. *Best Global Brands*. [Online] Available at: http://www.interbrand.com/best_global_brands_intro.aspx [Accessed 1 December 2009].

Jacobides, M.G. & Winter, S.G., 2005. The co-evolution of capabilities and transaction costs: Explaining the institutional structure of production. *Strategic Management Journal*, 26, pp.395-413.

Jaffe, A.B. & Lerner, J., 2004. *Innovation and Its Discontents*. Princeton: Princeton University Press.

Jantsch, E., 1967. *Technological Forecasting in Perspective*. Paris: OECD.

Jick, T.D., 1979. Mixing qualitative and quantitative methods: Triangulation in action. *Administrative Science Quarterly*, 24(4), pp.602-11.

Keupp, M.M., Beckenbauer, A. & Gassmann, O., 2010. Enforcing intellectual property rights in weak appropriability regimes: The case of de facto protection strategies in China. *Management International Review*, 50(1), pp.109-30.

Kitching, J. & Blackburn, R., 1998. Intellectual property management in the small and medium enterprise (SME). *Journal of Small Business and Enterprise Development*, 5(4), pp.327-35.

Klemperer, P., 1990. How broad should the scope of patent protection be? *RAND Journal of Economics*, 21(1), pp.113-30.

Kline, S.J. & Rosenberg, N., 1986. An overview of innovation. In R. Landau & N. Rosenberg, eds. *The Positive Sum Strategy*. Washington, DC: National Academy of Engineering. pp.275-305.

Kodama, F., 1986. Technological diversification of Japanese industry. *Science*, 233, pp.291-96.

Koktvedgaard, M. & Levin, M., 2004. *Lärobok i Immaterialrätt*. 8th ed. Stockholm: Norstedts Juridik.

Kortum, S. & Lerner, J., 1998. Stronger protection or technological revolution: What is behind the recent surge in patenting? In *Carnegie-Rochester Conference Series on Public Policy 48*. North-Holland, 1998.

Lanjouw, J.O., Pakes, A. & Putnam, J., 1996. *How to Count Patents and Value Intellectual Property*. NBER Working Paper No. 5741.

Laursen, K. & Salter, A., 2006. Open for innovation: The role of openness in explaining innovation performance among U.K. manufacturing firms. *Strategic Management Journal*, 27(2), pp.131-50.

Lawson, T., 1997. *Economics and Reality*. New York, NY: Routledge.

Lawson, T., 2003. *Reorienting Economics*. New York, NY: Routledge.

Leiponen, A. & Byma, J., 2009. If you cannot block, you better run: Small firms, cooperative innovation, and appropriation strategies. *Research Policy*, 38, pp.1478-88.

Lemley, M.A., 2000. Reconceiving patents in the age of venture capital. *Journal of Small and Emerging Business Law*, 4, pp.137-48.

Lemley, M.A. & Shapiro, C., 2007. Patent holdup and royalty stacking. *Texas Law Review*, 85, pp.1991-2049.

Lev, B., 2001. *Intangibles: Management, Measurement, and Reporting*. Washington: The Brookings Institution.

Levin, R.C., Klevorick, A.K., Nelson, R.R. & Winter, S.G., 1987. Appropriating the returns from industrial research and development. *Brookings Papers on Economic Activity*, 3, pp.783-820.

Lichtenthaler, U., 2010. Intellectual property and open innovation: An empirical analysis. *International Journal of Technology Management*, 52(3/4), pp.372-91.

Machlup, F., 1958. *An Economic Review of the Patent System*. Study No 15 of the Subcommittee on Patents, Trademarks, and Copyrights of the Committee on the Judiciary, US Senate. Washington, DC: US Government Printing Office.

Mansfield, E., 1986. Patents and innovation: An empirical study. *Management Science*, 32(2), pp.173-81.

Mansfield, E. et al., 1977. Social and private rates of return from industrial innovations. *The Quarterly Journal of Economics*, 91(2), pp.221-40.

March, J.G., 1991. Exploration and exploitation in organizational learning. *Organization Science*, 2(1), pp.71-87.

Marr, B. & Adams, C., 2004. The balanced scorecard and intangible assets: similar ideas, unaligned concepts. *Measuring Business Excellence*, 8(3), pp.18-27.

Marshall, A., 1890. *Principles of Economics*. London: Macmillan.

McConnachie, G., 1997. The management of intellectual assets: Delivering value to the business. *The Journal of Knowledge Management*, 1(1), pp.56-62.

Merges, R.P. & Nelson, R.R., 1990. On the complex economics of patent scope. *Columbia Law Review*, 90(4), pp.839-916.

Mintzberg, H., 1978. Patterns in strategy formation. *Management Science*, 24(9), pp.934-48.

Mintzberg, H. & Waters, J.A., 1985. Of strategies, deliberate and emergent. *Strategic Management Journal*, 6(3), pp.257-72.

Mun, J., 2006. *Real Options Analysis: Tools and Techniques for Valuing Strategic Investments and Decisions*. 2nd ed. Hoboken, NJ: John Wiley & Sons.

National Resource Council, 1993. *Global Dimensions of Intellectual Property Rights in Science and Technology*. Washington, DC: National Academy Press.

Nelson, R.R. & Winter, S.G., 1982. *An Evolutionary Theory of Economic Change*. Cambridge, MA: The Belknap Press of Harvard University Press.

OECD Statistics, 2009. [Online] Available at: http://stats.oecd.org [Accessed 1 December 2009].

Patel, P. & Pavitt, K.L.R., 1987. Is western Europe losing the technological race? *Research Policy*, 16, pp.59-85.

Patel, P. & Pavitt, K.L.R., 1991. Large firms in the production of the world's technology: An important case of 'non-globalisation'. *Journal of International Business Studies*, 22, pp.1-21.

Pavitt, K., 1982. R&D, patenting and innovative activities: A statistical exploration. *Research Policy*, 11(1), pp.33-51.

Pavitt, K., Robson, M. & Townsend, J., 1989. Technological accumulation, diversification and organisation in UK companies 1945-1983. *Management Science*, 35(1), pp.81-99.

Penrose, E., 1959. *The Theory of The Growth of the Firm*. New York: Wiley.

Porter, M.E., 1980. *Competitive Strategy: Techniques for Analyzing Industries and Competitors*. New York: The Free Press.

Porter, M., 1990. *The Competitive Advantage of Nations*. New York, NY: The Free Press.

Prahalad, C.K. & Hamel, G., 1990. The core competence of the corporation. *Harvard Business Review*, 68(3), pp.79-91.

Priem, R.L. & Butler, J.E., 2001. Is the resource-based "view" a useful perspective for strategic management research? *Academy of Management Review*, 26(1), pp.22-40.

Rassenfosse, G., 2011 (forthcoming). How SMEs exploit their intellectual property assets: evidence from survey data. *Small Business Economics*.

Reitzig, M., 2007. How executives can enhance IP strategy and performance. *MIT Sloan Management Review*, 49(1), pp.37-43.

Rockman, H.B., 2004. *Intellectual Property Law for Engineers and Scientists*. Hoboken, NJ: IEEE Press.

Roos, J., Roos, G., Dragonetti, N.C. & Edvinsson, L., 1997. *Intellectual Capital: Navigating the New Business Landscape*. London: Macmillan.

Rosenberg, N., 1963. Technological change in the machine tool industry, 1840-1910. *The Journal of Economic History*, 23(4), pp.414-43.

Rosenberg, N., 1982. *Inside the Black Box: Technology and Economics*. Cambridge, MA: Cambridge University Press.

Rosenberg, N. & Birdzell, L.E., 1986. *How the West Grew Rich: The Economic Transformation of the Industrial World*. New York: Basic Books.

Scherer, F.M., 1965. Firm size, market structure, opportunity, and the output of patented inventions. *The American Economic Review*, 55(5), pp.1097-125.

Scherer, F.M., 1983. The propensity to patent. *International Journal of Industrial Organization*, pp.107-28.

Scherer, F.M., 1999. *New Perspectives on Economic Growth and Technological Innovation*. Washington D.C.: Brookings Institution Press.

Scherer, F.M., 2004. A note on global welfare in pharmaceutical patenting. *The World Economy*, 27(7), pp.1127-42.

Schumpeter, J.A., 1934. *The Theory of Economic Development: An Inquiry into Profits, Capital, Credit, Interest, and the Business Cycle*. Cambridge, MA: Harvard University Press.

Schumpeter, J.A., 1942, 1976. *Capitalism, Socialism and Democracy*. 5th ed. London: George Allen & Unwin.

Scotchmer, S., 2004. *Innovation and Incentives*. Cambridge, MA: MIT Press.

Smith, M.J., 1998. *Social Science in Question*. London: SAGE Publications Ltd.

Solow, R.M., 1956. A contribution to the theory of economic growth. *The Quarterly Journal of Economics*, 70(1), pp.65-94.

Solow, R.M., 1957. Technical change and the aggregate production function. *The Review of Economics and Statistics*, 39(3), pp.312-20.

SOU, 2006. *Patent och innovationer för tillväxt och välfärd (SOU 2006:80)*. Stockholm: Statens Offentliga Utredningar.

Spence, M., 2007. *Intellectual Property*. New York: Oxford University Press.

Swann, P., 2000. *The Economics of Standardization.* Final Report for Standards and Technical Regulations. Manchester: Directorate Department of Trade and Industry, University of Manchester.

Sveiby, K.E., 1997. *The New Organizational Wealth: Manageing and Measuring Knowledge-Based Assets*. San Francisco: Barrett-Kohler.

Teece, D.J., 1986. Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy. *Research Policy*, 15, pp.285-305.

Teece, D.J., Pisano, G. & Shuen, A., 1997. Dynamic capabilities and strategic management. *Strategic Management Journal*, 18(7), pp.509-33.

Thumm, N., 2004. Motives for patenting biotechnological inventions: An empirical investigation in Switzerland. *International Journal of Technlogy, Policy and Management*, 4(3), pp.275-85.

Thurow, L.C., 1997. Needed: A new system of intellectual property rights. *Harvard Business Review*, 75(5), pp.94-103.

Trott, P. & Hartmann, D., 2009. Why 'open innovation' is old wine in new bottles. *International Journal of Innovation Management*, 13(4), pp.715-36.

Tushman, M.L. & O'Reilly, C.A., 1996. Ambidextrous organizations: Managing evolutionary and revolutionary change. *California Management Review*, 38(4), pp.8-30.

Wernerfelt, B., 1984. A resource-based view of the firm. *Strategic Management Journal*, 5, pp.171-80.

Wigren, C., 2003. *The Spirit of Gnosjö*. PhD thesis. Jönköping: Jönköping International Business School.

Williamson, O.E., 1975. *Markets and Hierarchies: Analysis and Antitrust Implications*. New York: The Free Press.

Williamson, O.E., 1983. Credible Commitments: Using Hostages to Support Exchange. *American Economic Review*, 73(4), pp.519-40.

Williamson, O.E., 1985. *The Economic Institutions of Capitalism*. New York, NY: The Free Press.

Williamson, O.E., 1996. *The Mechanisms of Governance*. New York, NY: Oxford University Press.

von Hippel, E., 1988. *The Sources of Innovation*. New York: Oxford University Press.

von Hippel, E., 2005. *Democratizing Innovation*. Cambridge, MA: The MIT Press.

Wright, B.D., 1983. The economics of invention incentives: Patents, prizes, and research contracts. *American Economic Review*, 73(4), pp.691-707.

Paper I

This paper is not included in the pdf-version of this thesis. Please contact Marcus Holgersson, marhol@chalmers.se, for a copy of the paper, or find it here:

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Paper III

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Paper IV

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