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Patent Risk of Technologies

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To my dear family

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Abstract

Patents and other intellectual property rights are being used increasingly as means for doing business, and business centred around pure owning and exploitation of patent rights to generate revenue has become commonplace. It is therefore necessary and advantageous for companies to understand the value of their patents and the significance of patents to their business, as well as to be able to determine the risks of patent infringement in their business and determine the pecuniary value of the patent risk.

The aim of this thesis is to offer companies some practical tools for valuing patent risk against their products and services from other companies' patents in a given technology. For that, the fundamental concepts of patents are presented to the extent it is necessary to understand them for the modelling in this work. Also valuation of patents as an asset is discussed with the help of references to prominent literature in this field of economics. Furthermore, methods for managing risks in general are introduced as a foundation for combining patent valuation and risk management into patent risk valuation.

In the thesis, a component model is presented for valuation of patent risks taking into account business factors, research and development activity, the specific technology in question and the relevant company and patent environment. The model is based on direct estimation of the expected values of the components of patent risk in a given technology.

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I also want to thank those people in the Nokia Intellectual Property Rights department who supported me in this work in one way or another. Mika Lehtinen introduced me to the exciting world of patents, and I have learned a lot of what I know of this business from him. Our discussions are priceless and very important to me. Folke Johansson continues to be my role model of a patent professional. I am grateful to the instructor of this thesis, Dr. Pekka Sääskilahti, for the comments he gave on the thesis and for keeping me on the right path, as well as Dr. Xavier Carpentier for his insight and references that ignited this work. I needed (again) the advice of patent attorneys to make sure that the description of patents is truthful, and I want to thank Terhi Nykänen and Robert Gray for their comments. In addition, I want to thank the many people who have worked with me for a long time and also name a few who contributed to the thesis: Dr. Juha Vattulainen, Dr. Fehmi Chebil, Donal O'Connell, Erkki Yli-Juuti, Matti Kauppi, Ulla James, Susanna Martikainen, Harri Valio, Anand Gupta, Ray Wood, Dr. Roberto Castagno, Anssi Kanto, Prajeet Patel. In my journey of learning leadership and business, I have crossed paths with many people and I could, of course, produce here a combined dump of the phone books of Nokia and my N95 phone to thank these people, and the gesture would be excessive only in size. I recognize I have a precious opportunity to work together with passionate and innovative people in a very human company that is engaged in connecting people in this world.

It is inevitable that I have not mentioned everyone here I should have mentioned, and my only excuses for that are the numerous years the work has lasted and my notoriously bad memory. If you are reading this and think that I should have thanked you you are probably right, and I ask you to contact me and offer me the happy opportunity to correct that mistake.

Kim Simelius
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Contents

Chapter 1

Introduction

The world of patents has definitely changed. It has always been known that some portion of patents are granted although they do not fulfil the legal criteria for patentability. With the increased activity in monetizing the patents that companies own through aggressive licensing and litigation, the existence of these weak patents has become a significant challenge for today's businesses. Companies in the manufacturing and services businesses end up paying large sums of money in patent licences or damages for patents that should not exist. This phenomenon represents a clear inefficiency in the economy: the rewards for innovation do not end up with those entities who deserve it and resources are being misallocated. In addition, the sometimes disproportionately large awards that are commonly being granted by courts to the holders of individual patents present significant — and largely unknown — risks to companies. This phenomenon of high damage awards and the question of whether the quality of examination of patent applications is on high enough level has brought legislators and government agencies to plan and take actions to improve the patent system in practise.

Globalization of business being more a fact and a necessity than a fear or an opportunity, today's businesses need to consider their movable – intangible – assets very carefully. Protection of companies' intellectual property internationally has become important, and successful global companies seek intellectual property rights (IPR) like patents, trademarks and design protection virtually in all countries they operate in. This global competition also means that companies are exposed to intellectual property rights of other companies they have never met before. In the consumer electronics and services area, the convergence of technologies intensifies this competition even further.

All the above has made it necessary for the companies of today to understand the patent environment they operate in. Patent valuation is challenging, and consequently the valuation of risks of third party patents to a company's business is even more challenging as uncertainties of development of legal environments in different countries come into play. The regulative efforts to ensure that companies understand and manage their financial risks and make decisions according to good governance call for tools and processes to be in place to measure and quantify risks. The aim of this thesis is to offer some practical tools for valuing this patent risk in a technology so that companies or authorities can make decisions to act upon the risk.

Chapter 2 introduces the fundamental concepts of patents to the extent it is necessary to understand them for the modelling in this work. In this chapter, also valuation of patents as an asset is discussed with the help of references to prominent literature in this field of economics. Furthermore, the methods for managing risks in general are introduced as a foundation for combining patent valuation and risk management into patent risk valuation later in the thesis.

Chapter 3 presents a component model for valuation of patent risks taking into account business factors, research and development activity, the specific technology in question and the relevant company and patent environment. The model is based on direct estimation of the expected values of the components of patent risk in a given technology. The business and R&D factors in the model make use of the concept of patent value distribution. In practise this is distribution of value of all patents in the relevant technology and attributing a portion of this value to patent risk, as other companies than the patent holder may see the same value as risk towards themselves. Specific elements related to patents in the technology in question and the competitive environment are also accounted for in the model. Suggestions for refining the model are presented for situations where the components of patent risk are interdependent and direct estimation of the expected value becomes mathematically challenging.

In Chapter 4 a short summary of the patent valuation methods are presented, the model for patent risk valuation is summarized and evaluated, and recommendations for utilizing the results and for further research are presented.

Chapter 2

Methods and Materials

2.1 Patents

A patent is a bargain between the inventor and society: the inventor allows his invention to be made public in return for receiving a right to forbid others to make, sell, import or use the invention protected by the patent. Contrary to how patents are often portrayed in the economics literature, a patent does not give its holder a monopoly to use the invention, but instead a patent gives the patent holder a negative right to prevent others from making use of the invention. The difference may sound trivial, but it is not: useful products are typically protected by multiple patents held by multiple patent owners, which leads to a situation where no single patent holder is able to benefit from her invention without the permission of the other patent holders. An example is given later in this section of a situation where a lawnmower is protected by two patents. In reality, lawnmowers are protected by hundreds of patents, so the situation is more complicated than in the example.

Patents are national rights in the country where they have been granted. If a company sells products on Finnish and other European markets only, a patent granted to its competitor in the USA and covering the product is not a threat to the company. To obtain reasonable coverage for an invention companies often apply for a patent for the invention in multiple countries. The so-called priority system simplifies applying for a patent in multiple countries — later patent applications in other countries claiming priority from the first application can be filed within one year from the filing of the first application. A patent can also be applied for through some regional patent systems, the most important of which is the system provided by the European Patent Convention that allows patents to be centrally granted in approximately 30 European countries at the moment. After the centralized examination and granting procedure, the national patents still need to be validated in the individual designated states where the patent holder wants to have her invention protected. The Community Patent that would be an EC-wide patent has been on the drawing board for years, but is not yet close to being implemented. Also, it is not possible to get a worldwide patent for an invention, although a patent applicant can request worldwide patentability examination for her invention through the so-called PCT system (Patent Co-operation Treaty). A PCT application does not, however, lead to a patent, but needs to be converted into national and regional applications that can then subsequently be granted as patents. Continuation and divisional applications can be filed on the basis of pending patent applications, or the pending patent applications can be converted to applications for other kinds of intellectual property rights, depending on the national legislation. As has been described in the foregoing, a single invention often results in a bunch of patents and patent applications — such a bunch is called a patent family. (Mueller 2006; Charmasson 2004)

2.1.1 Fundamental Concepts of Patents

The requirements for obtaining a patent for an invention are set by the patent law of each individual country. The basic requirements of patentability are novelty, inventiveness and industrial applicability (e.g., in Europe, repeatable and technical in nature). Patent laws also contain some exclusions from patentability, and typically medical diagnostic methods, games, computer programs as such and inventions contrary to *ordre public* cannot be patented. (EPC 2006; FIP 1967)

The invention claimed in a patent application is required to be novel over the state of the art. What is meant by this is that the same invention as claimed in the patent application must not be known through a published document or by any other public means prior to the date of the application. Novelty is absolute: a small deviation from the state of the art is enough to make the invention novel. Also, it does not matter whether someone has e.g. actually read the public document, since according to patent law, patentability is normally destroyed by the mere possibility of this taking place, i.e., availability to the public.

The requirement of inventiveness means that the invention claimed in the patent application must at the time of filing the application be substantially different in an inventive manner from the known state of the art. According to the European Patent Convention, this is understood so that if the person skilled in the art encounters the technical problem that is objectively solved by the claimed invention, he would not be able to solve the problem or would at least not arrive at the same solution. That is, the solution to the problem is not readily derived from what is already known without any inventive activity. There is, however, no discrete boundary for what is inventive and what not, but instead this is decided case-by-case in the examination of the application — and to complicate matters still, the rulings by the courts of law may deviate from this interpretation.

The patent application is filed at a patent office that will then undertake the examination of the patent application. The patent application contains basic information on the application, title, abstract, description of the invention, figures and patent claims. The basic information contains the names of the inventors, the name of the applicant, the patent attorney representing the applicant, possibly (e.g. in a European patent application) the designated states where the patent is applied for, information on priority requests from an earlier application, and depending on the jurisdiction some other information. The abstract is a short description of the invention that is then presented in great detail in the description part of the application, with reference to the figures. The invention protected by the patent is defined in the patent claims that express in a concise and accurate manner what falls within the scope of the invention. When the patent application is filed at the patent office, it receives the date of filing, from which date on certain rights are given to the applicant, and against which date the novelty and inventiveness of the patent application are determined. The patent office also classifies the patent application, and 18 months after the priority date, the patent office publishes the patent application. (EPC 2006)

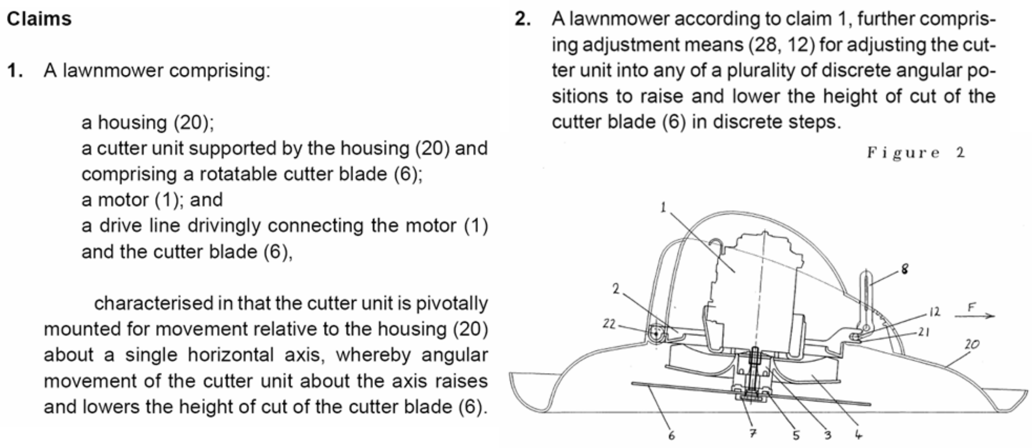
The priority date of the patent application determines the date at which the novelty and inventiveness of the invention claimed in the patent application are determined. The priority date is the application date of the application where the invention was first presented. As was mentioned earlier, it is possible to file patent applications for the same invention to other countries within one year from the priority date by claiming priority from the first application. This arrangement gives the applicant more time to decide in which countries to file for a patent, and also the possibility to abandon the patent application before incurring the significant costs of international patenting.

The patent office seeks to determine whether there exists prior art against the patent application rendering the claimed invention unpatentable, and presents such prior art to the applicant in so–called office actions. The applicant can reply to the office actions by changing the patent claims and arguing against the logic of the office action. This dialogue typically converges towards the mutual understanding of the appropriate scope of protection that can be granted in a patent. The patent is granted in most cases 3 to 5 years from the application date. In order to keep the patent in force, the patent holder needs to pay so-called maintenance fees that increase over time. The patent can remain in force for a maximum of 20 years from the date of application, unless the time has for some special reason been extended.

The scope of protection of the patent is defined in the patent claims. Examples of patent claims and the respective figures of the patent are presented in Figure 2.1. In two-part patent claims, the preamble defines the state of the art, and the characterizing part presents the specific characteristics of the invention. In one-part claims, the state of the art and the characteristics of the invention can be intermixed. An independent patent claim contains the characteristics of the invention that are present in all the embodiments of the invention protected by the claims. The independent claims define the scope of protection of the patent, and they can be interpreted without reference to other claims, whereas dependent patent claims specify the scope of protection and they need to be interpreted together with the claims they refer to. The description of the invention and the figures of the patent can be used in the interpretation of the patent scope. The interpretation of the patent scope takes place when one needs to determine whether e.g. a device infringes the patent. In order for the infringement to take place, each and every element of an independent claim of the patent needs to be present in the device — even one missing element is enough to avoid infringement. In contrast, if the device has some additional elements compared to the independent patent claim, infringement still takes place. (Mueller 2006; Charmasson 2004)

2.1.2 An Example of Patent Protection

In the following, an example of the negative right conferred by a patent to the patent holder is given with the help of lawnmower technology, which is being



Claims

1. A lawnmower comprising:

a housing (20);
a cutter unit supported by the housing (20) and comprising a rotatable cutter blade (6);
a motor (1); and
a drive line drivingly connecting the motor (1) and the cutter blade (6),

characterised in that the cutter unit is pivotally mounted for movement relative to the housing (20) about a single horizontal axis, whereby angular movement of the cutter unit about the axis raises and lowers the height of cut of the cutter blade (6).

2. A lawnmower according to claim 1, further comprising adjustment means (28, 12) for adjusting the cutter unit into any of a plurality of discrete angular positions to raise and lower the height of cut of the cutter blade (6) in discrete steps.

Figure 2.1. Exemplary patent claims and the corresponding figure. On the left, the first independent claim (1.) of the European patent EP0766911 is shown. On the right, a dependent claim (2.) and a figure depicting the invention are shown. The reference numbers in the claims refer to the figure. For clarity, line graphics are typically used in patents. (Espacenet)

separately developed by persons A and B. Let us assume that we are living in a time slightly earlier than this, and the concept of a lawnmower is not yet known. Instead, people keep the grass short by letting sheep pasture on it, or by having personnel cut the lawn with the help of scissors and knives. Good inventions are often born from problems in daily life, and it may indeed be that the persons A and B have come to think of a better way to keep the grass short as a result of some by-laws that forbid having sheep within the city limits (person A) or that the cost of grass-cutting personnel has become too high compared to the efficiency of the workforce (person B). As a result, person A has invented a device for cutting vegetation and having wheels and comprising at least one metallic cutting element in the essentially lower part of the device, and has applied for a patent for the device. This device is useful in the sense that it can, contrary to sheep, be steered accurately and predictably, and the relatively weak material of the sheep's teeth has been replaced by metal in the cutting element. Also, person B has invented a device for cutting vegetation comprising an engine for generating force needed for the cutting, and has applied for a patent for the device. This device is useful in the sense that it replaces human muscles by an engine for generating the cutting force, it is efficient compared to the previously known methods of cutting grass, and it is fairly economical to use. Because the devices of both person A and person B are novel and inventive over the state of the art, the patent office has granted patents for both devices.

Both patent holders now decide to start developing their invention to a marketable product. Person A notices during the development that there are now engines available on the market and adding an engine would make his device even more useful, and he makes the necessary changes to his device. Person B notices that it would be easier to use his effective device for achieving an even cut if there were wheels in the device and if the cutting blade were turned towards the ground so that it reaches contact with the underlying vegetation without turning the device. When person A starts to sell his device, person B notices that the device infringes the patent of B, since it is a device for cutting vegetation and it has an engine. On the other hand, the device manufactured by B also infringes A's patent, since it is a device for cutting vegetation, and has wheels and a (probably metallic) blade, but neither of A nor B has noticed the infringement. The devices by A and B turn out to be very much alike, and they both enjoy success on the market.

This situation can be investigated with the help of Table 2.1. Before A and B start to develop their inventions, neither infringes the other one's patent, since none of the devices have all the elements of the independent claim of the other person's patent. As person A adds the engine to his device, it comes to have all the elements of B's independent claim: a device for cutting vegetation and an engine. The same happens when B adds the wheels and turns the cutting blade towards the ground, since now his device has all the elements of A's independent claim: a device for cutting vegetation, wheels and at least one (metallic) cutting element in the essentially lower part of the device. Naturally, B can avoid infringing A's patent by making the blade of another material than metal.

To increase his profits and market share, B decides to send A a letter, where he demands that A stop manufacturing and selling the devices since they infringe B's patent. In addition, the products already sold should be withdrawn and A should pay damages to B on the basis of lost revenue. After some investigation, A replies with a threat to sue B for patent infringement, since the device manufactured by B infringes A's patent, and requests B withdraw his demands and pay licence fees for the devices B is selling, since A claims to be the original inventor of the lawnmower. The dispute is settled with a royalty-bearing cross-licence agreement between A and B where B agrees to pay royalties amounting to some percentage of the revenues of his lawnmower business for the next ten years, since B has a larger turnover than A. Additionally, both patent holders grant a licence to all

Table 2.1. Patent infringement analysis of lawnmowers. On the left, the elements of the patent claims of the patents of A and B are listed. The other columns indicate whether the element is present in the device of A (columns 2 and 4) or device of B (columns 3 and 5).

Element	Original device of A	Original device of B	New device of A	New device of B
Device for cutting vegetation (A+B)	Yes	Yes	Yes	Yes
Device with wheels (A)	Yes	No	Yes	Yes
At least one metallic cutting element (A)	Yes	Yes	Yes	Yes?
Cutting element in the lower part of the device (A)	Yes	No	Yes	Yes
Engine (B)	No	Yes	Yes	Yes

their patents with a priority date earlier than 10 years from signing into the future for the life of the patents.

2.1.3 Use of Patents

Using patents to protect the research and development investment is one of the most natural uses of patents for companies manufacturing and selling goods. A patent application remains secret for one and a half years from its priority date, and the company has this time of secrecy to develop products and cumulative technology based on the invention before the competitors become aware of the invention. What is of key importance is, however, that other companies lose the possibility of obtaining a patent for the same invention as soon as the patent application has been filed. When the patent is granted, the patent holder gets the right to stop the competitors products that are using the patented invention, and under certain conditions, also receive damages retroactively from the time before the patent is granted. By using patents, the company can therefore obtain a competitive advantage, especially if competitors do not have patents that are needed by the company.

The patent holder can give a licence to the patent to another company, and typically the patent holder receives licence fees or a licence to the other company's patent in return for giving the licence. In the latter case the agreement is called a cross-licence agreement. Although patent licensing neutralizes the possibility of stopping the competitor's products, patent licensing can still provide competitive advantage to the company. The patent licence fees increase the competitor's costs, and therefore the company can sell its own products comparatively cheaper, all other things being equal. Also, consistent licensing of new technology to the competitors can lower the incentives for the competitors to invest in their own research and development, if they can be sure they will always receive technology cheaper by licensing it.

There are also companies whose entire business is based on obtaining licence income — these companies are called patent sharks or patent trolls. Such companies often take shape when the primary business of the company becomes unprofitable, and the company continues to exist by converting itself into a patent shark. Some patent sharks have been founded to specialize in patent licensing. Since patent sharks do not, at least significantly, develop products or technology for the products, they typically also need to obtain patents through other routes than by patenting their own research and development, e.g. by acquiring patents from other companies. Patent sharks are difficult negotiation counterparts to product companies, since they do not need a patent licence from the other party, thus rendering the patent portfolio of the product company almost ineffective (Lemley & Shapiro 2007). Furthermore, patent sharks often employ as their strategy to wait until the product companies have significant infringing business before they ask for patent royalties, creating a situation called "patent hold-up" (Shapiro 2006). It would seem at the moment that patent sharks impair the patent system and economic growth, since the product companies fail to receive the same protection for their research and development as they are used to, which in turn lowers the incentive to develop technology.

Patents can naturally be sold and bought, and many companies use this avenue to obtain a balanced and strategically meaningful patent portfolio. During the past years, patent auctions have become more common, and this may be a sign of improved liquidity on the patent market. In the patent transactions that have reached the public, patents have been worth up to millions of euros. Patents can be used as collateral, and in such a case, the provider of the loan needs to understand the value of the patent. For start-up companies, a proper patent portfolio may be the prerequisite for obtaining venture capital.

2.1.4 Patents as Information Sources

In order for patents to effectively carry out the bargain between the inventor and society, patent laws require the invention to be described in the patent application in a manner that enables a skilled person to make and use the invention without undue burden of additional research. A patent can be invalidated on the grounds that this so-called enablement requirement is not fulfilled, which increases the incentive for the inventor to provide a good disclosure of her invention. For this reason, patent documents are often easier to understand than corresponding scientific papers, where the authors typically have an incentive to hide some of the information in order to keep ahead of their peers. Consequently, patent publications contain a significant portion of the technical knowledge in the world.

New patent publications are updated to patent databases with a delay of one to two months, and many of these patent databases are offered as a free service to the public. The patent documents are classified according to patent classification systems in the databases, whereby documents around the same technical subject matter belong to the same patent class. There is typically no copyright for patent publications, so, for example, the pictures and text of the documents can be used freely — of course, it is customary and ethically sound to mention the source. Some patent databases have been listed in the appendix.

Patent databases are of use in studying the patentability of an invention or following competitors' patents. Often, the study is carried out by searching patents from the database with a combination of keywords and patent classifications, or if the purpose is to study the patents of one company only, by limiting the applicant to be this company under study. Typically, the target is to capture as many of the relevant patent publications as possible (aiming for *high sensitivity*), since the goal is to have access to all information on the topic that may be of significance — a couple of missed patents can become very expensive. In patent studies it is characteristic that in addition to the relevant patent documents, the search will return a large number of irrelevant patent documents as well, in other words, the search has *low specificity* — it can be that only one per cent of the documents is eventually somewhat relevant. Therefore, it is necessary to make an effort to read the patent documents that were returned by the search at least partially to determine their relevance. For example, patent statistics can give a wildly erroneous picture of the patent landscape unless the documents have been verified by reading. Of course, direct patent statistics have their value and place, and patent statistics have been used as a rare indicator of research and development activity and innovation capability of a company.

2.2 Determining the Value of a Patent

A patent is a document with three facets, since it is based on technological growth in the form of an invention, it can be part of business and the target of trade, and it gives its holder certain legal rights. Therefore, to understand the value of a patent, all three aspects need to be taken into account: the technology protected by the patent needs to be central and relevant, the patent has to cover other agents' business in a significant manner, and the legal scope and history have a clear impact on the patent value. In this section, methods for the valuation of patents are introduced both starting from the theory presented in the literature, as well as from the practical uses of patents. Key components for the patent risk model of chapter 3 are highlighted in footnotes.

2.2.1 Theory of Patent Valuation

The bargain between the inventor and society where the inventor receives patent protection in exchange for making her invention public is not a simple one to carry out. Complicated legislation and uncertainty is attached to the bargain, which makes it difficult for a company to decide whether the invention should be protected by a patent or kept secret (Rabino & Enayati 1995). In a wider sense, a company that owns rights to a plurality of inventions needs to weigh the competitive benefits given by a patent against the fact that competitors can copy the invention, knowing that the patent will most probably not cover all alternative embodiments of the invention (Anton & Yao 2004). Predicting technological development and other factors affecting the value of the patent is difficult, which is manifested in the fact that only a couple of per cent of all patents have significant value (Schankerman & Pakes 1986). This has to do with two things: many technologies or ways of implementing them never become part of what is actually used in products, and even if a patent covers a technically relevant solution, its importance among other inventions needed to build the product is rarely very high (Rahnasto 2007).[1] Straightforward and easily applicable methods for valuing patents are needed, since transactions related to patents have increased in number over the recent years (Reitzig 2004), but it is likely that the market could be larger with a more transparent valuation framework in place. Managing the risk of patent infringement in companies has also gained in importance through the constantly increasing damages awarded by courts in cases of patent infringement (Green 2002) and the significant cost and effort related to patent lawsuits (Kesan & Ball 2006).

The socially optimal breadth and length of patent protection is a significant question in the society (Gilbert & Shapiro 1990; Takalo 2001), since patents are likely to have impact on technological development and growth of the economy, although the mechanisms are somewhat under debate (Takalo & Kanniainen 2000). Patent statistics can, for example, provide fairly reliable conclusions on research and development activity (Griliches 1990) which is in turn an indicator of technological development. The ratio of number of patents to research and development investment has also been studied, and seems to be diminishing (Wilson 2003). At least on the industry level, the value of patents can be determined through the value of research and development investment, since the companies seek to get return for their investment by applying for patent protection, but there are other types of private value created in R&D, as well. It has been found that the so-called equivalent (monetary) subsidy rate (ESR) for research and development would need to be 4–35% of the R&D investment in the case the patent system was removed (Schankerman 1998). [2]

Technological development is rarely drastic but rather incremental (Denicolò 2001), and one invention alone rarely gives a permanent competitive advantage. In practise, it is more often so that companies investing heavily in research and development gain leadership in the technology and thereby are also able to obtain earlier patents in the technology. [3] Patenting cumulative inventions (inventions that build on other inventions) easily leads to a situation where the holder

[1] It is necessary to understand what is the value share of a given technology in building products and services that make use of this technology.

[2] The equivalent subsidy rate can be used as a basis for determining how much of the total R&D investment results in value accumulation to patents in a given industry

[3] Companies that are followers in creation of a new technology are likely to be exposed to earlier patents of other companies. This situation is very much specific to each technology and can change over time if the follower company is able to invest in R&D to develop more advanced technologies.

of the later patent cannot sell the product using the invention without a licence from the patent holder of the earlier invention. On the other hand, as was apparent from the lawnmower example, the patent holder of the earlier invention may in practise need a licence to the later invention as well. In this case the patent office and the courts determine the right of the patent holders to get compensation for their patents by determining the limit for inventiveness that is required of the second invention in order for it to be patentable (Chang 1995; Green & Scotchmer 1995). If a small degree of inventiveness is enough, the patent holder of the later invention can more easily be compensated for her patent. If the requirement for inventiveness is high, later inventors cannot easily obtain patents for inventions that are related to the earlier invention. This determination in fact dictates how much surplus is allocated to the earlier inventor and how much to the later inventor. Consequently, there has been development on the patentable subject matter (Roberts 2001), patent breadth and the length of the patent protection, although the overall direction of these developments e.g. in the USA can not easily be deduced from the court rulings (Gallini 2002). The cumulativeness of technology and patents also leads to the challenge where society needs to set boundaries for licence agreements between holders of complementary patents, because such agreements can in extreme situations be anti-competitive in nature and increase the social costs of patents (Chang 1995; Shapiro 2003).

Recently, there has been discussion that simultaneous innovation instead of cumulative innovation may be more common than what has been believed. In simultaneous innovation, inventors come up with their ideas independently of each other but at approximately same time. This is especially true in areas where standardization plays a strong role, since inventors are bound by the standards to concentrate on similar problems. The optimal behaviour for a company in the environment of simultaneous innovation is different from an environment of cumulative innovation, where secrecy is a good choice (Kultti, Takalo & Toikka 2007). Also, the optimal patent policy by society depends on the type of innovation taking place (Kultti, Takalo & Toikka 2006). In the case of simultaneous innovation, the existence of a patent system in society makes collusive behaviour between innovators more difficult, since patenting innovations is dominant to collusion (Kultti & Takalo 2007) and at the same time increases spreading of information. In simultaneous innovation environments, the fragmentation of patents across numerous owners is a reality, and in fact, from the welfare view-point, fragmentation is optimally the higher the less R&D investment innovation requires (Kultti & Takalo 2007). This also speaks for the dependency between patent value and R&D investment in a given technology.

Patent protection of an invention is rarely accurate in the sense that the patent is granted exactly for the inventive subject matter that is novel and inventive over the state of the art as required by patent law. The applicant may have wanted to limit the scope of protection of the patent during prosecution in order to obtain the patent quickly, or the examination process has been of low quality and the patent has been granted having an excessively broad scope of protection. The quality problems of the examination in patent offices have been a concern especially in complex technologies that develop fast. The problem can be alleviated in many ways, e.g. through an opposition process, whereby anyone can file an opposition against a newly granted patent through a comparatively simple patent office procedure (Harhoff & Reitzig 2004). There are even arrangements — some governmental (Peer To Patent 2007) and some private (Electronic Frontier Foundation 2007) — where patent applications and patents are challenged publicly to ensure only truly patentable inventions enjoy patent protection. It has also been proposed that the people who are able to successfully challenge weak patents should be rewarded, e.g. by awarding them a limited monopoly (Choi 2005). [4]

A patent has value only if the patent holder is willing to use it against an infringer (Carpentier 2006). A lot of uncertainty and asymmetric information is attached to a patent infringement lawsuit, not to mention high costs, because detecting infringement and proving it in court is challenging. This leads to a situation where a patent holder may accept patent infringement even without any compensation from the infringer or at least agree to a licence agreement with the infringer, even though the potential damages awarded to the patent holder were significantly high (Crampes & Langinier 2002). Likewise, active approach to licensing and always being willing to sue any potential infringers may increase the value of patents artificially, especially if the patent in question is known by the patent holder to have weaknesses. [5] On the other hand, executing a successful

[4]Such rewards do exist even without an official system, since the ability to challenge weak patents protects the company from having to pay licence fees or damages for such patents. Furthermore, the ability to develop circumventing solutions enables the company to obtain patents for these alternative solutions and gain a better foothold in the technology.

[5] It is necessary for companies to understand and react to the litigation environment in the technologies they operate in, since this has clear impact on operational costs of the company in terms of lawyer's fees and also may contain large hidden risks as the damages granted by courts

licensing program in a company is becoming increasingly challenging (Sobieraj 2004).

The patent holder needs to have an understanding of the value of the patent so that she can make the decision on paying annuities to keep the patent in force. This leads to a high correlation between patent value and patent age (Lanjouw, Pakes & Putnam 1998). Citation analysis, i.e., determining the number of patents citing the patent, can also be useful in determining the value of the patent (Harhoff, Narin, Scherer & Vopel 1999). The number of citations has been proposed to indicate how central the technology protected by the patent is, but on the other hand, a large number of citations more accurately indicates that there are numerous different technical solutions compared to the earlier one and the earlier patent therefore is not central. Also, the number of citations from the patent to other patents can indicate the quality of the patent, the number of patent claims can indicate the breadth of the patent, and naturally the number of countries where the patent has been applied for indicates the geographical protection sought for the invention. Through factor analysis, these indicators can be used to model the value of a patent in a statistical sense (Lanjouw & Schankerman 2004).

On the other hand, the number of patents and the quality indicators of patents do not directly give the value of a company's patent portfolio, since the value of the portfolio is small, if the company is not ready to use them in court and the competitors know this. This leads to country-specific legal costs and their allocation to the defendant and plaintiff having an effect on the patent value (Lanjouw 1998). The value of patents can thus be modelled by keeping them as options to sue an infringer. The quality indicators of a patent can be seen to correlate with the value of the patent through the dependence that the more valuable the patent is, the more likely it is to be used in court (Marco 2005).

Direct causality between quality indicators and the value of patents is not possible, however. This is because detecting patent infringement is often difficult — for example, a process invention being used without permission in a secure factory can not be seen by the patent holder. Therefore, valuing production-related inventions is a bit questionable, although some methods for such have been presented (van Triest & Vis 2007). On the other hand, directly visible and easily understandable inventions e.g. related to the user interface of consumer electronics may give more valuable patents since infringement is easy to show, but also

may be surprisingly high.

because consumers tend to value such features more and removing them would potentially hurt sales or be costly and time-consuming to change. Where standardization is used to ensure interoperability, patents related to standards can be highly valuable as well, since showing patent infringement can be done against the standard, as everyone needs to obey the standard. [6]

Modelling patents as options can be done in a different way, too, since the patent confers a number of rights on the patent holder, of which the right to sue an infringer is of key importance. To keep the patent in force, the patent holder needs to pay annuities, i.e., the patent holder has an option to keep the patent alive for a fee. The decision of the patent holder to keep the patent in force indicates the value of the option, since a rationally behaving patent owner pays the annuity only if he believes that it is smaller than or equal to the value of the income flow on the next period plus the value of the remaining option (Pakes 1986; Eloranta 2002). This model makes quite heavy assumptions regarding the patent holder, however: the patent holder should know how much income it expects to generate during the next period and to be able to estimate the value of the remaining option.

The most applicable theoretical results come from investigation of the effect of patents on the business of a product company. The age of the patent indicates, as mentioned above, the patent holder's belief in the private value of the patent and the value of the patent is therefore tied to the life cycle of the related technology. Definitions of novelty and inventiveness describe the value of a patent as such: they indicate how much the invention needs to differ from the earlier inventions in order to be patentable. The eventual scope of protection determined by the patent claims naturally indicates the technical scope of the patent, and this correlates with the number of claims in the patent. Difficulty of designing around the patent is closely related to the scope of protection: the more difficult it is for a competitor to develop an alternative solution, the more valuable the patent is. The length and the depth of the invention disclosure also affects the patent value, because the competitors are able to copy the invention with a good description of the invention. A group of patents is also stronger than the same patents individually, because a larger group of patents is more difficult to challenge purely

[6] Both in applying for and using patents a company needs to think about whether infringement of the patent can be shown, because patents tend to be more valuable in technologies where infringement is easy to show. On the other hand, the risk of incurring costs from patent infringement — whether accidental or willful — is larger in those technologies where infringement is easy to show.

for practical reasons relaed to timing and cost of patent disputes, and the position of a patent in the portfolio is a determining factor for its value, too. Earlier, the value of patents has been modelled as an option to prevent others from using the invention, and the option to licence the invention is also closely related to this. The value of a patent is therefore determined by

- The age of the patent
- Novelty and inventiveness
- Number of patent claims
- Difficulty of designing around
- Length and depth of the invention disclosure
- Portfolio effects.

In a study done on the patents of the semiconductor industry, the factors indicating patent value best were inventiveness, difficulty of circumventing the patent (designing around), the position of the patent in the portfolio and the length and depth of the disclosure. (Reitzig 2003)

Different technologies and different industries can exhibit very different behaviour in valuation of patents. In pharmaceutical technologies, patent litigation is very common and patents are often not licensed to other companies. The patents are also typically old, because it takes a long time to develop the technology to the market. In telecommunications industry, which relies strongly on interoperability, it has become customary to license patents to other companies, and the relevant patents are typically much younger due to rapid development of technology. Therefore, the patent valuation methods need to be adapted to the industry and technology in question.

Almost all the above methods for the valuation of patents fail if the patent holder is a patent shark. The social costs of such a business are significant, since no surplus ends up with the consumers, and the costs of the product and service companies increase. On the other hand, existence of patent sharks may increase the possibility of monetizing patents by selling them, and thereby may increase incentives to innovate where patents are not used to support product or service business. The value of patents when they are held by patent sharks is determined to a large degree by the legal environment, i.e. the damages obtainable in courts, and by the licensing strategy of the patent shark. The value of patents is purely the present value of the licence income stream, and this value may have very little to do with the real value of the patents. Often, patent sharks sit on their patents until the product and service companies infringe their patents with a large volume of business (although the patent may be technically rather insignificant), and then seek to obtain maximum damages in the licensing negotiations or through court proceedings (Reitzig, Henkel & Heath 2006, 2007). [7]

The number of patent applications filed by academic organizations has been growing over the past years, and in the USA this development has been encouraged by legislation. Universities are almost in the same position as patent sharks in the sense that they do not typically have any significant product or service business. Yet, it has to be remembered that the research and operations of universities have significant positive externalities in society, and perhaps this has been the reason in many nations to consider it appropriate for universities to collect licence fees. On the other hand, a major role of universities in society is to conduct basic research, and the public availability of research results from such basic research is key to creating the positive externalities. In practise, universities quite regularly collaborate with companies in the development of new technologies, in which case it is natural that the resulting inventions are patented, as the monetization of patent rights created in universities happens without complication (Simelius 2005). The value profile of the patents owned by universities is markedly similar to that of the product companies, perhaps indicating that they view the role of patents in a similar manner to most product companies. (Sapsalis, van Pottelsberghe de la Potterie & Navon 2006)

2.2.2 Patent Valuation in Practise

In practical situations, all the information needed to use the theoretical patent valuation methods is hardly ever available, and greatly simplified methods need to be applied. Such situations arise in filing a patent application, during prosecution of the patent application, in deciding to pay the annuities for the patent, using the right to prevent others from utilizing the invention or licensing the patent, and naturally when the patent is being considered to be used in court. The value of the patents of other companies needs to be understood when the company is in the process of acquiring a patent or taking a licence to it, when the company needs to defend against patents in court or in negotiations, opposing a patent, designing

[7] The value of the company's ability to defend itself in patent disputes is very clear in the case of patent sharks, but is a key factor in determining licence fees and damages in relation to competitors, as well.

products that do not infringe patents, or in business collaboration and mergers and acquisitions.

When an invention is made by a company employee, the company faces a decision whether to file a patent application on the invention or not (Eloranta 2002). This decision is typically based on two criteria: what would be the obtainable scope of patent protection for the invention, and how significant would the patent be to its business strategy. These criteria are evaluated with the help of experts who can give an opinion on patentability and the business value of the potential patent. A similar decision needs to be made when the company receives an office action from the patent office, needs to pay an annuity fee on the patent, or is considering the geographical coverage in terms of filing the patent application in foreign countries (Pitkethly 1997). At later stages of the patent prosecution, more information on the development of technology and future business strategy of the company is typically available, thereby making the decision easier. When the patent is eventually granted and the company is getting ready to use the patent in licence negotiations or in litigation, the company needs to understand the value of the patent well, since the costs of using a patent can be extremely high, and a court case may determine the company's future. In such situations, the company will most likely resort to the help of patent attorneys in determining the legal status of the patent, the help of technical experts in understanding the relevance of the patent against the products of the competitor, and to the help of economists and business analysts to determine the competitors exposure to the patent and the business case of using the patent as a whole.

When the company is acquiring patents as such or through the acquisition of a company, the value of patents can be determined in a similar manner to when the company files patent applications themselves. However, the history of the patents to be acquired needs to be studied in the due diligence process: the patent may be already licenced to the competitors of the company, the patent may in fact be invalid since prior art has turned up after the grant of the patent, or the annuities may not have been paid for the patent. In defence against other companies' patents, the relevance to the technology and the validity of the patent are challenged by studying the scope of the patent carefully and finding prior art against the patent. Sometimes it may even be that the company is already licenced to the patent through earlier patent licences or business collaboration agreements. Because it is expensive and resource-consuming to defend against other companies' patents, and because of the significance of the costs and implications of patent licences, the company acts wisely if it seeks to minimize the risk of patent infringement already when it is developing products and technologies. This is done through choices of technology, by acquiring or licensing the necessary patents in an early phase, by selecting the right collaborators and agreeing on the responsibilities in terms of patent risk with them, proactively clearing invalid patents away by oppositions, and also by developing a patent portfolio for the company that can be used in cross-licence negotiations. [8]

In the foregoing, the value of individual patents has been discussed without much consideration of effects that arise when patents are bundled into a patent portfolio (Parhcomovsky & Wagner 2005). The basic definition of these portfolio effects is that a patent portfolio of n patents has a value different from $n\alpha$, where α is the expected value of the value of a single, valid and relevant patent in the portfolio. Now, let $\Gamma(n)$ be the true value of the portfolio, and let p be the probability of a single patent in the portfolio being irrelevant or invalid, i.e., the courts would find no infringement of a valid patent if this patent was brought against a product in a court case. We can then identify three areas in terms of how the portfolio value depends on n (see Figure 2.2), using the indication of $\Gamma'(n)$ and $\Gamma''(n)$ for the incremental value of the nth patent and the change in incremental value from the $(n-1)$th patent and the nth patent. In the first area, where there are few patents in the portfolio, the value function $\Gamma(n)$ has the following properties:

$$(1-p)\alpha \approx \Gamma'(n) \ll \alpha, \text{ and} \tag{2.1}$$

$$\Gamma''(n) > 0. \tag{2.2}$$

Equation 2.1 indicates that when there are few patents in the portfolio, challenging the relevance and validity of the portfolio is relatively easy, and the patents are valued at $(1-p)$ of their original value. Equation 2.2 expresses the fact that adding patents to the portfolio makes challenging the whole portfolio more difficult in practise.

In the second area there are already so many patents that $\Gamma(n)$ behaves in a

[8] The existence of licences and the ability to negotiate licences, e.g. by using its own portfolio, is one key element determining the company's vulnerability to other companies' patents.

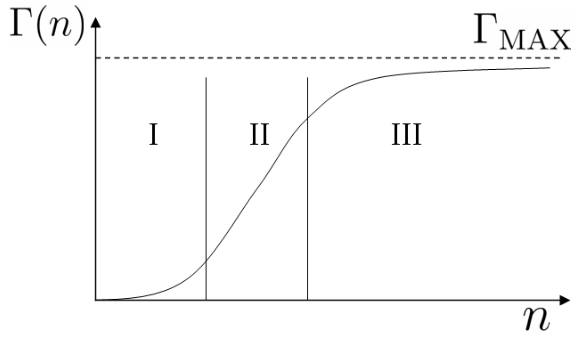


Figure 2.2. The value of the patent portfolio as a function of the number of patents in the portfolio.

linear manner:

$$\Gamma'(n) \approx \alpha, \tag{2.3}$$

$$\Gamma''(n) \approx 0. \tag{2.4}$$

According to Equation 2.3, each additional patent will bring a constant marginal value α to the portfolio and thus the value of the portfolio can be determined through the value of individual patents. The total value of the portfolio cannot grow indefinitely, however, since it is limited by other factors than the existence of valuable patents, such as the ability of the company to make use of all inventions, or the willingness of licensors to pay the same price for the last patent as they paid for the first 10 or 20 patents. Thus, the value of $\Gamma(n)$ approaches some limit, or in other words

$$\Gamma(n) \rightarrow \Gamma_{\mathrm{MAX}}, \quad \text{when} \quad n \rightarrow \infty, \tag{2.5}$$

$$\Gamma'(n) \rightarrow 0, \quad \text{when} \quad n \rightarrow \infty, \tag{2.6}$$

$$\Gamma''(n) < 0. \tag{2.7}$$

In practise, Equation 2.6 sets a limit for the company regarding the size of a useful portfolio to have in a technical area, because at some point the marginal costs of an additional patent equal the marginal value added by the patent. A high number of patents in a given technology (high patent density) also indicates that there are many redundant patents in the technology. A high number of patent holders is an indication of complexity in the relation of the patents to each other — some patents may have been born out of cumulative innovation while many may be the result of simultaneous innovation, and determining a fair share of reward to patent holders becomes very challenging. [9] In this thesis, it is not taken into account that there can be multiple technologies involved in any single product or service.

The determination of the portfolio effects of standards-related patents may deviate from what has been presented above in the sense that the linear section of the value function is reached very quickly if not right from the beginning, and the value limit of the portfolio may be higher. Alternatively, the value of the portfolio in the second and third regions may be completely linear, but still limited to a reasonable cumulative value: new patents can be modelled to be as valuable as the earlier ones, and the increase in the number of patents just changes the slope of the value curve. It is reasonable to assume that the value of individual patents does not fluctuate significantly, and that the value of the portfolio is to a great extent determined by the number of patents that are truly valuable in the portfolio.

2.3 Risk Management

Risk management is an integral part of business in successful companies. The approach to risk management should be more to understand the key long-term business goals of the company and identifying and managing the risks related to them, instead of a set of rules or specific controls (Carey & Turnbull 2001). Furthermore, the risk management mindset needs to be built-in to the management processes of the company, not a separate function for meeting the regulations. An integral risk management approach will allow the company to stay on top of risks it faces and choose the level of risk-taking that is appropriate for its business — risk-free businesses are of course not very profitable. The idea of risk management is to keep the risks under control, not to eliminate them. How the risks are then managed depends very much on the nature of risks the company faces.

Some level of prioritization is useful for managing the myriad of risks to the company, and Carey *et al.* propose a simple four-field for this purpose (see Fig. 2.3). Risks that have high likelihood of occurring and that have high impact on the business (area A) obviously call for immediate actions. The risks that have high impact but are not that probable (area B) call for strategies of managing

[9] The density of patents and the fragmentation of patents across patent holders are key indicators of the type of patent environment for a given technology, and determine the characteristics of exposure to other companies' patents. Defending against a large number of patents may be financially inefficient, and having many companies to deal with poses operational challenges.

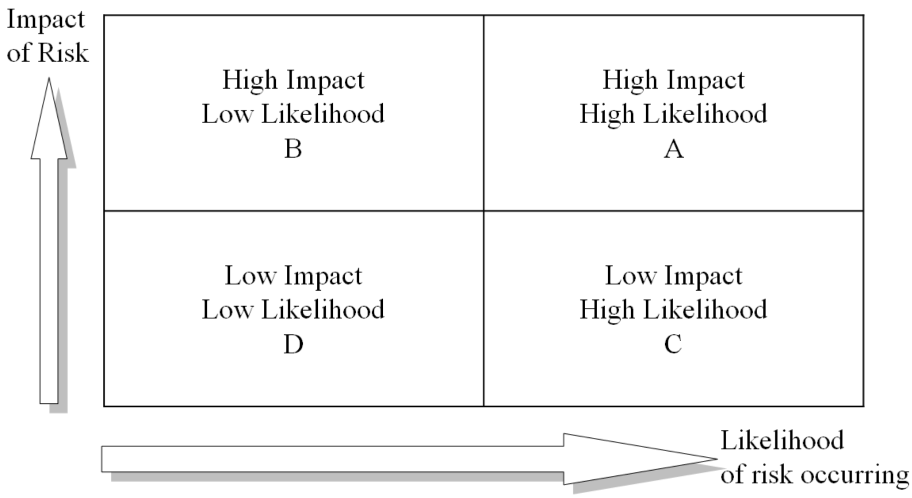


Figure 2.3. Risk prioritization. Risks can be prioritized by their impact on business and the likelihood of the risk occurring. Different ways of managing risk are appropriate for the different areas (A, B, C, D). Adapted from (Carey & Turnbull 2001)

the risks like insurance or somehow else transferring at least part of the risk to someone else. Small risks occurring with high probability (area C) can most likely be handled as part of the business provided there are processes to do so. Small risks with low probability (area D) can be followed but do not require immediate action.

It is not immediately apparent why risk management increases shareholder value (Stulz 2001). If the shareholders manage their portfolio professionally, they have diversified their assets across several companies. Shareholders do not, therefore, appreciate companies diversifying their operations, since that does not add value to them. Also, lowering the risk may not even be visible to the shareholder, since risk management just smoothes the ups and downs of the company cash flow, but does not alter the long-term earnings.

The value from risk management is two-fold: it reduces the probability of costs related to distress, and it increases the value of the company to other stakeholders and thereby enables good business down the road. For example, a company making consumer electronic devices should be able to execute its strategy on making the devices without being hit by risks that have nothing to do with its core business. Also, managing risks well will enable the company to build sound relations with workers, suppliers and customers due to at least apparently lower risk of financial distress. These relationships help the company to reach

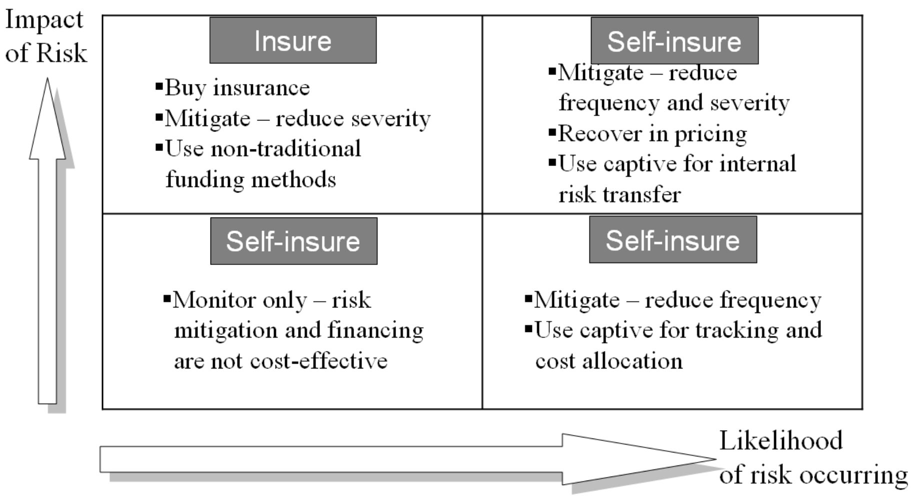


Figure 2.4. Risk management. Risks with low probability and high impact to business are typically insured, while other kinds of risks are managed through the company's own operations by, e.g., reducing their probability and severity. Adapted from (Hanley 2001)

higher earnings compared to a situation where the relations are not so good due to unpredictability of the company's business which is a consequence of poor risk management. (Stulz 2001)

One proposed risk management process has the steps of identification, assessment, profiling, quantification and consolidation (Hanley 2001). Before risks can be dealt with, they need to be identified, followed by assessment of their probability of occurrence and impact on business. Risks are then profiled to attach them to risk groups, that can be subsequently modelled and quantified. Such profiling and quantification then allow the company to apply different risk management strategies based on the type of the risk (see Fig. 2.4). To be relevant on the corporate level, these results still need to be consolidated, and the company can then consciously decide on actions to manage the different risks like taking an insurance or doing nothing. The basic approaches to risk management are to modify the company's operations (reducing probability and severity of risk or recovering the risk in pricing), to modify its capital structure (the amount of debt), or to employ financial instruments (insurance) (Meulbroek 2001b). In addition to preparing for "normal" business risks, the companies should also be prepared for crises which differ from risks in the sense that the predictability and quantifiability of crises is poor compared to risks, and the magnitude of their impact to business is very high (Mitroff 2001, 2002; Mitroff & Alpasian 2003).

Different valuation methods have been developed to attribute a pecuniary value to risks, and the different tools are applicable to different types of risks. One very popular method is the Value at Risk (VaR) model, where the losses are given a confidence level and a corresponding value. For example, we might say that the Value at Risk for exchange rate losses is 1 million euros with the confidence level of 95 per cent, where we mean that 5 per cent of the losses will be higher than the 1 million euros (we do not know how much higher, though). The VaR model has become popular in quantifying corporate risks both through availability of tools (the RiskMetrics tool by JPMorgan) and regulatory developments. However, the Value at Risk method has shortcomings, e.g. due to non-normality of markets and some simplifications of the model related to portfolio theory (Glasserman 2001). It is therefore important to understand the model being employed for risk quantification, or in some cases supplement it with another model than can better model the risks in areas where e.g. VaR fails, such as the extreme value theory (EVT) adapted to modelling rare events (Finger & Malz 2001) or the Conditional Value at Risk (CVaR) theory that allows to predict outcomes when the VaR limit is exceeded (Martansaari 2007).

When the company cannot manage a risk through its own operations or the use of captive due to the size of the risk, it turns to ways of insuring the risk. Traditionally, companies have been employing layers of conventional insurances for risks they cannot retain (Kanto 2007). Some developments e.g. in the legal front have lead to a situation where conventional insurances are not available for companies to the extent there is demand for them. Consequently, companies have turned to creating captive insurance companies that use reinsurance to cover larger risks. Finally, the largest risks can nowadays be securitized through large insurance companies. (Dickinson 2001)

Corporate-level insurance policies have been used to provide cost benefit to the company while managing all the risks of the company in a holistic manner (Meulbroek 2001a). Such approaches fit well with the notion that risk management should be a corporate level issue and built in to the processes of the company. All in all, it is clear from the literature that a systematic approach to managing risks in companies is needed, and such an approach provides value to the shareholders. Also, there exist tools for managing risks systematically on the general level, and what remains is the understanding and modelling of specific risks. This will be addressed in the next chapter.

Chapter 3

Results

In this chapter, the Patent Risk Indicator model is developed and some potential applications are presented. First, the baseline Patent Risk Indicator model is derived starting from basic economic considerations. Then, the model is refined by grouping the individual factors to meaningful and measurable quantities and the composition of these quantities is explored in more detail. Next, the application of the model in practical business is described. Finally, some considerations are presented on how the model could be improved in cases where the statistical properties of the model's variables are more complex than what is assumed in the baseline model.

3.1 Baseline Patent Risk Indicator Model

The source of patent value in a specific technology is the R&D investment used to develop the technology and to implement it in products and services (see Fig. 3.1 for references). In the model, companies A and B1–BN form the closed system where a specific technology is developed and used. The companies make a revenue (1) from the products and services (2) that use this technology. This revenue is partially re-invested into R&D (3) for developing the technology, creating products and services and for coming up with inventions that can be turned into patents (4) by investing in patent applications and prosecution. The share (5) of the patent value of the total R&D investment is equal to the equivalent subsiby rate (ESR) mentioned earlier. As presented in the previous chapter, the value of a patent portfolio has many factors. In the baseline model, the factors relating to

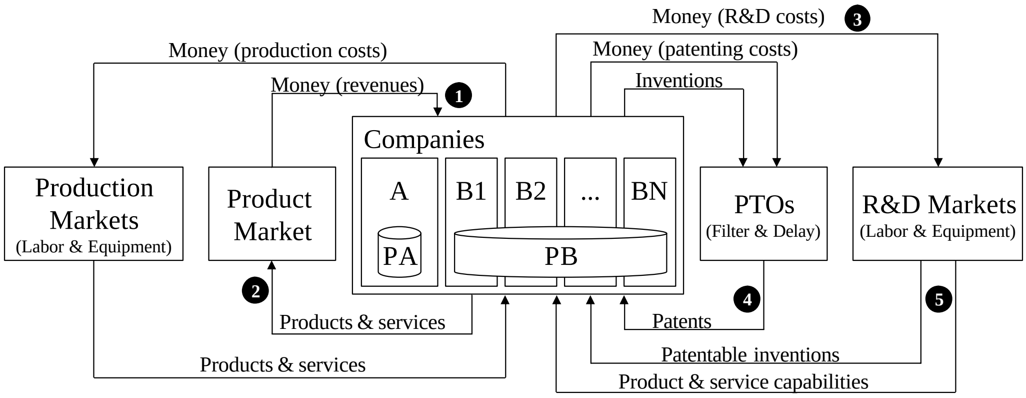


Figure 3.1. Elements of the Patent Risk Indicator model. Companies A and B1–BN invest in R&D and patenting and thereby accumulate their patent portfolios PA and PB. The markets that are relevant for R&D, patents, production and sales have been shown, but many (like the capital markets) have been omitted. The figure also depicts a *closed patent market*, i.e. the patents in a certain technology are generated by the companies using that technology, and patents are not sold to companies outside the market. The numbers 1–5 indicate measurable quantities that are relevant to the model.

all patent portfolios in a specific technology are taken into account to arrive at the total patent value of the economy starting from the total R&D investment. In Figure 3.1, this value is the value of the patent portfolios PA and PB. The model then assumes that this patent value is partly attributed to licence fees collectable from other companies and partly to other values, and the share attributed to the licence fees is the total patent risk in the industry. This risk is then scaled for each company by the company's market share (revenue share of A) and the share of the patents pertaining to the technology held by other companies (the share of the portfolio PB of all patents). The patent risk is targeted to the products and services sold and produced on the market. The factors of the model are explained in Table 3.1.

In the following, the formulation of the baseline Patent Risk Indicator model will be derived. Starting from the total value $\pi_{PatValue}$ of patents in the economy — a quantity unknown at this point — a company's patent risk depends on the share θ_{Lic} of this patent value attributable to licensing income, the company's market share θ_{Market}, the value share θ_{Tech} of this specific technology among all technologies in the relevant market and the share of patents other companies hold. The last quantity is naturally $1 - \theta_{Pat,comp}$, where $\theta_{Pat,comp}$ is the share of patents

Table 3.1. Factors of the baseline Patent Risk Indicator model. In the model, the π variables represent different pecuniary values, and the θ variables represent different activity shares that relate the value variables together.

Variable	Explanation
$\pi_{PatRisk}$	The value of the patent risk of a company from using a specific technology
$\pi_{PatValue}$	The value of the patents
$\pi_{RDI,tot}$	Total R&D investment of the economy for developing a specific technology
$\pi_{RDI,comp}$	The R&D investment of a single company for developing a specific technology
π_{Exp}	The value of revenue exposed to the patents pertaining to the technology
$\theta_{RDI,comp}$	Share of a company's R&D investment of the total R&D investment used in developing a specific technology
θ_{Market}	Market share of the company in relevant markets
θ_{RD}	Share of the company revenue used in R&D investment in total
θ_{Pat}	Technology-specific share of patent value of R&D investment
θ_{Lic}	Share of patent value attributed to licensing income
θ_{Tech}	Technology share of a specific technology to all technologies in the products and services on the relevant market
$\theta_{Pat,comp}$	Share of patents the company owns of all the relevant patents

the company holds in this technology. Taking all these factors together, we get

$$\pi_{PatRisk} = \pi_{PatValue}\theta_{Lic}\theta_{Market}\theta_{Tech}(1 - \theta_{Pat,comp}). \tag{3.1}$$

The total patent value in the economy can be expressed in terms of the share of patent value θ_{Pat} generated from R&D investments in this specific technology, and

$$\pi_{PatRisk} = \theta_{Pat}\pi_{RDI,tot}\theta_{Lic}\theta_{Market}\theta_{Tech}(1 - \theta_{Pat,comp}), \tag{3.2}$$

where $\pi_{RDI,tot}$ is the total R&D investment in the economy targeted at developing the specific technology in question. In terms of the R&D investment $\pi_{RDI,comp}$ of a single company, this can be expressed as

$$\pi_{PatRisk} = \frac{\pi_{RDI,comp}}{\theta_{RDI,comp}}\theta_{Pat}\theta_{Lic}\theta_{Market}\theta_{Tech}(1 - \theta_{Pat,comp}), \tag{3.3}$$

where $\theta_{RDI,comp}$ is the share of the company's R&D investment of the total R&D investment targeted at developing the technology. If we still introduce the share θ_{RD} that the company ploughs back to R&D from its revenue in this market (and which revenue is also the exposure π_{Exp}), the model takes the form

$$\pi_{PatRisk} = \frac{\pi_{Exp}\theta_{RD}}{\theta_{RDI,comp}}\theta_{Pat}\theta_{Lic}\theta_{Market}\theta_{Tech}(1 - \theta_{Pat,comp}). \tag{3.4}$$

By grouping the terms we get a formulation of the model that allows to examine factors related to the company's business, its R&D, characteristics of the technology and of course the relevant patents. The baseline Patent Risk Indicator model is therefore

$$\pi_{PatRisk} = \underbrace{\pi_{Exp}\theta_{Market}}_{\text{Business factor}} \underbrace{\frac{\theta_{RD}}{\theta_{RDI,comp}}}_{\text{R\&D factor}} \underbrace{\theta_{Pat}\theta_{Lic}\theta_{Tech}}_{\text{Technology factor}} \underbrace{(1 - \theta_{Pat,comp})}_{\text{Patent factor}}. \tag{3.5}$$

These factors are in most circumstances interdependent, as will become obvious from the following discussion.

3.2 The Factors of the Patent Risk Indicator Model

The Business Factor

The components of the business factor are the revenue exposure π_{Exp} and the market share θ_{Market} of the company. The revenue exposure is the turnover of the products and services in the relevant markets. For example, if the company is making car tyres and mobile phones, and we are interested in the patent risk of GSM technology, we would pick the mobile phone market as the relevant market and take the exposure to be the turnover from mobile phone sales and exclude the car tyre business. We would, however, also include mobile phone sales that do not employ the GSM technology — this matter is (by definition here) taken care of in the technology factor. The market share is similarly the company's market share in the relevant market counted by turnover.

The patent risk of a technology increases both with the increase of exposure and with the increase of market share. In fact, the business factor can also be expressed in the form $\pi_{Market}\theta^2_{Market}$, where the π_{Market} is the total market size, and in the form π^2_{Exp}/π_{Market}. These formulations make it possible to evaluate the impact of revenue, market share and market size changes to patent risk in a given technology, under *ceteris paribus*. For example, the following conclusions are possible:

- When the market share of the company increases and market size stays the same, the patent risk increases proportionally to the square of the market share. For example, if the market share increases from 30% to 40%, the patent risk almost doubles.
- When the company grows with the market, keeping its market share constant, the patent risk increases linearly with the market size growth.
- When the company maintains its revenue on a declining market, the patent risk grows, since it is inversely proportional to the market size when the revenues are constant.

In addition, the market share and revenues of the company affect the patent risk indirectly through the other factors. For example, a company with a high market share and revenue is able to have a good position in terms of its R&D and patent portfolio, which in turn lowers the patent risk. A large market size may attract patent licensing, or if the market is small, the transaction costs may be too large for effective licensing, which again directly affects the patent risk.

The R&D Factor

Since the source of patents related to the development of new technology is generally the R&D activity, the relative strength of the R&D activity of a company influences its patent risk position. This happens through a few processes. First, the internal level of R&D activity (the average share θ_{RD} that the company invests of its revenue) is a key contributor to the overall patent value of this technology in the economy. The higher the investment to R&D in the economy, the more patents there are and the higher the patent risk is. Second, the relative level $\theta_{RDI,comp}$ of R&D investment roughly determines the position of the company among all companies in the development of the technology. When a company has a leading position in development of the technology, it also has an advantage in terms of patents, since it is likely to be ahead in the patent race, and may also have the power to influence the selections of how the technology is implemented and thereby which patents end up being relevant. Both advantages work to lower the patent risk.

Again, the R&D activity affects the patent risk through the other factors, as well. High R&D level may improve the company's position in the market and even drive the whole market size if the technology becomes important. The level of R&D is typically tied to the level and quality of patenting, which drives the share of value going into patents. Naturally, the share of patents is a fairly direct result of R&D activity, although the internal patenting processes and the innovation culture of the company affect the patent position very much. Being early and strong over time in the R&D activity is likely to result in a good patent share.

The Technology Factor

Some contributors of patent risk are tied to the nature of technology in question. The share of R&D value θ_{Pat} attributable to patent value depends strongly on the technology. In some technologies like user interfaces of computers, the use of a patent (or *patent infringement*) is easy to detect, while in other technologies like processor technology detecting the infringement requires costly and difficult tear-down work. Likewise, some technologies are easy to take into use, and such technologies benefit more from the existence of patent protection, whereas technologies that are difficult to implement have a natural barrier of entry and higher first-mover advantages. In some technologies, standardization plays a strong role both through allowing easier detection of patent use since everyone needs to implement the technology according to a written standard, and through removing some of the first-mover advantage.

The level of patent licensing is also related to the nature of technology. Some technologies are used primarily for creating differentiation of the company's products and services, while others are taken into use to make the product work or even to create interoperability between products. In technologies where the technology is used for differentiation, patents are more likely to be used for blocking the competitors, and extracting licence fees is less common. In technologies allowing interoperability or basic functionality, licensing is more commonly used to recover some of the R&D investment and to provide return on the patenting investment.

Technologies are rarely stand-alone in the sense that they would be the sole contributor to the sales of a product or service. For example, typical consumer electronics products contain tens or hundreds of different technologies and are consequently using a large number of patents. The significance of any single technology is typically fairly small, but naturally complete technologies providing fundamental functionality of the product or technologies appreciated by the company's customers have a higher importance than others. The technology share θ_{Tech} also varies across products and services depending on the number and kind of technologies used.

The Patent Factor

In the baseline Patent Risk Indicator model, the patent factor only accommodates the share of patents the company has. Due to the complexity of patent licensing, other factors than the mere number of patents are highly important. Therefore, the share $\theta_{Pat,comp}$ of patents needs to be understood more broadly than the number of patents — or better, the model should be modified to take these additional factors into account. Some of these factors relate directly to patent risk, while others are more related to the company's ability to manage the patent risk it faces in a given technology.

As described earlier, the aggregation of patents into patent portfolios may somewhat modify the value of a single patent due to the portfolio effects that come into play. Small patent portfolios are in practise easier to defend against, which means that the patent risk from small portfolios is typically low. Reasonably sized portfolios result in the patent value being rather close to the value without consideration of portfolio effects, but overly large portfolios carry a dead weight, since it is in practise difficult to convince a licencee of the value of, for example, yet another hundred relevant patents. As an operational matter, the number of patent portfolios — that is, the fragmentation of patents in the industry — also affects the patent risk of a technology. A situation where there are three patent holders with good portfolios is an easier one to solve through licensing than a situation where there are thirty patent holders with ten reasonably good patents each. The fragmentation also treats different size of companies differently: smaller companies may not need to worry about other patent holders much in a very fragmented technology, since patent holders may find it more attractive to extract licence fees from the large companies due to their large revenues.

The behaviour of patent holders modifies the face value of patents. In some technologies, there are a high number of litigations, which increases the patent risk significantly. The patent litigation costs in the US amount to millions of dollars in each case, and the damages ordered by courts have been increasing. Although litigation costs are not taken into account in this model due to their transactional nature, this is driving the licence costs up, and also creating an environment where smaller companies have to pay for patents they do not use, since the patent holder is threatening them with a lawsuit they cannot afford. This challenge is especially large with patent trolls that do not produce anything themselves and therefore have no patent risk of their own. Many such companies also try to create a perception that their patents are needed, even sometimes going to the extreme and engaging in foul play by clearly overstating or ”padding” their patent strength (Dewatripont & Legros).

The kind of patents is also a large factor in the patent risk they pose to companies. As mentioned earlier, patent use is easier to detect for some technologies compared to others, and the easier it is to detect infringement, the higher the patent risk is in this technology. In some technologies, the patent density is overly high due to a competitive situation or the nature of the technology. In such cases, the inventive contribution of one patent may be small, and consequently the value of the patent is smaller among all the patents. Furthermore, narrow patents are often easier to avoid if a company chooses to do this, since alternative solutions are abundant. Sometimes a large patent density is the effect of follower companies patenting around the original core technology, in which case the older patents may be more valuable and pose more risk. This is only true in a limited manner as discussed earlier, and applies in technologies where innovation is sequential instead of simultaneous.

Patent quality is a central issue when it comes to using the patents, and therefore it also affects the patent risk directly. Patent quality relates to things like how the patent claims are drafted, what kind of claim categories are used, how broad the specification is and what kind of claim interpretation that allows, the way in which the specification has been written and whether it supports the claims well, how prior art has been handled for the patent and many more. All these are also dependent on the jurisdiction — notably, US patent law differs clearly from European patent law — and therefore the introduction of patent quality highlights the necessity of doing patent risk calculations country by country.

In addition to the features of the patents causing the patent risk, in real-life business one has to take into account also the company's ability to manage the risk. Existence of licences and the ability to negotiate licences to patents is one key factor affecting the patent risk, since a good licence agreement can reduce the patent risk in a technology significantly. Acquisition of patents can also convert a risk to an asset, but as described earlier, the patents in a company's portfolio need to fit in its business strategy. Business relations and agreements may also reduce patent risk proactively, and reactive ability to prove patents invalid (*"patent killing"*) and to find alternative solutions (*"design-around"*) through a strong R&D and patent organizations are ways to mitigate the risk internally.

All in all, evaluating the patent factor correctly for a given technology is a complex process and needs to be done by experts. It is not sufficient to rely on statistics from patent databases, and in many cases not even on human selection of relevant patents from the search results. Alone patent quality is difficult to evaluate, and taking into account geography and the fact that patents are national rights and written in their respective languages makes patent evaluation very challenging. When portfolio effects, individual technology features and complex litigation comes into play, the uncertainty of the patent factor value may become fairly high.

3.3 Application of the Patent Risk Model

The main use of the Patent Risk Indicator model is to quantify the patent risks for different technologies. Before this can be done, it needs to be decided which are the technologies to be studied and at which level of granularity the quantification is done. Such decisions naturally affect the work involved in using the model, but they may also affect the reliability of results. For example, if the technology to be studied is defined to be too narrow, the evaluation may not capture all relevant patents and the patent risk for implementing the technology to products is underestimated. The quantification of patent risk should preferably be done in monetary terms so that the results are meaningful and comparable across technologies.

In the evaluation of the factors of the Patent Risk Indicator model for each technology, it is very useful to document the reasoning behind choosing different values for the variables. Such reasons may include business outlook, expected technology adoption and other technological development and information about the studied patent landscape and the conclusions drawn. This documentation enables decision makers to review the basis for the patent risk value, and they can be revisited when conditions change or when risk mitigation actions are being planned.

The fact-based documentation of the model variables enables a company to mitigate the patent risks in each technology. Naturally, the business factor drives the value of the patent risk in all technologies. Higher market share and larger markets will attract patent holders to contact the company, and for large companies it is therefore necessary to make sure such contacts can be managed efficiently. For new entrants, a high value of the patent risk may indicate that the best strategy is to refrain from using the technology. The R&D factor can be understood to indicate that the higher the R&D investment of a company in a given technology, the smaller the patent risk. The reasons for this are at least two-fold: higher R&D investment is likely to give a leading position in patents and thereby reduce the risk from competitor's patents, and good R&D capabilities can be used to directly reduce the risk by avoiding and invalidating other companies' patents. The technology factor points towards the advantages of developing alternative and complementary technologies, which reduces the significance of the technology in question and reduces patent risk in that technology. Of course, using a high number of technologies creates another kind of risk: the stacking of royalties can become an issue. Finally, the patent factor clearly gives justification for the company on one hand to develop a strong portfolio in technologies it uses and on the other hand to actively avoid and invalidate other companies' patents in the technology, and then use the resulting position to obtain licenses for only the necessary patents and thereby reducing the risk.

For the model results to be useful in managing the operations at company level, the results of the patent risk model need to be consolidated across technologies and visualized. For this purpose, the results can be plotted in a bubble chart four-field, where the horizontal axis shows the patent risk of a technology and the vertical axis shows the ability of the company to mitigate the risk (see Fig. 3.2). Additionally, the revenues directly related to the use of the technology can be depicted as the area of the bubble. Estimation of the direction of the change of the patent risk and the risk mitigation ability are shown with an arrow inside the bubble. Such a representation enables a company to identify the technology areas with higher risk and take necessary actions to mitigate the risks.

Depending on the position of the technology on the risk map, the company can do different things to manage the patent risk of that technology. Normally, when the company is just one of the companies developing and using a technology, the patent risk of a technology is highly correlated to the company's ability to manage the risk (see technology group C1–C7 in Fig. 3.2). Therefore, at an appropriate point, for example when the company is increasing the use of the technology, it can employ typical risk mitigation strategies through licensing (and using its own patent portfolio), acquisitions, avoiding patents and doing business deals. When the company has then established its presence and gotten to a leading position, its ability to mitigate the risks is high, while the remaining risks are low (see technology group B1–B2 in Fig. 3.2). If a company is new in an area of technologies, it faces a situation where the risks may be relatively high but the ability to mitigate the risks are still low, and the company needs to start building the capability by e.g. increasing its R&D activity in the area and obtaining patents in the relevant technologies (see technology group A1–A5 in Fig. 3.2).

3.4 Further Development of the Patent Risk Model

Typically, the factors of the Patent Risk Indicator model are correlated — for example, the market share and the revenues of the company are directly linked. In

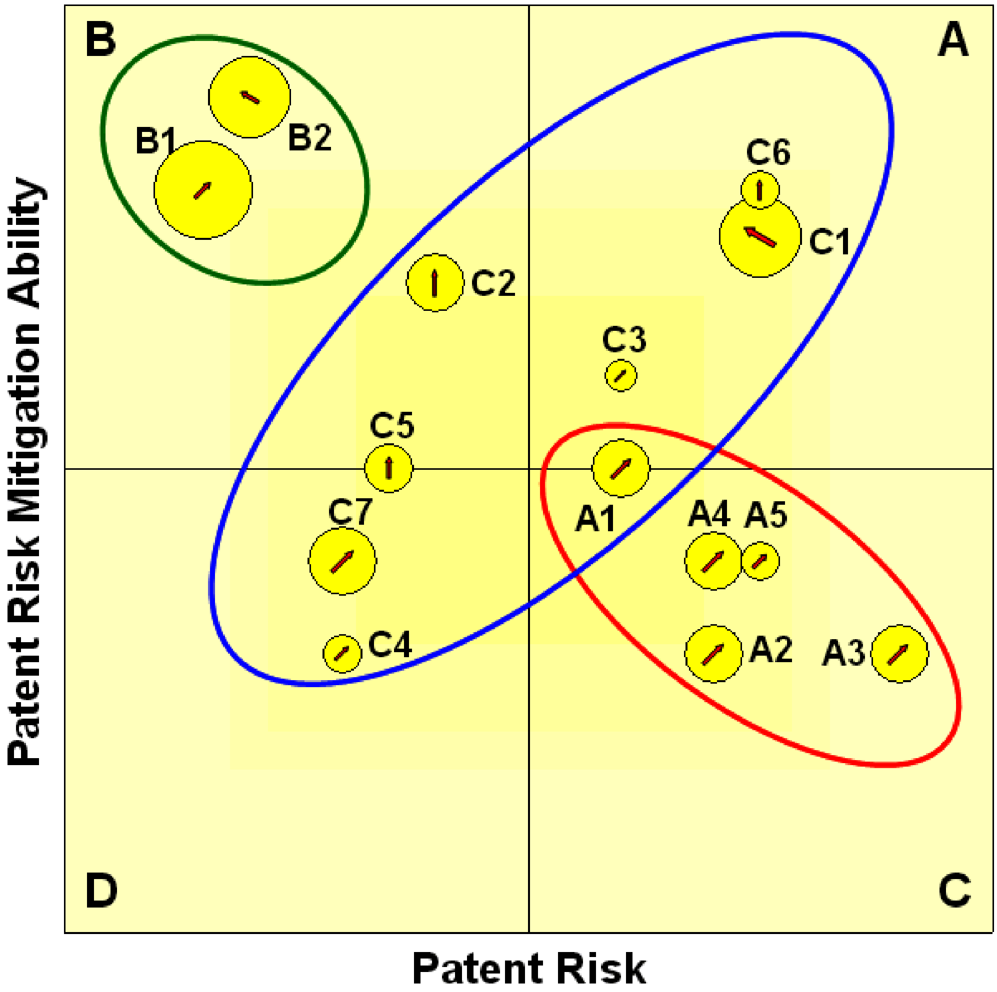


Figure 3.2. The Patent Risk Map shows the patent risk and the risk mitigation ability in a bubble chart four-field. The bubble sizes indicate the related revenue for each technology, and the arrows inside the bubbles indicate the direction of change of the risk characteristics. Individual technologies from technology areas A1–A5, B1–B2 and C1–C7 have been grouped together using the blue, green and red ellipses, respectively.

practical use, it would be desirable to be able to compute confidence intervals for the patent risk that the model outputs. However, when the probability distributions of individual variables are conditional on other variable's values, direct computation of the confidence interval does not yield correct results. In that case, the model could be improved by introducing Monte Carlo simulation to the computation of the results, whereby the probability distribution of values of variables can depend on other variables' values for each simulation step. Such an improvement can be readily implemented to the current model, since the computation of the confidence intervals already takes place through an exhaustive simulation with static probability distributions for each variable.

All the factors of the patent risk are quantities that depend on time. The market size and market shares are ordinarily projected in strategies of companies, and likewise the technologies in question have a life cycle over which their maturity and application changes. Research and development activity produces inventions, but these inventions end up being granted patents only many years later, and often at different times in different countries. The patent portfolios are changing with time, and this has even accelerated in recent times through the more commonplace sale and acquisition of patents. And naturally, patent licences and other business arrangements change over time. Consequently, a patent risk model that is able to perform predictions necessarily needs to model the time-dependency of the variables, as well. Additionally, time-dependence needs to incorporate autoregressive behaviour, since many variables depend on other variables with a certain lag.

For the model to be more useful in business decision making, it should support multiple scenarios for a single technology, whereby it would be possible to examine the effects of different business decisions and risk mitigation actions on the patent risk. Furthermore, since in real life many technologies are combined to make a product or service, it would be useful to have a model for combining the patent risk of multiple technologies. The results of the different scenarios, combinations, geographies and time instances could then be stored into a database where business managers could visualize them to support their decision making.

Chapter 4

Summary and conclusions

A patent is a bargain between the inventor and society, where the inventor receives the right to forbid others to utilize her invention and in return the inventor allows the invention to be published. The patent holder is not given a monopoly right to use her own invention, but instead a common situation is to have several patent holders owning patents to the same product. There are many ways to use a patent, and therefore many factors contribute to the value of a patent to a company. By enforcing the patent and using the privilege to forbid others to utilize the patented invention, the patent holder can obtain benefits for her business, the patent can be sold or licenced, or two patent holders can enter into a cross-licence agreement and thereby the company can avoid paying licence fees to some degree. The strength of the patent is affected by the relevance of the technology it covers, technical and legal matters that have come up during patent prosecution, and the significance of the patent to the business of the competitors. These theoretical factors have been discussed in the economics literature, and there are some established ways of determining the value of patents in practise, but, for example, most courts of law do not apply any commonly recognized method of valuing patents according to the knowledge of the author. Many decision makers in companies and in society are not familiar with the valuation methods of patents, or at least there is disagreement of the appropriate methods to be applied, which causes uncertainty to the value of the companies' patent portfolios as well as makes it difficult to value the patent risk of technologies.

As more and more attention is paid to patents in society and in companies, it would be of great use to develop and apply generally acceptable methods for valuation of patent risks that would have their roots in economic theory far deeper than what has been presented in this thesis. In order to enable this, the connection from research on patents should have a more direct link to the everyday challenges of managing patent risks in companies. So far, literature on patent valuation is abundant, but the flip side of the coin — valuation of the risk of patent infringement — has perhaps been less in the focus. Since the patents will at least for the time being continue to be a weakly liquid good for which there are no proper public markets, it would be important to have data available on the value of patents in different fields of industry. The valuation of patents could also be institutionalized in order to alleviate the unclarity of patent quality in practical transactions by referring to accepted 'patent ratings', in the manner that credit ratings are nowadays used. Harmonizing the methods used for patent valuation would also alleviate the unclarity related to patent risks.

In this thesis, a model for the patent risk of technologies has been derived. The model takes into account business factors, research and development activity, characteristics of the specific technology in question and the relevant company and patent environment. The model can be used to determine the patent risk of a technology starting from variables that are straightforward (although sometimes tedious) to value. The model also predicts how the patent risk behaves in different market and patent conditions. The model can be applied to different technologies and thereby offer the possibility to compare the patent risk across technologies. By introducing the ability to mitigate the patent risk to come up with a patent risk map, the necessary risk mitigation actions can be planned. The model can be further developed to offer more reliable confidence intervals for the patent risk, to model time-dependent behaviour of the patent risk factors and to offer improved tools for decision making through scenarios and visualization. Empirical research on the parameter values of the patent risk indicator model for different technologies and comparison to license fees in the same technologies could also offer interesting insight to patent risks in reality.

Patent licensing costs can amount to several per cent of the company revenue, and thereby reduce the profits of the company by tens of per cent, depending on the profit margins and whether the company is able to transfer the licence costs to prices. It is therefore necessary and advantageous for companies to understand the value of their patents and the significance of patents to their business, as well as to be able to determine the risks of patent infringement in their business and determine the pecuniary value of the patent risk. This behaviour could be encouraged by society by regulating the valuation of patents and intellectual property right in financial statements, and requiring publicly listed companies to estimate the value of their patent risk as part of the information given to investors. Furthermore, companies should have adequate organizations, processes and tools in place to assess and manage patent risks. For large companies, the successful management of patent risks can bring or take away a significant competitive advantage in terms of profit margins, and for smaller companies the identification and handling of patent risks can be a matter of (economic) life and death.

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Appendix
Information on Patents

Links to the patent laws and guidelines of different jurisdictions:

- Finnish patent law:
  http://www.prh.fi/fi/patentit/lainsaadantoa/patenttilaki.html
- European Patent Convention:
  http://www.european-patent-office.org/legal/epc/index.html
- The U.S. patent law: http://www.uspto.gov/web/patents/legis.htm
- Instructions for applicants (Finland): http://www.prh.fi/fi/patentit/hakusuomi/patenttiopas.html
- Decisions of the Boards of Appeal of the European Patent Office:
  http://www.european-patent-office.org/legal/case_law/e/index.htm
- WIPO patent guide: http://www.wipo.int/patentscope/en/patents.html

Links to patent databases:

- Espacenet: http://fi.espacenet.com
- USPTO database: http://www.uspto.gov/patft/index.html
- WIPO database:
  http://www.wipo.int/pctdb/en/search-adv.jsp
- JPO database:
  http://www19.ipdl.inpit.go.jp/PA1/cgi-bin/PA1INIT?1176138582046
- Google patents: http://www.google.com/patents
- Delphion (commercial): http://www.delphion.com
- Dialog (commercial): http://www.dialog.com