THE ECONOMIC THEORY OF PATENTS: A SURVEY

by

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Abstract

This paper surveys recent economic analyses of patent protection. The focus is on models that have occurred in the theoretical Industrial Organization literature.

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1. Introduction and Some History

The word patent originally stems from the latin 'litterae patentes', which can be translated as 'open letters'. Open here really means 'usable more than once'. Ordinary letters containing special rights were sealed on the outside. Once used, the seal was broken and the letter had no value afterwards. An open letter has the seal on the inside and the special right can thus be used more than once (see David 1993 and the references therein).

Most economic historians refer to fifteenth century Venice and seventeenth century England as the states having the oldest patent systems. Some jurists go back in time even further and mention ancient Greece as the origin of intellectual property. In the third century B.C. in Sybaris, a town in the southernmost part of current Italy, a monopoly right was granted for one year to cooks who had invented new and extraordinary recipes. The intention of this special law was that the cookery artist could exploit his invention on the one hand, and that others would be stimulated to improve the recipe of the rewarded cook on the other (Brinkhof 1988). Other historical dissertations on the origin of the patent system come up with the practice of mining in Austria in the thirteenth and fourteenth century as one of the roots of current patent law (see Kaufer 1989). The Alps were an ore-mining area with a tradition of common law concerning the granting of property rights on mining, timber and water use to those who first detected the mine. When mining became technically more complicated because the easily accessible mines were exhausted, special privileges, based on the existing mining law, were granted to those who designed devices that extended mining possibilities (such as new mechanical means to draw the water from the lower mines).[1]

Although these primitive systems all have aspects similar to modern patent systems, the first well-developed patent system existed in fifteenth century Venice. On March 19, 1474, the first general patent law was passed by the Venetian Senate (David 1993).[2] Another patent

1. Kitch (1977) makes a similar observation and points at the analogy between patents and mineral claims in the American West in the late nineteenth century.

2. The argument for the institution of a patent system is found in a correspondence cited in David (1993): "We have among us men of great genius, apt to invent and discover ingenious devices... Now, if provisions were made for the works and devices discovered by such

system, on which most modern patent systems are based, emerged in England. During the period of Elizabeth and James I, the policy of granting privileges of monopoly resulted in the Statute of Monopolies in 1623. This Statute of Monopolies is often called the Magna Charta of the right of inventors, because it was the first patent law to lay down the principle that only the first inventor should be granted a patent (Machlup and Penrose 1950).

Many countries followed the example of England and instituted patent systems.[3] From the start, however, the patent system has been criticized by opponents. The criticism was strongest in the 1860s and 1870s. At that time a strong antipatent movement existed in England, Germany, and, especially, Switzerland and the Netherlands. A major explanation for the antipatent movement was the presence of a strong free-trade movement. Patent protection was intuitively associated with tariff protection. The antipatent movement was politically rather successful in weakening the patent laws. In the Netherlands the patent system was even completely abolished in July 1869, and in Switzerland the introduction was further prevented.[4] However, from the 1870s onwards the tide changed and the victory was eventually for the advocates of the patent system. One reason for their victory was the economic crisis of 1873, which suppressed the free-trade movement and made protectionism popular. Another reason was the Paris Industrial Property Convention of 1883, where an important rule of international patenting was formulated. This rule says that nationals of each member state must be given the same treatment in other states as that given to its own nationals. If a country had no patent system, its nationals could not get protection abroad. The basic idea behind this rule was to induce countries without patent systems to institute

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persons, so that others who may see them could not build them and take the inventor's honour [sic] away, more men would then apply their genius, would discover, and would build devices of great utility to our commonwealth."

3. By the end of the eighteenth century France (1791) and the US (1793) had their patent systems. During the first half of the nineteenth century the institution of patent systems spread out. For example, Austria instituted a patent system in 1810, Russia in 1812, Prussia in 1815, Belgium and the Netherlands in 1817, Spain in 1820, Sweden in 1834, and Portugal in 1837 (Machlup and Penrose 1950).

4. See Schiff (1971) on the economic consequences of the abolishment in the Netherlands, and the absence of a patent system in Switzerland.

them. Countries where the antipatent movement was strongest were thus brought to institute patent systems: Switzerland instituted a patent system in 1887 and the Netherlands re-instituted it in 1912 (Cornish 1989).

Machlup and Penrose (1950) surveyed the arguments pro and contra which were used in the patent controversy in the nineteenth century. They reported four types of arguments to justify the creation of patent rights, stressing a patent to be: (i) the natural property right in ideas; (ii) the just reward for the inventor; (iii) the best incentive to invent; and (iv) the best incentive to disclose secret information. The first argument, which was especially popular in France, says that intellectual property is not different from material property. An inventor has a natural right to his invention. The counter argument is that a natural right to an invention does not prevent others from using it (which, in fact, patents do). The second line of arguments stresses that an inventor should be compensated and rewarded for his efforts. The argument against it is that an inventor indeed needs to be rewarded, but that a patent is not necessary because rewards would also follow without. The third argument is more familiar in modern economics. Invention needs to be stimulated because of the net social gain it generates. Patents are the least expensive means to provide innovation incentives. Opponents argue that the patent system is not efficient. The costs of bureaucracy, court personnel and lawyers make the patent system too costly and unattractive. Moreover, the welfare loss due to monopoly is, of course, a major cost of the patent system as well. The final type of argument points at the disclosure of inventions, which without the patent system would have been secret to the public. Arguments brought forward against this point are, first, that inventions are often developed simultaneously by more persons. Since collective secrecy is hard to establish, disclosure would also take place without the patent system. Second, an individual inventor can hardly exploit his invention without revealing it anyway.

Nowadays these old arguments are still brought forward. They show up in the modern economic literature which this essay will review. Other review articles on the economics of intellectual property are Penrose (1951), Vernon (1957), Machlup (1958), Kaufer (1989) and David (1993), all with major sections on historical backgrounds; Besen and Raskind (1991) and Merges and Nelson (1992), emphasizing the legal and business practices;

La Manna (1992) and Crampes and Moreaux (1993), focusing on dimensions of patent protection; and Griliches (1990), dealing with the empirical aspects of patents. The reader is referred to White et al. (1978) and Cornish (1989) for the detailed legal aspects of intellectual property. This paper will differentiate from these existing surveys and focus mainly on the theoretical models of patents developed in the Industrial Organization literature. After explaining the basic legal and economic aspects of intellectual property in section 2, the rest of the paper is organized as follows. First, in section 3, I will sketch the legal and procedural aspects of patent granting in steps. The procedure as described in the European Patent Convention is typical of most modern patent systems and will be used as a guideline. The next sections will review the literature along three themes. These themes are inspired by the major stages of patentable technical change as shown in figure 1. The first is the stage of prepatent technological competition, where firms compete with weapons like research and development (R&D). The second stage concerns the patenting decision and the patent procedure. The final, postpatent stage is where a firm has obtained protection. The opportunities for exploitation of this protection are central to this stage.

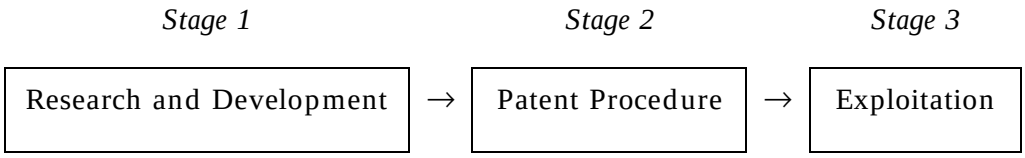

Figure 1. Stages in patentable technical change

I will work backwards in time, starting with the last stage. Section 4 will discuss models that deal with the stage of patent exploitation. How can a patentholder make his patent profitable? From the point of view of competition policy, monopoly positions are always suspicious. Patent monopolies are therefore subject to all kinds of restrictions dictated by competition policy. In addition to these legal restrictions, what are the opportunities for competitors to invent around the patent? In brief, what are the rights and restrictions of the patentholder? Next, section 5 will review the second stage of the granting procedure as

determined by patent laws. Studies on the private and social economic choices and trade-offs relevant to this procedure are discussed. The information disclosure decision, as required by patent law, plays a major role in the literature. In addition, the requirements for patentability are studied, such as the stringency of the novelty requirements. Once the possible benefits and costs of patent protection are known, the first stage of research and development can be studied. The effects of patents on the innovation incentive are central to section 6. Alternative ways to provide incentives are also described there. Finally, section 7 presents a schematic overview of the various models discussed (table 2, p. 34), which may also be convenient as a guide when reading sections 4 through 6.

2. The Legal and Economic Basics

(a) Intellectual Property

Intellectual property can be loosely defined as the rights which can be enforced on products of the human mind. Besides patents, other important forms of intellectual property are copyright and trade marks. These three forms of intellectual property imply different rights. Patents, for example, provide an exclusive control over a technical invention for a limited time period, in general about 20 years. The exclusivity of a patent is rather strong: a patentholder can keep others from exploiting the protected product, even if they have generated it independently from the patentholder. A less strong exclusivity - applied to, for example, topographies of semiconductor chips and new plant and seed variations - allows for reverse engineering. The rightholder cannot prevent others from stripping down the invention and using it as the base for their own creation. A second form of intellectual property, copyright, provides temporary protection on literary, artistic and musical creations. Copyright can be enforced up to 50 years after the dead of the creator. A copyrightholder can prevent others from exactly copy or exploiting his creation. However, he cannot prevent others from exploiting their similar, independently produced creations. A third form of intellectual property, which attracts a lot of attention in the juridical literature but less in the economic literature, is the trade mark. Trade marks, such as firm names, brand names and logotypes, can be protected by filing them in a trade mark register. If registered, other firms

are not allowed to use the same trademark. In this way, the reputation of a firm built up over time, for example through advertising, can be protected. Registered trade marks are usually protected for 7 years with the possibility of prolongation.

The patent is the intellectual property right that provides the strongest protection. The price, however, to be paid for this strong protection is the considerable effort necessary to obtain a patent. An application must be filed officially in a patent office. After time-consuming examination procedures, the patent is granted, or not. Copyright, on the other hand, is obtained almost automatically when an artistic work is finished. It suffices for authors to sign with the © mark, their name and the place of first publication. The same holds for trade marks, which only have to be registered without any examination at all.

(b) Economic Rationale

Before discussing the economics of intellectual property, it is useful to give a more detailed definition of the object that patents protect. In most juridical literature and patent laws, patent are said to protect 'inventions'. In my opinion, the term 'new technical information' would be better because it is more general and better represents the important issues. The latter term indicates that the good *information* is involved, which, as we will see below, has some special economic characteristics. This information is not about market conditions or behaviour of competitors - it is *technical* information about a product or process. In the context of patents and technological progress, particularly the *new* technical information is relevant.

The fundamental economic argument for patents is well known: because of externalities in the production of new technical information on the one hand, and because of the collective good character of information in general on the other, the social value of new technical information is often higher than the private value. The result is underprovision, even in a market with perfect competition (Arrow 1962). Patents are instruments designed to correct this market failure. They increase the private value of new technical information so that the difference between the social and private value decreases or even disappears. Less or no underprovision of new technical information in the market is the intended result.

The first element of the argument refers to the collective good character. Indeed,

technical information can be considered as a collective good. A pure collective good has two characteristics (Cornes and Sandler 1986): nonrivalry and nonexcludability. Nonrivalry is present here because the consumption of information by one person does not affect the use by others. It is furthermore impossible or very costly to exclude others from consumption of information. Due to these features it is socially optimal to make the new technical information freely available (at zero price) once it is generated. The second element of the basic argument concerns the externalities in R&D. In the process of generating new technical information, externalities occur; information spills over to other firms without them paying for it. A firm can thus hardly appropriate its new technical information and the associated returns. Therefore, little or no incentive is present in private firms to generate new technical information.

The patent system is instituted to provide an incentive to carry out R&D and to exploit the collective good character as much as possible. A patentholder has the exclusive but temporary right to a piece of new technical information. The exclusivity of a patent provides monopoly power, resulting in supranormal profits, necessary to recapture the R&D costs. Only then, a firm is prepared to carry out R&D in the first place. In return for a patent, a firm does not only have to carry out R&D, but it also has to disclose the new technical information publicly, in an way comprehensible to an expert in the field. The social benefit of information disclosure is that it prevents duplicate R&D and makes it possible for other firms to build further on it.

It is often suggested that patents are *creations* of property rights. In my opinion, it would be more precise to consider patents as *adjustments* of 'ordinary' property rights. Economic theories on the origin of the institution of ordinary property rights can also be applied to technical information. Basi-cally, these theories (for example, Buchanan 1974) state that, without the institution of property rights, the (physical) protection of property goes along with defense and enforcement costs. If property rights are guaranteed by the state, the cost of protecting a good is no longer necessary. For this reason, the institution and enforcement of property rights by the state is beneficial to society. Property rights to inventions can be explained in the same way. An inventor could protect his invention physically and prevent others from imitating it. So why should the property right to invention be explicitly

created while there exist natural rights to other property? I argue here that in order to correct the market the property right for new technical information is adjusted in such a way that market failures become less harmful. These adjustments are as follows: a patent is (i) a *temporary* and (ii) a strongly *exclusive* property right.

First, consider the exclusivity of the right. The most important aspect of a patent is not the possibility to exploit the right, but to prevent others from doing so. As mentioned above, patents also protect against firms which have independently generated a similar invention. Ordinary property rights do not have this power. The question then is: Why is this strong version of excludability needed? Two arguments can be brought forward. First, the enforcement costs that occur when proving whether or not an invention is generated independently would be very high without strong exclusivity. The enforcement costs of property rights on tangible goods may already be high and have considerable impact (see Barzel 1989, De Meza and Gould 1992), so the rights on intangible technical information are certainly hard to enforce. If the property right is made strongly exclusive, these transaction costs do not occur. An identical invention is never tolerated, independently generated or not. No proof of the patentholder is needed.

The second argument is related to the increased market and negotiation power of a patentholder who has a strongly exclusive right. I will give a simple example which highlights the point. Suppose for the moment that the lifetime of the patent is infinite and the enforcement costs are zero. An R&D lab has generated new technical information and wants to sell this. A reason for selling the information may be the inability of the lab to exploit it itself. The cost of generating the new product (the physical form of the new technical information) is c. Other firms can also generate the new product, but they have a cost disadvantage relative to the lab; they face a cost of $c + d$. The R&D lab has thus a comparative advantage of d. The private return of the new product is v and is equal to the social return. Suppose that the R&D lab is the only supplier in the market and that there is also one demander, for example the only firm that has the right facilities to exploit the new product. In the case of ordinary property rights, the R&D lab cannot prohibit the demanding firm from generating and exploiting it itself. The maximum price that the R&D lab can therefore charge is $p = c + d$. This is the reservation price for the buyer; if the price were

higher, he would be better off inventing the product himself rather than buying it. Suppose that this maximum price is indeed agreed upon. The profit for the R&D lab then is $\pi = d$, which is equal to its relative R&D cost advantage. The profit of the buyer who exploits the new product is $\pi = v - c - d$. Note that the incentive for R&D, given by the profit for the lab, is independent of the social value of the invention generated. It is completely determined by the comparative advantage in performing R&D.

If, however, the property right is as exclusive as in the case of patents, the distribution of profits changes. The reservation price of the buyer is not $p = c + d$ anymore, because the buyer is no longer permitted to generate the new product himself. The reservation price of the buyer is now $p = v$. This is what can be gained with the new product. Suppose that this reservation price becomes effective. The profit for the R&D lab then is $\pi = v - c$ and that of the buyer is $\pi = 0$. In this case, the incentive is better designed. It is the social value of the invention v that drives its generation by the R&D lab.

Summarizing, what can be learned from this simple example? The main conclusion is that in case of ordinary property rights, the incentive to innovate is solely determined by the cost advantage of the R&D lab, whereas in case of strongly exclusive rights the R&D lab is guided by the social value of the invention. The allocation of R&D means from a social point of view is thus better in the case of strongly exclusive property rights.

Besides stronger exclusivity, the second adjustment of the ordinary property right concerns the lifetime. Ordinary property rights are not temporary. Why are patents temporary? The economic reasoning goes as follows. Being a collective good, new technical information should be provided at zero price. This is, however, not possible if an incentive has to be provided. By making the patent temporary, the new technical information is available at zero price once the patent has expired (for the question of how temporary patents should be, see Nordhaus (1969) in section 4).

These are the important basic economics of intellectual property and patents in particular. A vast amount of literature has emerged on the fine-tuning of these basic arguments. Subtle parts of the patent system are more deeply analyzed. As mentioned in the Introduction, I will present this literature in a reverse chronological order. I will start by discussing the rights and restrictions once a patent is granted. Next, I will deal with economic

choices in the patent-granting process. Finally, I will review the models dealing with the impact of patents on innovation incentives. But first, I will describe the patent procedure of the European Patent Office, which is typical of most modern patent systems.

3. A Typical Granting Procedure

I will use the patent-granting procedure of the European Patent Office as a guide of exposition.[5] Where important differences between procedures can occur, this will be mentioned. The successive steps of the procedure are as follows:

Step 1. Application and Formal Examination

A European patent application must be submitted to the European Patent Office in Munich or its branch in The Hague. Within one month after the filing of the application, a filing fee must be paid. There are very precise prescriptions with respect to the form of application files. For example, the marges on the application files are determined by law. More importantly, the application must contain a specification of the invention, made up of two parts. First, a full description of the invention, possibly with technical drawings and schemes. Second, claims that indicate the invention where protection is looked for. An applicant and his patent attorney have to make choices when formulating these claims; broad claims are more likely to be disapproved, because claims of current patents might be infringed. If approved, however, these broad claims provide more protection.

The application remains secret up to 18 months after filing. Priority is obtained directly after filing, or, in case the same application was submitted to another patent office first, priority starts at that filing date (at least if the country of filing joined the Paris Convention). The priority date determines the point at which the application becomes state of the art.

5. Apart from the granting procedure, the European Patent System is not typical in some other aspects. But for the purpose of describing a patent procedure, these aspects are not important.

The European patent system applies the "first-to-file" principle; only the inventor that applies for a patent first may be granted a patent. This first-to-file system is used in most patent systems. There is another principle, used in, for example, the US and Canada, according to which not the first who files but the first who invents may obtain patent protection. The choice of the first-to-file principle or the first-to-invent principle, is particularly important in conflict situations when two firms claim the same invention.

In some countries, for example Belgium, the granting procedure stops after the first step of application. A patent is granted unconditionally and immediately. In that case the patent system is a 'registration system' comparable with trade mark systems. In countries with an 'examination system', several steps must be taken before a patent is possibly granted.

Step 2. Search

On the basis of the specification, an initial inventory of the state of the art surrounding the invention is carried out by the EPO. A fee has to be paid for this search. The state of the art is primarily estimated from past patent specifications and scientific publications. Priority rights of current applications are checked as well. The explorative search report can be used by firms to obtain insight into the state of the art in which they are active or to test whether the invention is sufficiently novel after a first inventory.

Step 3. Publication

Only after 18 months the application becomes public. These 18 months give a firm the time and opportunity to perfect the invention or to start a production process. After publication, the previously secret technical information becomes part of the state of the art. Competitors of the inventing firm then can also obtain the information. During the 18 months period of secrecy, the applicant can still decide to withdraw his application without public disclosure.

Step 4. Substantive Examination

Amendment of the application is possible between the search report and the request for examination. Requests for examination can be filed up to 6 months after the search report. The substantive examination of the patent application is guided by various requirements. A

patent is only granted for an invention that (i) is new; (ii) involves an inventive step; and (iii) is industrially applicable. If these requirements are not met, a patent is not granted. Not all intellectual products can be considered inventions. For example, computer programmes and discoveries or scientific theories cannot be patented; plant and animal variations have recently been patented in the EPO, although according to the official EPO statutes this is still prohibited. The novelty requirement (i) must be read as: new for the public. New means: not being part of the state of technique as it is publicly known. The state of the art the moment that priority is obtained is relevant. An invention that was previously used in secret can thus be patented. In contrast, an invention that was ever described in a scientific journal cannot. The second requirement, an inventive step, means that an invention is not obvious for a person who is expert in the relevant technical field. Trivial developments and improvements of a new product or process are thus not patentable. If the invention is judged not to be novel enough, the possibility exists sometimes, for example in Germany, to get a utility model (or 'petty patent'). Such a utility model is similar to a regular patent but has a shorter legal lifetime (of about 6 years).

Step 5. Grant

If the application meets the requirements for patentability and validity, it passes the examination phase and a European patent is granted. To a large extent, the national patent laws of the countries that were designated in the application are relevant to the European patent. The lifetime, for example, of the European patent is determined by the national lifetimes. In order to keep the patent valid, a renewal fee has to be paid to the EPO every year. In most patent systems increase these annual renewal fees in years after granting.

Step 6. Opposition and Appeal

Up to 9 months after the grant, third parties can oppose against the granting decision of the patent office. Third parties may believe that the requirements for patentability are not fulfilled and that the patent infringes their patents. The opposition department of the EPO is charged with judging the opposition. If the opposition is held to be valid, the applicant is given the opportunity to change the specification in order to satisfy the opposition. The EPO,

however, can also decide to withdraw its grant. After the opposition decision of the patent office, the initial applicant can appeal against this decision as the last possible act.

To give an impression of the decisions of the EPO and the applicants, table 1 gives some key figures of applications filed in the period 1978-1985. About 69% of the applications were eventually granted a patent. Of the applications that were not granted a patent, 4% was refused after formal examination, 6% was withdrawn by the applicant and 21% was deemed withdrawn (disapproved by the patent office). No opposition was filed in 82% of all grants. The opposition in the remaining 18%, was either respected, rejected or is still in process.

Table 1. Key figures on the EPO patent procedure (1978-1985 applications)

Procedural Status	#
Application	197,337
Refused	7,689
Withdrawn	12,244
Examination Required	177,169
Deemed Withdrawn	40,430
Granted	135,372
No Opposition	110,917

Source: Espace-Bulletin EPO
Note: Some applications are still in process. This explains the accounting differences occurring.

4. Exploitation of the Granted Patent: Rights and Restrictions

The restrictions on the exploitation of the patent rights and the associated monopoly position can be divided into two groups: those caused by the market and those caused by the gove-rnment. The first group of restrictions stem from competitors in the market who invent around the patent. Contrary to what is commonly thought or assumed in models of, for

example, patent races, patents do not provide perfect protection. The very fact that patent do not last forever but are temporary illustrates this point best. But to some extent, even during the patent lifetime, competitors can imitate and build further on the patented product. The second group of restrictions, which stem from the government, have to do with the monopoly position of the patentholder. Patent policy and competition policy are in natural conflict: while patent policy provides a legal monopoly position, competition policy often aims at suppressing it.

(a) Inventing Around by Competitors: Length, Breadth and Height of Protection

A patentholder is not perfectly protected. The protection is limited and can be described by using three dimensions: (i) the length of protection: how long does the right last?; (ii) the breadth of protection: to what extent does the patent protect against imitations? (how similar are imitations allowed to be?); and (iii) the height of protection: how novel are improvements required to be? One could say that length indicates the possibilities for competitors to invent 'behind' the patent, breadth to invent 'aside' the patent, and height to invent 'above' the patent.

Patent Length

The historic reason in early England to set patent life to 14 years, with a possible extension of 7 years, was to protect foreign masters, who came to teach English appentrices, from competition of their apprentices once they mastered an art or skills (see David 1993 and its references). Without this protection, foreign masters would never come to England to disclose their technology and skills. Since the average time to teach apprentices was 7 years, the protection lasted for two generations of apprentices.

More formal models have been developed to study the impact of patent duration and to determine optimal lifetimes. Nordhaus (1969), the seminal work in patent design, describes the trade-off which a benevolent social planner faces when he chooses the lifetime of a patent. Nordhaus assumes perfect protection during the patent. The trade-off occurring is between the strength of the innovation incentive and the size of the deadweight loss. Longer patent protection induces more R&D efforts, because the expected returns are higher, and

consequently improves the induced innovation, which is a larger cost reduction in Nordhaus' analysis. The welfare cost of inducing larger innovations is a longer-lasting and larger deadweight loss caused by the patent monopoly. The socially optimal length is where these two opposing forces are in balance at the margin. Nordhaus uses a framework originally developed by Arrow (1962). A major assumption underlying both studies is a monopoly in the invention market. Kamien and Schwartz (1974) and De Brock (1985) analyze the optimal patent life given a competitive invention market. Another extension is advanced by Goyal and De Laat (1991) which take more innovations into consideration.

David and Olsen (1992) point at another aspect of patent length. The longer patents last, the better learning externalities can be internalized. A monopoly with larger cumulative output, compared to more isolated firms, therefore better exploits learning effects. These positive effects of learning might offset the deadweight losses caused by the monopoly.

Although, especially in the early analyses, much emphasis is placed on the length of patent protection, there is some evidence that this dimension might be less relevant than is often thought. Empirical work by Schankerman and Pakes (1986) reveals the limited importance of *de jure* patent lifetime. Using renewal fees data, Schankerman and Pakes are able to determine the value of holding patents. As long as the expected returns from holding a patent are larger than the costs of holding the patent (determined by the annual renewal fees), it is worthwhile to extend protection. Their data show that the effective lifetime of patents is often shorter than the legal lifetime. One possible reason may be that competitors invent around a patent during the lifetime, which makes the patent decreasingly valuable in time.

Patent Breadth

The claims in the patent specification determine the scope of patent protection. A broad protection can be obtained in two ways. First, the claims can be formulated broadly, but this might cause a number of problems. A claim can be broad to the extent that it is in the scope of protection of another patent. Moreover, if a broad protection is sought through broad claims, the applicant must have a pretty clear picture of all possible applications of the invention. Only then can the applicant protect as many potential future developments as

possible. A second way to obtain broad patent protection is through the jurisdiction in patent disputes. A judge may interpret the claims broadly so that broad protection is obtained. Broad here means that the words in the claims are not taken literally, but are interpreted broadly. In the legal literature, the distinction between the 'fencepost' principle and the 'guidepost' principle[6] is made in this context. The fencepost principle says that claims literally define the exact patent protection. According to the guidepost principle, claims only provide an indication of the protection. Equivalences, for example, of what is written down in the patent specification are also left to the exclusive use of the patentholder.

The scope of patent protection is important in infringement cases. A patentholder can suspect infringement if other firms enter the market with similar products and processes. Two types of infringement can be distinguished. First, possible infringement from imitations which are very similar to the patented product with the exception of some minor differences. The protection against such imitations could be defined as *breadth* of protection. The second type of possible infringement stems from improvements of a patented product or process. This type will be described in the next section on patent *height*.

Within the patent breadth literature a further distinction can be made between models that define breadth for one market on the one hand, and for more markets on the other. Klemperer (1990), Waterson (1990) and Gallini (1992) belong to the first category, while Kitch (1977), Merges and Nelson (1992) and Matutes, Regibeau and Rockett (1993) belong to the other category. I will start with the first category.

Since it is a seminal article, I will discuss Klemperer (1990) more extensively. In a model of horizontal product differentiation, Klemperer defines patent breadth (or width as he labels it) as the distance on the product spectrum away from the patentholder's product where competing firms are allowed. All consumers are assumed to prefer, at equal prices, the patentholder's product.[7] Consumers can differ in two aspects: first, the travel cost per

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6. There exist some synonyms of what is labelled here as the guidepost principle. The 'signpost' system, for example, is used by Waterson (1989), or the 'equivalence' doctrine, for example, is used by Merges and Nelson (1992).

7. In the horizontal differentiation literature, it is more common to assume a (uniform) distribution of consumers over the product spectrum rather than a mass point at 0 as is done

unit of distance and, second, the reservation price of buying the product. A simple version of the model is illustrated in figure 2. The horizontal axis represents the product spectrum, with the patentholder and all consumers located at 0 and competitors located at b (given by breadth). The vertical axis represents the consumer cost per unit purchased for a consumer with reservation price m. Three consumers with identical reservation prices but different unit travel costs t are depicted in the figure. Consumer 1 is indifferent between buying the patentholder's product at 0 with price p* and buying the competitively provided alternative at b and incur the total travel cost of t_1b. Consumer 2 buys from the competitor because the consumers costs are lower there ($p^* > t_2b$). Consumer 3 buys from the patentholder because paying price p* costs less than travelling to the border b ($p^* < t_3b$).

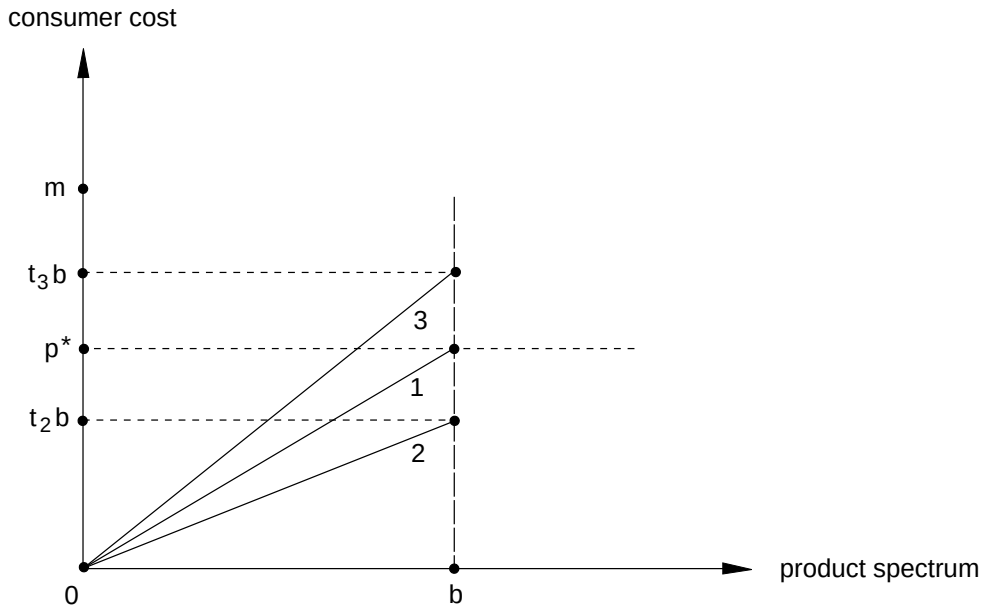

Figure 2. A simple illustration of the Klemperer (1990) model

here (see Eaton and Lipsey 1989). However, if consumers have different transport costs, the analysis is very similar to one where consumers are distributed over the product spectrum.

Compared to the maximum welfare which results from a competitive provision of all varieties on the spectrum, the institution of positive patent breadth induces two types of welfare losses. The first welfare loss results from consumers who shift to less preferred varieties offered at a lower price. These consumers face travel costs. Consumer 2, who incurs travel costs t_2b, is such a consumer. The second type of welfare loss occurs as consumers drop out of the market. If the reservation price of consumer 3 is below the price charged by the patentholder ($p^* > m$), he would not buy. This type can also occur for the consumers who buy the competitively provided variety at the border b. If the reservation price m for consumer 2 is smaller than the total travel cost ($t_2b > m$), he will not buy.

Starting point in Klemperer's analysis is a minimum profit level that has to be provided to the patentholder in order to make him invest in R&D and generate the new product. Patent policy makers have two instruments at their disposal: patent breadth and patent length. A long but narrow patent can provide as much profit as a short but broad patent. The problem is to determine the mixture of breadth and length that is optimal from a social welfare point of view. The distributions of travel costs and reservation prices among consumers turn out to be decisive for the optimal mix. I will give two examples. First, if all consumers face identical travel costs, the patentholder will set the price such that all consumers buy from him. In figure 2, suppose that all consumers have the same travel cost t_1 as consumer 1. The optimal price p^* will then be just above t_1b. No consumer will buy from the competitors. The first type of welfare loss, incurred by travelling, will thus not occur here. The second type of welfare loss, incurred by high prices, is minimized if the breadth is set very narrow and the lifetime is large enough as to provide the minimum profit required. Thus, if consumers face identical travel costs, very narrow patents are optimal. An opposite conclusion emerges if the reservation prices of all consumers are identical. Infinitely broad patent protection precludes all competition. The patentholder can then, without the need to take into account competitors, charge a price equal to the reservation price of all consumers.[8] Neither travel costs nor deadweight losses occur. Thus, given identical reservation

8. This price strategy is comparable with perfect price discrimination, which is commonly known to cause no welfare loss, compared to perfect competition.

prices, very broad protection is optimal, mixed with a lifetime that marginally provides the minimum profit level required.

Where Klemperer assumes a fencepost patent system with an exact border of protection (b in figure 2), Waterson (1990) assumes a guidepost patent system with inexact coverage. Given the presence of a patent, a competitor has to decide whether or not, and where to enter the product spectrum. The potential entrant takes into account the expected cost if the patentholder takes him to court over violation of patent rights. If a court case does occur, the outcome is uncertain.[9] The expected court costs for the imitator increase if he locates closer to the patentholder. Among the various conclusions resulting from this model, the most important is that not all inventions will be patented.

The extension of the Klemperer model by Gallini (1992) involves the cost of imitation. One could interpret Nordhaus' (1969) assumption of perfect patent protection as an assumption of prohibitively costly imitation. Klemperer, on the contrary, assumes costless imitation. Intermediate imitation cost levels are examined by Gallini. In her model, an imitator can either choose to wait until the patent has expired and then duplicate costlessly, or choose to imitate, at some cost, during the lifetime of the patent. Major point of the paper is that the first possible strategy of waiting becomes less attractive if patent length increases. Because imitation causes the profit of the patentholder to decrease, extension of patent length may not improve the incentive to innovate. This is in contrast with, of course, Nordhaus (1969), where extending lifetime always increases the incentive, but also with Klemperer where very narrow patents can be optimal (when consumers have identical travel costs). If the strategy of costly imitation is open, broad patents which do not induce imitation, mixed with a lifetime that is enough to provide the desired reward, are optimal in Gallini's model.

The models of Klemperer, Waterson and Gallini all consider the breadth of patent protection in one market. A second category of theories define patent breadth for more markets. In a mainly descriptive article Kitch (1977) exposes his prospect theory of the patent system. By prospect he means "a particular opportunity to develop a known technological

9. Meurer (1989) develops a model which studies the choices and possibilities for both parties when patent litigation occurs.

possibility" (Kitch 1977, p. 266). Prospects can cover different (perhaps related) markets. Kitch argues that the process of developing prospects can efficiently be undertaken in the patent system by giving the inventor and holder of a pioneering patent sufficient control over the prospects. Most patents are granted early in the innovation process before commercialization. By providing prospects, the inventor is given more incentive to invest in developments of his invention since he does not need to be afraid of early imitation. A second advantage is that the inventor can coordinate the development of prospects by imitators. Wasteful duplication of research can thus be avoided. Furthermore, by auctioning prospects, a prospect tends to be developed by the most efficient imitator. Kitch (1977) suggests that the US patent system has been performing the prospect function quite well by providing broad protection. Merges and Nelson (1992), in a study of patent scope decisions of US Courts, doubt as to whether the US patent scope has been broad. Moreover, contrary to Kitch, they doubt that the scope should be broad. They emphasize that if many inventors aim for the same goal, a broad patent for the lucky first one can only hinder subsequent innovations.

Although no reference is made to Kitch's prospect theory, the model of Matutes, Regibeau and Rockett (1993) could be considered as its formalization. Their starting point is a basic innovation which has various applications to be developed in the future. These possible applications, which are all known to the inventor and the potential imitators, are comparable with Kitch's prospects. In brief, the authors compare two protection regimes. The first is a regime of 'length' protection, where the patentholder has the exclusive right to introduce applications during the patent lifetime. If the patent expires, imitators can introduce applications as well. The other is a regime of 'scope' protection, where certain applications are reserved for the patentholder. Imitators can then, during the patent lifetime, introduce nonreserved applications without infringement. The regime of 'scope' protection is shown to generate' higher welfare levels than the 'length' protection. The length of the period which the basic inventor chooses to wait before patenting (in which applications can be developed) and the pattern of development of subsequent innovations are taken into account when deriving this conclusion on welfare. This formal analysis tends to support the view of Kitch that inventors should be granted broad patents with control over many prospects.

Patent Height

Besides imitation, another source of possible patent infringement stems from improvement. If improvements of a patented product are introduced in the market, the incumbent patentholder is likely to loose profits. The strength of this threat for a patentholder depends primarily on the novelty requirements used by examiners in the patent office. If these requirements are more stringent and, thus, fewer improvements are approved, the current patentholder is better protected. The extent of protection against improvements is defined here as patent height.[10] So far, only few theoretical analyses have appeared on the issue of patent height. This lack of attention seems curious for two reasons. First, most industrial R&D is allocated to product improvements (Freeman 1982). Second, patenting history has shown that many patents are improvement patents (see Baker 1976).

Van Dijk (1992) presents a model where the height of protection is central. The major point there is that the competition stemming from improvements is basically different from the competition from imitations. Whereas the breadth of patent protection can be described in a model of horizontal differentiation, the height of protection can be described in a model of vertical product differentiation. The reason is that all consumers in a market are expected to prefer, at equal prices, an improvement to an older product. By definition, improvements are then vertical differentiations. They are comparable with different qualities of a product: high quality is preferred to low quality. Just like breadth can be defined on the horizontal product spectrum, height can be thought of as defining a protected region on the vertical spectrum. In a duopoly model with a patentholder and an improver, Van Dijk (1994) examines how height affects the competition in product improvements. Major conclusions are that low patents do not affect free competition (because some distance is naturally chosen), intermediate patent can benefit both the patentholder and his competitor, and high patents, by blockading entry, solely benefit the patentholder and provide him with absolute monopoly power.

A paper related to the dimension of height is Van Cayseele (1989), which discusses

10. In an economic context, the term patent height was first used by Klemperer (1990), p.127. I understood from an EPO official that the term height is actually used within the EPO in discussions on standards of patentability.

safety regulation in the pharmaceutical industry. From an analytical point of view, the requirements for safety imposed by health policy very much resemble the requirements for novelty imposed by patent policy. Another related paper is Scotchmer and Green (1990). Although Scotchmer and Green also deal with the stringency of the novelty requirements, their focus is not on the scope of protection but on the disclosure of information. Their paper is discussed in the next section.

(b) Conflicts with Competition Policy

The major social cost of patents, once granted, is the deadweight loss caused by the market power positions they protect. Competition policy is designed to limit or, in any case, control economic power positions. One can thus conclude that patent policy and competition policy are in natural conflict. If, as is the goal of patent policy, some reward must be given to inventors, it is clear that competition policy has to act loosely against patent monopolies. For example, if the patentholder was not allowed to set a price above marginal cost, the value of the patent would be zero. What, from a welfare point of view, would be the optimal price allowed to be set by the patentholder? Gilbert and Shapiro (1990) examine this question. Although their paper is entitled "Optimal patent length and breadth", it deals in fact more with competition policy than with patent breadth policy. Patent breadth in their model directly determines the price that a patentholder can charge. As in Klemperer (1990), a minimum profit level has to be given to a potential inventor. Two instruments are available to the government to achieve this: (i) the lifetime of protection; and (ii) the price that the patentholder is allowed to charge during the lifetime, which is directly determined by breadth. Permitting higher prices raises the patentholder's profit on the one hand, but causes the monopoly-associated deadweight losses to increase on the other. Gilbert and Shapiro find that if higher prices are increasingly costly in terms of deadweight loss, infinitely lived patents are optimal. In other words, it is better then to set lower maximum prices than shorter patent lives.

Hausman and MacKie-Mason (1988) analyze the practice of third-degree price discrimination by a patentholder. Price discrimination is often not allowed for by competition policy, not even in the case of patentholders where the rules are usually softened. The

authors show that, under conditions that will be explained below, price discrimination as compared to uniform pricing raises static welfare. This result holds for price-discriminating monopolists in general, but is especially relevant for patentholders because the conditions under which it holds are particularly relevant to new products. One condition is that new markets are served under price discrimination, which are not served with uniform prices. But even without opening new markets, a Pareto improvement occurs if scale economies are present, which is typically the case for new, patented products.

Finally, Gilbert and Newberry (1982) discuss the role of patents in preemption practices. A patent creates opportunities for a firm with monopoly power to maintain this power. Indeed, a monopolist has an incentive to patent new technologies before potential competitors and thus to stay monopolist. Their point is that the extra cost of accelerated R&D can be smaller than the profit lost when a competitor enters the market. Such preemptive activity can even lead to 'sleeping' patents which are neither used nor licensed. The patenting time as determined by technological competition is then earlier than the optimal introduction time, determined, among other things, by the existing capital stock of the firm. The disadvantage of the practice of preemptive patenting for social welfare is obvious. A monopoly position is sustained and, in the case of sleeping patents, new technologies, for which R&D was carried out, are not used. Yet, preemptive patenting may be less distortive than other forms of preemption.

(c) Licenses

Another source of profits for a patentholder, besides marketing innovations himself, stems from the right to grant licenses to others. There exists a vast amount of literature on licensing, which addresses questions as: What is the optimal number of licensees? and; What is the optimal payment structure, i.e., the optimal proportion of royalties vs. fixed fees? I will not summarize the models on these issues here. For a complete survey of the literature on licensing, the reader is referred to Kamien (1992). As opposed to voluntary licensing, the requirement of compulsory licensing can be considered a restriction on the rights of a patentholder. Tandon (1982) develops a model, based on Nordhaus (1969) and Arrow (1962), where the welfare effects of compulsory licensing are studied. His results suggest that the use

of compulsory licensing can be socially efficient. Additionally, he finds that, given compulsory licensing, infinitely lived patents are optimal. Tandon's model can be considered as being basic to the models on patent breadth discussed above, in the sense that it is the first to allow for competitors aside the patentholder.

5. Economic Choices in the Granting Procedure

This section will discuss the economic choices, both private and social, which are relevant during the granting procedure. It will not discuss what happens prior to the application. The R&D stage will be discussed in the next section since it is heavily affected by later stages. The amount of investment in R&D depends on the revenues which can be expected from it, which in turn depend on the opportunities provided by the patent system. There are two groups of factors that determine the expected returns from patent protection. First, the exploitation possibilities once a patent is granted. This group was dealt with in the above section. Second, the economic choices during the application procedure, which will be described in this section.

(a) Information Disclosure

The first choice of an inventing firm is whether or not to apply for patent protection. The obligation of information disclosure plays an important role in this choice. In the specification of the invention, the technical information must be outlined in a comprehensible manner. This specification becomes public 18 months after filing the application. The disclosure obligation causes a trade-off for the inventing firm. As the secret technical information is revealed to competitors, these competitors can absorb the new information, perhaps at some adoption cost, and use it while inventing around the patent. Does the advantage of protection, even imperfect, outweigh the disadvantage of giving up secret information?

A patent race with two patentable inventions, an intermediate and a final one, is an appropriate model to study this information issue (see Grossman and Shapiro 1987, and Harris and Vickers 1987 for these races). Scotchmer and Green (1990) use such a multistage

patent race to examine the relation between disclosure decisions and the novelty requirements of the patent office. First they observe a social trade-off in setting the stringency of examination. The social goal of providing an innovation incentive is best served under strong novelty requirements, which is expected to result in higher profits for the patentholder. The social goal of early information disclosure, on the other hand, is served under weak novelty requirements. Innovations become public earlier. Strategic private considerations regarding information disclosure make this trade-off rather complex. Suppose two firms race for a final patent with the possibility of intermediate patenting. The possibility of an intermediate patent is provided by weak novelty requirements and would be absent with stringent requirements. The firm that arrives at the intermediate patent first may not want to give up this advantage in the race and thus not patent, at the risk of being leapfrogged by the other and ending up with nothing at all. Another advantage of not patenting is that the other firm might drop out the race when it is signalled that there is too large a gap. Taking this type of strategic behaviour into account, Scotchmer and Green conclude that in general weak novelty requirements are socially preferred.

Another theme in their article is the rule that is applied in the case of disputes. When two firms simultaneously claim very similar inventions, which firm is to be granted the patent? There are two rules to determine the patentability. The first-to-invent rule says that only the first invention, from a historical perspective, is patentable. The first-to-file rule says that only the invention that was first reported through an application file is patentable. Scotchmer and Green find that, relative to the first-to-file rule, the first-to-invent rule discourages information disclosure. The reason being that, with first-to-invent, a first innovator tends to wait with claiming rights until other inventors show up. This way he prevents early spill-overs from disclosure while the patent can still be obtained.

In addition to the disclosure of technical information, the disclosure of private market information, only present with the inventor, on the possible profits of a competitor can play a role. Horstmann, MacDonald and Slivinski (1985) examine the signalling effects of a patent application. Their assumption is that a patent does protect against exact duplication but not against inventing around in the form of imitations. The profitability of duplication (in the absence of a patent) and imitation by a competitor is exactly known by the inventor. The

competitor only knows the distribution of possible profits. But the competitor can extract information from the inventor's patenting behaviour. Several conclusions on patenting and imitating behaviour can be drawn from their signalling model. For instance, if an imitation is not profitable, the inventor will always patent. Furthermore, if the inventor patents, the competitor will not enter the new market. Finally, if the inventor does not patent, the competitor will imitate.

It should be stressed here that patents are just one instrument to protect inventions and their associated profits. Alternative instruments are, for example, secrecy, exploiting the lead time and descending the learning curve. Secrecy implies no information disclosure. This alternative is more relevant to process innovations than to product innovations which enter the market physically. Lead time exploits the temporary information advantage. Competitors need time to study the invention and to be able to invent around.

(b) Permissive Patents

I have already pointed out that a patent is strongly exclusive and enables the holder to prohibit others to exploit similar inventions, even when generated independently. This right starts at the moment priority is obtained, which is usually on the application date. Thus, if two firms are involved in a patent race for an invention, only the firm that finishes first and applies for a patent will possibly obtain one. It may happen that two firms compete in R&D for several years with the race ending in a minor advantage for the eventual winner. The R&D expenditures of the loser cannot be recouped. A great deal of literature exists on the social costs and benefits of patent races (see Reinganum 1989 for an excellent overview). Aside from the advantage of increased chance that the invention will be generated more rapidly, duplicative R&D is always wasteful because identical information is generated twice. The dominant conclusion in these models is that an industry spends too much R&D from a social welfare point of view. The major reason is that if one firm increases its R&D, this diminishes the chance that the other firm wins the race. The first firm, however, does not take this effect on the second into account. Therefore, the common result is that the R&D expenditures at industry level (of the two firms together) are too high from a social welfare point of view (for a good example of a patent race model see Loury 1979).

La Manna, MacLeod and de Meza (1989) investigate whether a less strong form of patent exclusivity is socially beneficial. A patent system is studied where not only the winner of a race obtains a patent but also later finishers. A time limit, starting from the winner's application date onwards, could be set within which later finishers can still apply. The major trade-off occurring is that a losers-take-some reward structure diminishes the expected return from R&D because competition in the post R&D stage will drive profits down. At the same time, however, this competition will benefit consumers. A strict regime where the winner of the race takes all thus encourages R&D but impedes diffusion, while a permissive regime with multiple prizes discourages R&D expenditures but promotes diffusion. La Manna et al. find that, under certain conditions, the permissive regime[11], which allows for genuine but late finishers, is preferred to the strict regime, which prevents late finishers.

(c) The Strategic Role of the Patent Office

All models discussed so far describe a scenario where the patent office first sets the length and/or scope of protection and where the potential innovators react to this design later. In a broader framework, the patent office and an innovator could be considered as players in a patent regulation game. The game most commonly described in the patent literature is one where the patent office is the Stackelberg leader, who first chooses his strategy, and the innovator is the Stackelberg follower, who reacts to the leader's choice. For example, in Klemperer (1990) the patent office first chooses a mix of patent breadth and length and an innovator is supposed to react optimally to this mix. La Manna (1992) examines the possible strategic roles of the patent office in this regulation game. Instead of Stackelberg leader, the patent office in his model can choose to be the follower. In a game where the patent office has the role of follower, it provides a set of mixtures which are welfare maximizing and the innovator chooses from this set the profit-maximizing mixture. The patent office has two instruments at its disposal: patent height and lifetime. Height is given by a minimum cost reduction or a minimum outward shift of the demand function. A traditional patent game

11. The permissive regime could be interpreted as weak novelty requirements, or as a utility patent.

would be organized the other way around: the innovator has several mixes of patent height and length and the patent office chooses the socially optimal mix. One of the conclusions of La Manna (1992) is that for certain cost and demand parameters, the traditional role of the patent office as leader yields lower welfare levels than its role as follower.

6. Feedback to the Innovation Incentive

The basic economic intention of patents is that they reduce or, preferably, close the gap between the social and private value of an invention. An exclusive right provides the patentholder with market power and thus more revenues than would be possible without a patent. This extra profit, labelled as V here, is the carrot which induces a potential inventor to invest in R&D. Two questions are important for the design of optimal innovation incentives: (i) how large a V must be provided for the potential inventor?; and (ii) how can V be provided most efficiently?

(a) The Size of the Incentive

There is the natural problem in R&D incentive design that the extra profit V differs per invention. Nordhaus (1969) already pointed at the disadvantage of uniform patent lives. He has shown that the theoretically optimal life of a patent depends, among other things, on the price elasticity of demand for the product. Products with lower elasticity of demand should have higher optimal lifetimes. On the cost side, technological opportunities affect the optimal duration. Industries where many technological opportunities are present and inventions are thus easier, should have smaller optimal patent lives. As Nordhaus (1969) also remarks, invention-specific patent protection can hardly be realized.[12] Two reasons can be given for this. First, the information needed to estimate the social and private value of an invention is costly to process. Second, even if this information could be processed, it would be hard to

12. The institution of utility models ('petty patents') with about 6 years of protection for smaller inventions, however, is a - primitive - form of invention-specific lifetime.

obtain because inventing firms probably would have a tendency to overestimate the social value of their inventions in order to get more protection and profits. Although in practice optimal patent lives are very hard to determine for individual inventions, one could say that the scope of patent protection naturally adjusts for the importance of inventions. A basic invention can reasonably be expected to yield more social value than a minor improvement. Since more claims can be formulated for the basic invention, a wider protection is obtained, resulting in higher profits for the basic inventor. The basic invention then not only has higher social value but also more protection and higher private value than the improvement.

A deviant argument is advanced in Hirshleifer (1971). His article explains the pecuniary economics of invention. Contrary to technological effects of invention, by which are meant improvements in production functions, pecuniary effects are "the wealth shifts due to the price revaluations that take place upon release and / or utilization of the information" (Hirshleifer, p. 571). The original inventor is in the unique position to forecast the pecuniary effects of his invention. A major source of profit for an inventor lies in capturing these pecuniary effects. Inventions can thus be made profitable, even *without* patent protection. By providing patent protection and the associated extra profits, on top of the pecuniary effects, an inventor could well be overcompensated. To illustrate this, the future introduction of a certain product innovation can make the profits of firms producing current substitutes decrease. The product innovator could profit from this information by buying put options on the stock of his future competitors. R&D expenditures could thus be recaptured and a patent would not be necessary.[13]

(b) The Incentive Structure

Question (i) on the optimal size of V can be avoided by reformulating question (ii) as: how can the welfare loss of providing one unit of V be minimized? Kaplow (1984) introduces, in a mainly legal article, a ratio test as an instrument to judge monopolistic practices of patent-

13. An example of this kind was the news that Xerox developed a new colour film, in which silver is no longer used (*Volkskrant*, November 24, 1993). The photography industry is the largest buyer of silver and represents about 30% of total demand. As a result of this news, the price for silver on the international market dropped by 5% within two days.

holders. He proposes the ratio of the patentee's reward divided by the monopoly loss as a guideline for patent and competition policy. In general, he says, the higher this ratio, the more desirable, from a social point of view, the monopoly practice is. After formalization of the problem for the patent office to set an optimal mixture of breadth and length, Klemperer (1990) comes up with an identical (inverse) ratio of welfare loss divided by patentholder's profit as the objective function to be minimized. Thinking in terms of this ratio proves to be very useful in patent questions. The difficult question of incentive size is avoided and the focus can be placed on the structure of the incentive. As explained in section 4, both Klemperer (1990) and Gilbert and Shapiro (1990) assume an exogenous incentive size and search for the conditions under which the ratio of welfare loss to profit is minimized.

The practice of price discrimination by a patentholder, for example, can be examined with use of the ratio test. Van Dijk (1994) presents a model of patent breadth which shows that, given linear demand functions, the innovation incentive in the form of a fixed profit can be provided more efficiently by allowing for price discrimination by the patentholder. In the price discrimination literature (see Varian 1989 for an overview), it is a well-known result that price discrimination, as compared to uniform pricing, lowers static welfare for linear demand functions. Because profits always increase under price discrimination, it is not clear beforehand whether the ratio of welfare to profit is larger under price discrimination or under uniform pricing. The ratio under discrimination turns out to be equal to the ratio under uniform pricing if there is no explicit model of patent protection underlying the demand functions of the patentholder. From the perspective of providing an innovation incentive, the practice of price discrimination is thus neutral to uniform pricing. If an explicit model underlies the extent of patent protection and the resulting demand in each market, then the practice of price discrimination is shown to be a socially more efficient manner to provide an innovation incentive.

(c) The Patent as Incentive

As already pointed out above, the literature on the topic of patent races is extensive. A patent race describes the technological competition between two or more firms aiming for the same innovation. The patent race is often modelled as a winner-takes-all game (Reinganum 1989).

The winner of the race obtains a patent and the associated monopoly profit while the loser gets nothing at all. The solution of such games is often characterized by an overinvestment, from a social point of view, in R&D at industry level. As explained in section 5, the major reason for this result is the fact that one firm in the race does not take into account the negative effect on other firms if it increases R&D compared to the others. This is labelled in the literature as the 'common pool problem'. Mortensen (1982) shows that the common pool problem in patent races can be corrected. If the winner of a race were required to compensate each of the losers for the lost values of prospect, then the equilibrium in the patent race is socially efficient. The strong exclusivity of patents can be said to cause the industrial overinvestment. Modification of the exclusive character corrects this tendency.

Wright (1983) compares the performance of three instruments that provide innovation incentives: patents, prizes and research contracts. A patent is awarded to one successful inventor, a prize to all successful inventors. A research contract purchases units of research activity beforehand at a fixed price. As shown above, patents provide the inventor rewards at the cost of temporary deadweight losses. Instead of indirectly via patents, an equivalent monetary compensation could also be offered directly to researchers. This compensation could be funded by less distortionary means, compared to deadweight loss causing patent monopolies. Put this way, there is no reason to assume that patents are superior to prizes or research contracts (the monetary compensations) in order to induce invention. Wright points out that this conclusion on the disadvantage of patents may depend on an assumption of symmetric information, both present with an administrator and researchers, concerning the costs and benefits of research. In a context of asymmetric information on the cost and probability-of-success functions, any of the three alternatives may be the best choice. In brief, some of the considerations of Wright are the following. Compared to research contracts, the disadvantage of both prizes and patents is that they induce the common pool problem (socially excessive resources to innovation). Where this can be corrected in the case of symmetric information (also found in Mortensen 1982), it cannot be corrected for asymmetric information scenarios. However, the advantage of prizes and patents is that they are more decentralized invention incentives that use private information exclusively available to researchers. In this respect, patents perform even better than prizes because the information

on the benefits of success is also incorporated, whereas the benefits of prizes are fixed. The disadvantage of patents, however, is the incurred deadweight loss.

7. Summary and Concluding Remarks

This paper has provided an overview of the models on patents that have appeared in theoretical Industrial Organization. As a start, it has explained the basic economic arguments of patents and other intellectual property. Next, it has briefly outlined the patent-granting procedure of the European Patent Office. This procedure has formed the organizing principle behind the survey. More precisely, the theories were discussed in the reverse chronological order of a typical patent procedure. Table 2 provides an overview of the topics and articles that were discussed.

Most of the models discussed use a static, partial equilibrium framework. Partial equilibrium analysis allows for more and richer detail. The same might be said about static analysis; since the proceeding of time is not incorporated, more focus can be placed on the static moment. Although many useful insights emerge from these static and single market models, the inclusion of time into the analysis could prove to be very illuminating, especially in the context of technical progress. Some recent analyses use dynamic, general equilibrium models. An early analysis is Judd (1985) on product innovation. But this article had its major impact outside the patent literature; it can be considered as one of the first new growth models. Other analyses are Chou and Shy (1993), on the length of patent protection and its impact on new product development afterwards, and Helpman (1993), on the issue of global patent protection in the Uruguay Round. Future research can examine many known patent questions in a dynamic and general equilibrium framework. But it is felt that static and partial analyses continue to be useful, particularly when looking for and examining new questions.

Table 2. Overview of the Theoretical Patent Literature

		TECHNOLOGICAL COMPETITION
Innovation Incentive		Reinganum (1989): patent races
		Mortensen (1982): efficiency
		Kaplow (1984): incentive structures
Alternatives		Hirshleifer (1971): information
		Wright (1983): prizes, subsidies
		GRANTING PROCEDURE
Information Disclosure		Horstmann et al. (1985): signalling
		Scotchmer and Green (1990): novelty requirements
Permissive Patents		La Manna et al. (1989): application dates
Role Patent Office		La Manna (1992): rules
		EXPLOITATION
Rights:	**Length**	Nordhaus (1969): R&D monopoly
		Kamien and Schwartz (1974); De Brock (1985): R&D rivalry
		Goyal and De Laat (1991): multiple inventions
		David and Olsen (1992): learning economies
	Breadth	Klemperer (1990); Waterson (1990); Gallini (1992): one market
		Kitch (1977); Merges and Nelson (1992); Matutes, Regibeau and Rockett (1993): more markets
		Van Dijk (1994): price discrimination
	Height	Scotchmer and Green (1990): disclosure
		Van Dijk (1992): product improvements
Restrictions		Gilbert and Newberry (1982): preemption
		Hausman and MacKie-Mason (1988): price discrimination
		Gilbert and Shapiro (1990): maximum prices

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