UNITED NATIONS **E**

Economic and Social Council

Distr.
GENERAL

OPA/CONF.1/2002/4
1 August 2002

Original: ENGLISH

ECONOMIC COMMISSION FOR EUROPE

COORDINATING UNIT FOR OPERATIONAL ACTIVITIES

HIGH LEVEL TASK FORCE ON VALUATION
AND CAPITALIZATION OF INTELLECTUAL ASSETS

(First meeting, Geneva, 18-19 November 2002)

Valuing Patents and Patent Portfolios from a Corporate Perspective – Theoretical Considerations, Applied Needs, and Future Challenges

Background paper for discussion[1]

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Abstract

This paper seeks to complement Pithelky's (1999) survey on patent valuation methods. Focusing on two criteria that determine the suitability of a patent valuation method, this article takes up the issue of valuing patents – and patent portfolios in particular – where Pithelky (1999) left off. This paper first deepens the discussion about the prediction validity of cash-flows and their volatility in existing real option approaches (criterion 1). Secondly, it adds further aspects to the discussion of valuation methods from a strategic management perspective, namely information availability and evaluation costs (criteria 2 and 3). Identifying caveats to existing practice as to the satisfaction of all criteria the paper then reassumes the theoretical discussion of how to assess a patent's value from the scratch. In a next step it proposes alternative considerations for patent valuations. In particular, the article elaborates on the state of the art of valuing patent portfolios with publicly available indicators from the patent system. The paper concludes with a critical analysis of this alternative valuation approach and briefly discusses future challenges in the evaluation of IP.

1 This paper is complementary to Pithhelky's (1999) article entitled "The Valuation of Patents: A Review of Patent Valuation Methods with consideration of Option Based Methods and the Potential for Future Research". An understanding of patents and real options as described by Pithelky (1999) is expected. The author thanks his academic colleagues Loachim Henkel (MIT and Munich University) and Raffaele Oriani (Universita' di Bologna) for valuable comments and suggestions. The responsibilities for all remaining errors, however, lie with the author.

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1. Introduction

Patent laws (or their legal predecessors) have been in existence for a long time. Introduced in France in 1790 and in the US in 1791, the German patent law (originally passed in 1877) even belongs to the younger patent jurisdictions.[2] Thus, one should think that patent valuations should be standard issues for practitioners in the field and should offer no further questions to academics. As a matter of fact, this is not the case.

It is true that patent valuation issues are as old as the existence of patents themselves. One of the oldest evaluation purposes is that of damage award assessments in trials. Since the starting-point for evaluations of this type is a legal one, most of the corresponding literature in this field stems from lawyers.[3] Since the 1960s patents have also attracted the interest of theoretical[4] and empirical economists[5]. Accounting scholars write on to the valuation of intangible assets[6], and most recently patents have also gotten increasing attention by management scholars.[7] As Reitzig (2002) shows, however, the different disciplines have substantially different understandings of what the value of a patent is and how it can be assessed.[8] This finding very much corresponds to the understanding of Pithelky (1999, page 3):

> *The first questions to be asked of any valuation are: who is doing the valuation?, for whom? and for what purpose?*

This particular paper takes a strategic management perspective. I.e., valuation considerations in this paper are not bound by any formal legal constraints as eventually imposed upon by patent laws or accounting standards. Instead, this paper will regard a patent as an asset for a corporation whose value is determined by the value of its underlying technology, its technical, legal, and market uncertainty, and the competition scenario as perceived from the perspective of the patent holder. In that sense, this paper largely shares the point of view that from a corporate perspective patents are best viewed and valued as real options.[9]

However, the paper tries to take the discussion one step further by asking the following questions:

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2 See Beier (1978)

3 For Germany see for example Vollrath (1983), Assmann (1985), Lehmann (1988), Heil and Roos (1994), and Karnell (1996).

4 See for example Nordhaus (1967), Gilbert and Shapiro (1990), Klemperer (1990), Scotchmer and Green (1990), Gallini (1992), and Green and Scotchmer (1995).

5 See for example Scherer (1965), Griliches (1981), and Pakes (1986).

6 See for example Löcke (1998), KPMG (1999), and Schildbach (2000).

7 See for example Rivette and Kline (2000).

8 See Reitzig (2002), chapter 4.

9 Note that *strictly speaking* this paper must not claim to view patents as *real options* because the management perspective of the patent holder introduces a *subjective* dimension to the value. At least in theory, however, a real option should have an *objective value* which does not depend on the perspective of the patent holder. Yet, for the purpose of this paper I will stick to the term real option to express that the value of the patent protected invention is subject to a risk and that the patent holder may decide whether he exercises his exclusivity right or not. I will elaborate on the problem of the objectiveness of the underlying's value in more detail at a later point.

- How can we actually assess the input parameters (e.g. expected cash-flows, volatilities, etc.) when valuing patents as real options?

- And more specifically: How can this task actually be carried out at reasonable costs for large portfolios of patents when a few hundred patents or even more must be evaluated quickly?

From the experience of this author, especially the last question still causes most problems in the daily life of analysts and R&D managers.

To address the first question, the paper briefly reassumes the discussion initiated by Pithelky (1999) on "Real Options – Patents, Problems, and Solutions". To come up with suggestions as how to meet the second requirement for suitable patent portfolio valuations, the paper will first make a step back and reconsider fundamental issues for the evaluation of patent rights. In a next step it will elaborate on the state of the art and the anticipated future potential of patent portfolio valuation methods using econometrically validated indicators.

1.1. Real option valuation of patents – Existing practice and associated problems

Pithelky (1999) mentions three major problems when valuing patents as real options.

1. Determining the current price of the underlying by predicting the present value of cash-flows from the patent,
2. Determining the volatility of the underlying, and finally
3. Allowing for an evaluation that views patents as compound options.

In fact, I consider all of the three problems major issues when discussing the practicability of real options for patent valuations. Besides, I figure that for the particular problem of valuing a patent even the assessment of investment costs and the investment time are often complicated parameters to assess. Or in other words: Assessing any of the parameters entering the Black and Scholes formula (Black and Scholes, 1973) or even more complicated models imposes upon problems in the case of patent valuations.[10]

Still, interesting approaches to apply the Black and Scholes (1973) formula to patent valuations have been chosen in the past. Intuitively, market benchmarking is certainly an interesting idea to assess the input parameters that are needed to calculate the value of the patent as an option. By doing so, one implicitly assumes that a spanning traded IP asset or portfolio of assets can be found that shows the same volatility as the underlying of the patent or the group of patents subject to valuation. There exists also substantial empirical evidence that

10 See Geske (1979) for a model that takes account of the compoundedness of options. As a matter of fact, the compound option character of a patent is striking. One example of the compound character is mentioned in Pakes (1986). The owner of the patent (option) receives an additional option of renewing his patent after a certain period of time. For the purpose of this paper, I will not go into the details of the problems that are associated with the application of the Black and Scholes (1973) formula to patents because of the compound option character of patents. No formalizations will be presented. It should be kept in mind, however, that the real option valuation of patents might even require more complex models than the one presented by Black and Scholes (1973).

the market value of corporations is correlated with their IP stock.[11] In general, these findings render it plausible to apply market benchmarking to patent valuation.

From a scientific standpoint, however, I still wonder what we can actually say about the specific validity of such approaches to assess patent value.[12] Even though there may be various cases in which the approach yields scientifically valid results[13], I would be afraid that there is still a substantial number of scenarios in which spanning traded IP assets are hard to find: Patents protecting radical inventions, patents protecting inventions that are exploited by multi-product companies, bargaining patents protecting inventions in highly cumulative technologies, etc. In these cases, it may be difficult to find valid proxies for the present value of the cash-flows and their volatility by searching traded spanning assets.

Validity, however, is certainly only one criterion that affects the suitability of a patent valuation from a corporate perspective. Other criteria are information availability (time constraints) and evaluation costs for assessments. They shall be briefly presented in the next part.

1.2. Suitability criteria for patent valuation methods from a corporate perspective

As mentioned before, this paper takes a strategic management perspective. Here, typical questions for the evaluations of patents might likely sound as follows:

- What is the value of our own IP stock within a certain technology sector? (Controlling)
- What should we charge a certain licensee for the use of a specific group of patents? (R&D Strategy/Marketing)
- What is the maximum prize we should pay for the IP portfolio of a competitor that is for sale? (R&D Strategy)

The questions point at a category of applied management tasks where assessments are needed for groups of patents rather than individual patents. Which could in these cases be the caveats to the application of market benchmarking as described above?

In many of these cases it might be difficult to find a coherent *spanning* bundle of IP assets to apply real option models in the way it was mentioned above. ***Validity may become a problem***. But even if the bundle of patents to be evaluated was so coherent that an application of real option models might be feasible from that point, one might still face problems due to the novelty of the technology. The benchmarking application fails if equivalent stocks of IP assets are simply *not traded yet*. ***Information availability may become a problem***. Most importantly, however, it appears to be rather costly to apply a detailed real option based evaluation to each

11 See for example Griliches (1981), Conolly, Hirsch et al. (1986), Conolly and Hirschey (1988), Cockburn and Griliches (1988), Megna and Klock (1993), and Hall, Jaffe et al. (2000).

12 To the best of my knowledge there exists very little empirical evidence from large-scale scientific studies about the validity of market benchmarking based real option evaluations of patents.

13 Such cases may be valuations of patents in discrete product technologies held by one-product corporations (e.g. bio-tech patens held by start-ups).

individual IP asset or each sub-dividable bundle of IP assets when assessing the aggregate value of an entire portfolio of patents. ***Evaluation costs may become a problem.***

Implicitly, the summary of potential obstacles to the use of existing real option evaluations provides a list of criteria for the suitability of patent assessments from a strategic management perspective. No matter whether groups of patents or individual IP assets are evaluated,

1. **Evaluation validity** is an important criterion.
   In a variety of scenarios that are relevant from a management perspective, however, different criteria appear crucial, too. Particularly when valuing portfolios of patents,
2. **Evaluation costs** per patent start to play an important role. Besides,
3. Necessary **information** for the evaluation should be **available as early as possible** in the life-time of the patents that are to be valued.
4. Optimally, the necessary **information** should be **publicly available** so that it can be applied for the assessment of competitors' patents as well.

Thus, with respect to the evaluation criteria mentioned above there may exist numerous occasions in which market benchmarking evaluations of patents prove inconvenient or fall short. The question rises which potential methods might satisfy those applied management needs at all. This paper does certainly not aim at giving a final answer. It does not uncover the philosopher's stone, either. Rather than that the paper attempts to make some moderate progress by taking a step back first and then move into another direction which has been paid less attention by practitioners so far.

In the following I will, therefore, first reconsider basic questions such as: What is the value of a patent from a management perspective? And which potential ways exist at all to estimate its value? The first two sections in the next chapter will be dedicated to these two issues. In a next step I will then discuss the use of alternative indicators for patent valuations in more detail.

2. Patent valuation from a management perspective

2.1 A definition of patent value

What is the value of a patent from a management perspective? According to the understanding of this paper a patent's value is not observable. The value of a patent from a management perspective is a theoretical term (as will become clearer in the following). Thus, strictly speaking patent values can not be "measured" at all. They must be assessed or calculated according to their definition.

What is a suitable definition for patent value? As Harhoff, Scherer et al. (1999) can show, for a majority of empirically relevant scenarios a patent's value from a management perspective is defined best as the difference in discounted future profits the patent holder makes

during the remaining life-time of the patent vs. if his/her strongest competitor in the field held the patent.[14] This value is often referred to as the "asset value" of a patent.

Equation 1 formalizes this definition in a very general fashion.

$$Patent\ Value_{anticipated} = \hat{E}\left(\Pi_I^I - \Pi_I^C\right) = \hat{E}(p_I, q_I, c_I, p_C, q_C, c_C - p_I^*, q_I^*, c_I^*, p_C^*, q_C^*, c_C^*) \quad (1)$$

Legend:

Π_I^I:	Profits of the patent holder if he holds the technology
Π_I^C:	Profits of the patent holder if the strongest competitor held the patent
p_I, q_I, c_I:	Prices charged, quantities sold, and costs incurred by the patent holder
p_C, q_C, c_C:	Prices charged, quantities sold, and costs incurred by the competitor
p_I^*, q_I^*, c_I^*:	Counterfactual prices charged, quantities sold, and costs incurred by the patent holder if the competitor held the patent
p_C^*, q_C^*, c_C^*:	Counterfactual prices charged, quantities sold, and costs incurred by the competitor if he/she held the patent

The assessment of a patent's value according to this definition imposes obvious problems. According to the chosen definition it is not sufficient to calculate the (expected) present value of cash-flows for the patent holder if he/she holds the patent, but they also need to be assessed for a scenario in which the strongest competitor hold the patent. The expected cash-flows in the second scenario are, however, counterfactual; i.e. they can never be observed. This is why patent value is a theoretical term.

The question therefore is how the patent's value can be proxied.

Assuming that benchmarking the present value of cash-flows (and its risk or distribution) by looking at spanning IP assets is not possible for the reasons mentioned above, one has to think about different ways of estimating future and partly counterfactual cash-flows and their volatility.

A different approach to value patents is to identify their "value drivers" or operationalizations of those value drivers. Despite its obvious downsides[15] this methodology has been widely accepted in the field of company valuation where the practical assessment of

14 See Harhoff, Scherer et al. (1999). The authors compare asset and renewal values for patents in three different empirically relevant scenarios, namely (a) in a standard scenario where inventions do not build upon each other in a cumulative way and no blocking power can be exerted by the use of patents, (b) a scenario in which inventions build upon each other in a cumulative manner and where blocking power can be exerted, and (c) a scenario in which a patent protects a substitution technology.

15 From a theoretical standpoint, the value of the underlying of a real option is objective (see for example Laux, 1993). If the real option was traded, the objective value could be calculated from arbitrage considerations. From a theoretical point, assessing the value of the underlying of a real option using value drivers breaks with real option theory. From a practical standpoint, there is often no other way to pursue the valuation of a „real option".

"real options" is maybe equally difficult as in the case of valuing patents.[16] Section 2.2.1. will follow such an approach of an alternative real option valuation using value drivers instead of market benchmarking.

2.2. Assessing patent value without market benchmarking

In this section the understanding of what comprises patent value will be deepened first (2.2.1.). Different value drivers as known from the literature are embedded into a real option framework. The discussion of this value concept is not an end in itself but it shall enhance the reader's understanding as to how the value of patents should consequently become assessable by value proxies that are operationalizations of the latent value drivers. The latter discussion is presented in section 2.2.2. Along the suitability criteria for patent valuations from a management perspective laid out above the existing theoretical and empirical knowledge of the applicability of these proxies is discussed.

2.2.1. A different "real option" framework for patents

Table 1 compares financial options and real options.

Table 1: Financial Options and Real Options

Financial Option on Share	**Real Option**
Time to expiry	*Time left to invest in*
Exercise price of the option	Investment Cost of Project
Current price of the underlying share	*Present Value of Project Cash-flows*
Standard deviation of underlying share returns	*Standard deviation of the Project value (volatility)*
Risk free interest rate	Risk free interest rate

Source: Pithelky (1999) (slightly altered)

As Reitzig (2002) shows, the existing knowledge on value drivers (or value determinants) of patents can be sub-summarized under a real option framework.

Here, three of the parameters show patent specificities, that is the time to invest in, the present value of project cash-flows, and the standard deviation of the project value.

- When talking about patents, the *patent's duration (or life time)* corresponds to the maximum *time to invest in*.
- The *present value of project cash-flows* should be driven by the *patent's novelty, its inventive activity (non-obviousness), disclosure, breadth, difficulty in*

16 See Copeland, Koller et al. (1994), p. 42-44.

(technically) inventing around, its position within a portfolio of other patents, and the complementary assets of the patent holder.

- The *standard deviation of the patent's value (volatility)* should be driven by *technical, legal, and market uncertainty.*

In the following, the central terms mentioned above will be presented briefly. I will quote original sources from the economic literature so that the interested reader can go back to them. It would be beyond the scope of this paper to discuss the preliminary empirical evidence of the importance of all those value drivers in detail.[17] Thus, the discussion of empirical results is not carried out for all of the value determinants and is kept short where it is raised at all.

2.2.1.1. Patent duration

Various microeconomic models used to help designing patent systems optimally start from the premise that the economic value of a patent for its holder increases with the patent's duration. Younger models (see for example Matutes, Regibau et al., 1996) differ from their predecessors (see Nordhaus, 1967) mainly in that they make more realistic assumptions as to the distribution of returns-per-period over time.[18]

2.2.1.2. Novelty and inventive activity (non-obviousness)

Green and Scotchmer (1995) are the first to introduce "novelty" into an economic model of patent value. As a legal term, novelty is a well-known characteristic to legal scholars and practitioners in the field. Novelty describes the technological distance between a patent-protected invention and the state of the art. Similarly, inventive activity (or non-obviousness) has been well-known to lawyers for long but was officially introduced first by Green and Scotchmer (1995) into the economic discussion.

2.2.1.3. Patent breadth

Klemperer (1990) and Gilbert and Shapiro (1990) were the first to assume that the degree to which a patent protects an invention, namely the patent's breadth, affects the patent's value. The authors assume that the patent breadth has a positive impact on the patent value.

2.2.1.4. Disclosure

Green and Scotchmer (1995) assume that disclosing technical information confers a positive externality on the patent-holder's competitors which the patenting firm might want to avoid. Disclosure should reduce a patent's value for the owner.

2.2.1.5. Difficulty in inventing around

17 For a comprehensive overview see Reitzig (2002), chapter 3.

18 Consistent with the literature on technology cycles (see for example Kotler and Bliemel, 1995) the younger models do not assume that returns-per-period are constant but that returns-per-period are subject to the life stage of the underlying technology.

Patents should exert more blocking power the more difficult it becomes to circumnavigate the protected invention with a new technology. Gallini (1992) introduced this idea into a formal model for the first time.

2.2.1.6. Complementary assets

Patents protect products or processes. Oftentimes, complementary technology and other complementary assets are needed to commercialize the patent protected invention. Teece (1986) analyzes in more detail in what way the commercial success of an invention depends on the availability of complementary assets.

2.2.1.7. Technical, legal, and market uncertainty

The value of patents is subject to three kinds of uncertainty. Technological uncertainty was first acknowledged by Gilbert and Newberry (1982) in the economic literature on patents. The central idea is that patenting usually takes place at a point where the commercial success of the final product still depends on overcoming future technical obstacles. Next to technical uncertainties market uncertainties matter significantly. Again Gilbert and Newberry (1982) were the first to explicit this aspect in the theoretical economic literature on patents.[19] Finally, legal uncertainty enters the "volatility" of the present cash-flows from a patent. Legal uncertainty differs from the technical and market uncertainty in two ways. At first, it is partly determined by the patent owner. This imposes an additional problem to a real option evaluation of patents in that the volatility becomes endogenous. Lanjouw (1998) was the first to introduce this issue to the economic literature. Expanding on the model by Pakes (1986) she introduces legal uncertainty that is created by the risk of entering and winning infringement suits. Later studies, such as the one by Harhoff and Reitzig (2001) have taken up the idea in a somewhat different fashion. Secondly, legal uncertainty may hardly affect the value of the underlying in an upward fashion but the other way around (validity suits or infringement suits). Thus, it is questionable to what extent legal uncertainty affects the value of the option at all.

2.2.1.8. Empirical evidence – the importance of value drivers depending on the use of the patents

Talking about the empirical evidence a distinction needs to be made between the types of empirical evidence that exist for the time being – studies using expert ratings and studies using alternative measures both to proxy patent value and value drivers. To the best of my knowledge only one empirical study has been published that directly relates expert ratings of various value determinants to patent values. In this study, estimated values of 127 semiconductor patents were regressed on expert ratings of the various value drivers. For this very particular sample it turned out that the novelty and the inventive activity were highly correlated with the patents' values as predicted by the experts. The difficulty in inventing around and the disclosure turned out to be of minor importance. Due to the research design, the impact of other characteristics could not be assessed.[20] Interestingly, the results of the study showed, however, that the disclosure of the patents had a positive impact on the patents' values.

19 See Gilbert and Newberry (1982), p.521.
20 See Reitzig (2001a).

This particular finding emphasizes the importance to distinguish between different "uses" or modes of exploitation for patents when referring to value drivers for assessments. As well known from the literature, patents may serve various purposes. Until about twenty years ago, it was assumed that patents would dominantly be used to exclude competitors from the use of their technology. As a matter of fact, Harabi (1995) and Cohen, Nelson et al. (2000) do find empirical evidence for this traditional assumption until today. However, in recent years the literature also revealed that patents may serve other purposes. Rahn (1994) underlines the importance of patents as a means to "exchange technology" with competitors. In a survey of the American semiconductor industry, Hall and Ham-Ziedonis (2001) reveal that the main motives for patenting in the field are triggered by negotiation considerations. Thus, the findings by Reitzig (2001a) have to be put into perspective. Disclosure may exert positive externalities for a semiconductor company participating in a patent pool with major players in the field in that disclosing technical know-how conveys the impression of competence to potential negotiation partners. On the other hand, it may have negative externalities for chemical corporations that do not participate in patent pools and are rather interested in hiding as much of their technology from competitors as they can.[21]

Indirect empirical evidence for the validity of patent duration as a value driver was provided in two large-scale empirical studies by Schankerman and Pakes (1986) and Lanjouw, Pakes et al. (1996). Schankerman and Pakes (1986) use the observable renewal decision by patent holders from Germany, the UK, and France between 1955 and 1978 as the dependent variable within a structural estimation model that regards the renewal decision as an investment decision. Their data set comprises 1.7 million renewal decisions. The findings show that the overall value of a patent (from grant to lapse) increases nonlinearly with its age.[22] Comparable to the work of Schankerman and Pakes (1986) is the study by Lanjouw, Pakes et al. (1996). The authors analyze renewal decisions for German patent cohorts between 1953 and 1988. The data set consists of more than 20.000 observable renewal decisions. The results by Lanjouw, Pakes et al. (1996) are comparable to the ones by Schankerman and Pakes (1986).[23]

Indirect empirical evidence for the validity of novelty as a value driver is provided by a study carried out by Carpenter, Cooper et al. (1980). By showing that patent references to the scientific literature made during the examination procedure (see below for more details) are correlated with patent value they do sustain the assumption that novelty is a value driver of a patent.

Some very preliminary empirical evidence exists on the importance of the inventive activity as a value driver for patents. In a study of 613 European chemical patents Reitzig (2002) can show that indicators which plausibly operationalize the inventive activity of a patent are correlated with the patents' values.

Some preliminary empirical evidence also exists on the validity of patent breadth as a value driver of patents. Lerner (1994) showed that the value of American biotechnology firms increases with the 'scope' of the patents they hold. Lerner measured 'scope' by the number of

21 See Reitzig (2002) chapter 7 for some preliminary empirical evidence that disclosure may also have negative effects on a patent's value in the chemical industry.

22 See Schankerman and Pakes (1986), p. 1073.

23 See Lanjouw (1998), p. 697.

four-digit IPCs assigned to the patents in his sample. Arguing that the number of four-digit IPCs proxies for the breadth of the patent he sustains the theoretical assumption that patent breadth is positively correlated with patent value. Moreover, patent claims (see also below) should theoretically reflect a patent's breadth as well. By showing that patents weighted by their claims correlate with macroeconomic measures of national performance, Tong and Frame (1992) yielded some very first empirical evidence that patent breadth is another patent value driver. Lanjouw and Schankerman's (2000) findings that the likelihood of a patent being litigated increases with its number of claims again sustain that patent breadth may be an important value determinant of the patent.[24]

Finally, some empirical evidence exists for the importance of technical and market uncertainty. In a study published by the EPO in 1994, European patent applicants mention that in 7% of the cases when they decide against filing for a patent technical uncertainty affects their decision.[25] For Japanese applicants this is true in 14% of the cases.[26] The study also reveals that in 20% of the cases when European applicants decide against a filing market uncertainty affects their decision-making (for Japanese applicants this figure goes up to 31%).

2.2.1.9. An interim conclusion

Patent value is a theoretical term which is difficult to calculate. Real option assessments of patents are appealing in that they take into account the limited life-time of a patent and the uncertainty about expected cash-flows. Practical problems are imposed upon by the estimation of cash-flows and their volatility. Market benchmarking appears to offer an interesting approach to assess patent value in some but not in all cases. An alternative approach is to assess the value determinants of a patent. Since most of these value determinants are latent constructs they must be operationalized for a "measurement". Assessments of patents using value indicators may offer an interesting alternative approach to the valuation of patents.

2.2.2. Indicators of patent value

As mentioned above the discussion of value drivers and embedding them into an option framework was not an end in itself. This paper ultimately addresses the question how the value of patents – and large portfolios of patents in particular – can be assessed to serve applied management needs. Recalling the suitability criteria derived initially, valuations need to be scientifically valid, they should be executable at any time and for any type of patent portfolio (in-house and competitors), and they should not be costly.

One approach is to use indicators of patent value that are generated by the patent system itself. According to the framework developed in 2.2.1. such indicators are either valid if they operationalize one (or more) of the value drivers or if they refer directly to the present value of

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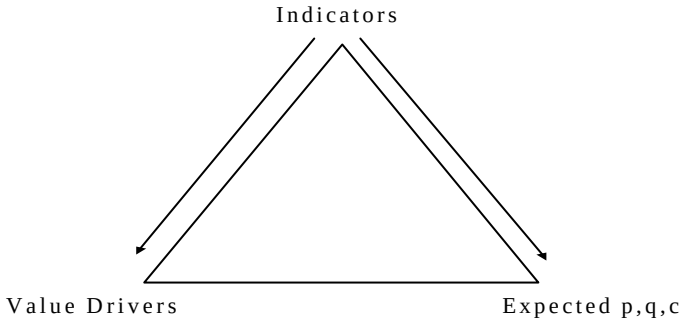
24 Note: As Lanjouw and Schankerman (2000) point out, claims also mark potential points of disputes; thus, their theoretical interpretation is more difficult than suggested above. Claims may refer to both, the *legal robustness* and the *breadth* of a patent simultaneously. Therefore, they may operationalize opposing effects at the same time. Thus, their suitability to empirically buttress breadth as a value determining parameter is limited.

25 See o.V. (1994), p. 109.

26 See Ibid., p. 110.

cash-flows from the patent (expected prizes, quantities, costs). Figure 1 illustrates the different types of validity for value indicators according to the understanding of this paper.

Figure 1: Ways to use indicators for patent valuations



This section will summarize the existing knowledge on the suitability of patent value indicators that are generated by the patent system itself.[27] The next section will then discuss issues as to how indicator assessments can actually be carried out, and it will also discuss the challenges of applying indicator valuations for the time being.

2.2.2.1. Empirically tested patent value indicators

Reitzig (2001b) presents a tabulated survey of the existing scientific empirical studies examining the correlation between a patent's value and patent information indicators. Studies are characterized by the underlying sample size, the underlying statistical/econometric model, the latent variable used as a correlate for the patent's value, and the resulting type of validity. The survey shows that many of the studies do not validate indicators of patent value directly. This is due to the fact that in many of the studies the dependent variable of the analysis is not the patent value itself but a value correlate. As a matter of fact, this renders the discussion of the empirical results difficult at times when trying to interpret the correlation between an observable indicator and the patent's value. To a certain extent it appears possible to draw some general conclusions about the validity of the variables tested as indicators of patent value.

In the following I will first very briefly describe what the certain variables mean and refer to the studies in which they were tested as patent value correlates. In the next section I will summarize the findings on their suitability as indicators of patent value. I will report on their validity[28], their availability, and the costs of computing them.

27 For a comprehensive discussion see Reitzig (2002) chapter 4.

28 It needs to be said clearly, however, that none of the studies listed in Reitzig (2001b) actually used a structural econometric model allowing for a test of validity of certain variables as indicators of distinct input parameters of a real option valuation. The empirical evidence existing as of today is not as detailed which is reflected in the state of the art of valuing patents with indicators (see 2.2.3.3.) and brings up future challenges, too (see 3.).

2.2.2.1.1. Backward citations

US and EP patents are examined before grant. Novelty and inventive activity (non-obviousness) are patenting requirements. In practice, patent examiners judge the fulfilment of these requirements by looking at the state of the art as reflected in existing publications, amongst others former patent documents. Relevant state of the art documents are quoted by patent examiners and are published with the patent application in examination. These documents are called backward citations. Backward citations were tested in the following studies: Carpenter, Cooper et al., 1980; Narin, Noma et al., 1987; Lanjouw and Schankerman, 2000; Lanjouw and Schankerman, 1999; Harhoff, Scherer et al., 1999; Harhoff and Reitzig, 2000.

2.2.2.1.2. Forward citations

The term forward citation refers to the number of times a granted patent is quoted as relevant state of the art during the examination of subsequently examined patents. Forward citations were tested in the following studies: Narin, Noma et al., 1987; Trajtenberg, 1990; Lanjouw and Schankerman, 1999; Albert, Avery et al., 1991; Harhoff, Scherer et al., 1999; Harhoff and Reitzig, 2000.

2.2.2.1.3. Family size

Family size describes some measure for the number of states in which a patent is valid. Family size was tested in the following studies: Lanjouw, Pakes et al., 1996; Lanjouw and Schankerman, 1999; Guellec and van Pottelsberghe de la Potterie, 2000; Harhoff and Reitzig, 2000.

2.2.2.1.4. Scope

The scope variable is supposed to capture a patent's breadth. The scope variable was tested in the following studies: Lerner, 1994; Harhoff, Scherer et al., 1999; Harhoff and Reitzig, 2000; Lanjouw and Schankerman, 2000.

2.2.2.1.5. Patent ownership

The patent ownership variable describes who holds the property right. In many studies, the variable was used to distinguish between individual and corporate ownership. Ownership was tested in the following studies: Lanjouw and Schankerman, 2000; Harhoff and Reitzig, 2000; Guellec and van Pottelsberghe de la Potterie, 2000.

2.2.2.1.6. The number of claims

The number of claims is supposed to capture the breadth of the patent. Either as an absolute number or as a weighting factor it was tested in the following studies: Tong and Frame, 1992; Lanjouw and Schankerman, 1999; Lanjouw and Schankerman, 2000.

2.2.2.1.7. The patenting strategy (mode of filing)

Patents can be filed in different ways. On an international level, an application via the so-called PCT route is an alternative mechanism to applying separately in various jurisdictions. Different strategic rationales are associated with the different modes of filing.[29] The mode of filing/patenting strategy variable was tested in the following studies: Guellec and van Pottelsberghe de la Potterie, 2000; Reitzig, 2002.

2.2.2.1.8. The number of applicants

Patents can be filed by more than one applicant. The variable was tested in the study by Guellec and van Pottelsberghe de la Potterie (2000).

2.2.2.1.9. The number of trans-boarder research co-operations

Applicants can have different nationalities. From this information a variable can be computed that reflects whether the patent application is the product of a trans-border research co-operation. This variable was tested in the study by Guellec and van Pottelsberghe de la Potterie (2000).

2.2.2.1.10. Key inventors

According to Lotka (1926) a small 'elite' of (key) inventors accounts disproportionately much for the scientific output of a corporation. A variable referring to key inventors was tested in a study by Ernst, Leptien et al. (2000).

2.2.2.1.11. Legal disputes (oppositions against patents)

EP patents can be legally "attacked" in an opposition procedure up until nine months after their date of grant. This variable was tested in the study by Harhoff, Scherer et al. (1999).

2.2.2.2. Indicators and their suitability for patent valuations – an interim summary

With respect to the validity of the tested variables as indicators of patent value, their availability, and the costs associated with the computation of the indicator I come to the following conclusions[30]:

Backward Citations have been tested as indicators for patent value in the past. The main distinction needs to be made between patent and non-patent citations. Based on theoretical considerations and results from various empirical studies in the field it seems as if both backward citations to the patent and non-patent literature operationalize novelty and they should therefore be valid correlates of a patent's value. Besides, the attractiveness of a technological field should also be reflected in the number of citations to the patent literature. Nonetheless, the studies also show that correlations between a patent's value and backward citations are not always straight-forward which somehow limits their applicability. Backward

29 See Reitzig (2002) for more details.

30 See Reitzig (2002), chapter 4 for a comprehensive discussion.

citations can be compiled for in-house patent portfolios and competitors' portfolios alike. They are available early in the life-time of a patent (after the publication) and are available at low cost (electronically stored in data banks).

Forward Citations belong the indicators that have been examined most extensively in the literature. Based on theoretical considerations and results from various empirical studies in the field it appears as if forward citations were valid correlates of patent value. Patents that are cited more often in subsequent examinations than others should – on average – have a higher technical and therefore economic value. Forward citations appear to operationalize inventive activity, too. Forward citations can be calculated from publicly available sources and are therefore applicable to in-house evaluations as well as for the evaluations of competitor patents. The downside of forward citations is that they are not available until substantial time after grant. Usually a time window of at least four to five years seems reasonable when computing forward citations. Thus, they are not really suited for the evaluations of patents at a very early stage in their life-time. Computation costs for this type of indicator are low.

Until today, **family size** has been tested as an indicator of patent value in several empirical studies. Based on theoretical considerations and results from various empirical studies in the field it appears as if the family size was a valid correlate of patent value. From a theoretical standpoint it makes sense to assume that patent applicants are only willing to incur the increased application costs (that are associated with the number of states of protection) if they expect corresponding returns from the patent. Regarding the information availability, family size may show certain disadvantages over the other indicators mentioned before. Despite the public availability of the information necessary to compute the indicator I am afraid that little variation may be seen along this indicator within certain corporations that file patents in standard countries only. Finally, the indicator is available early during the life-time of a patent and is computable at low cost.

Scope has been tested as an indicator for patent value in a series of studies. To me its theoretical foundation is questionable as the number of four-digit IPCs may well reflect the multi-functionality of a patent but not necessarily its breadth. It has not come out as a significant correlate of patent value in about half the studies mentioned above, either. Regarding its availability, the indicator appears attractive because it can be computed directly after the publication of the granted patent. Since it is electronically available, compilations costs are low.

Patent Ownership is an appealing variable for whose validity preliminary empirical evidence exists. From a theoretical perspective it is plausible to assume that corporate patents may be more valuable (especially in research intense industries), however, the rationale is less convincing than for other indicators (for example forward citations). Since the ownership information is available early in the life-time of the patent and computable at low costs the indicator may be interesting where it shows variation (it might not show enough variation when looking at the portfolio of just one corporation).

The number of claims are interesting as an indicator of patent value for various reasons. From a theoretical standpoint there is good reason the believe that they reflect the present value of the cash-flows from the patent by operationalizing its breadth. At the same

time the pure number of claims is a measure that is not all convincing. Claims are also difficult to assign to only one input parameter of a Black-and-Scholes based real option valuation of a patent (see below). Preliminary empirical evidence for their validity as a value indicator, however, exists. As far as their availability and computation costs are concerned, they used to be somewhat less attractive than the other indicators because until recently they were not electronically available. This has changed now.

As interesting as the number of claims is **the patenting strategy (mode of filing)** as an indicator of patent value. From theoretical standpoint it makes much sense to believe that the value of cash-flows from a patent as anticipated by its owner should be reflected by the owners' choice of the filing mode (different cost structures, timing issues, etc.).[31] Until now, however, there exist only two empirical studies validating patenting strategy variables as indicators of patent value. Depending on the type of variable computed, they may not be available until 29 months after grant (PCT II). The information necessary to compute the indicator is electronically available.

Very little empirical evidence exists on the validity of **the number of applicants, the number of trans-boarder research co-operations**, and **key inventors** as patent value indicators**.** Thus, I will refrain from a discussion of these indicators at this stage but finally discuss the suitability of **oppositions** as indicators of patent value. Even though they have not been validated in more than one study, either, they appear to have great potential as indicators of patent value. Expanding on a model by Lanjouw and Lerner (1997), Harhoff and Reitzig (2000) can show that also from a theoretical standpoint oppositions should clearly be correlated with the anticipated cash-flows from a patent. The major downside of the indicator is that it is not available until 9 months after grant and that it not only proxies the present value of cash-flows but also the legal uncertainty of the patent option.

Summarizing the discussion above the following may be stated. A variety of indicators of patent value have been successfully validated in the past. They differ in their availability in time and – to some lesser extent – in their computation costs.

Thus, at first sight it appears as if patent valuations using indicators from the patent system should be a straight-forward task. As a matter of fact, however, the lack of scientific knowledge with respect to the variety of effects that may be reflected by an indicator still imposes problems as will become clearer in the next part.

2.2.3. Assessing the value of patents with indicators

Until this point it was the purpose of this paper to show that alternative measures to a market benchmarking exist that can also be used for the assessment of patents and that might satisfy company's applied needs better when valuing patents and patent portfolios.

But how can indicators actually be used for patent assessments and why should indicators be particularly suitable for the evaluation of portfolios?

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31 For a detailed discussion see Reitzig (2001c).

2.2.3.1. A sophisticated patent valuation using indicators – the final goal

Theoretically, a sophisticated patent evaluation using indicators could look like this:

1. Identify relevant indicators for the patent(s) to be valued.
2. Assign the different indicators to the calculation of the present value of cash-flows and their volatility respectively.
3. Choose an algorithm for the calculation of the present value of cash-flows and their volatility through indicators (functional form, weights).
4. Calculate the value of the individual patents using the Black and Scholes (1973) formula.

In the case of a portfolio evaluation:

5. Calculate the portfolio value based on the information about the individual patents.[32]

Unfortunately, in practice we are still far away from this. As a matter of fact, a patent valuation using indicators these days is still rather rudimentary with respect to most of the steps.

This is due to lacking scientific knowledge as to how several of the steps mentioned above can be carried out correctly. In the following, I will first briefly show where the obstacles to carrying out a scientifically sophisticated valuation using indicators lie. I will then move on to describing the existing practice and I will explain why indicator assessments provide interesting alternatives in various assessment cases already today despite the existing shortcomings.

2.2.3.2. Obstacles to indicator valuations from a theoretical perspective

2.2.3.2.1. Identification of the "right" indicators

How to choose the "right" indicators for the evaluation of a particular patent or group of patents is a difficult task. Even though there is substantial empirical evidence that supports the hypotheses that backward citations, forward citations, family size, and other indicators are correlated with a patent's value it will be easy to find particular portfolios of patents where this is not the case.[33] As of today, companies will usually take a representative (historical) test portfolio whose value has been known to validate the significance of certain indicators for their

32 Note that his can be a tricky exercise because option values are not always purely additive. Thus, the option value of the portfolio will not necessarily be the aggregate option value of the individual patents. Consider two patent portfolios in which the individual patents have equal absolute option values. In one portfolio, however, the options are interrelated, in the other they are not. Then, the portfolio values of the two different portfolios will differ. The simple addition of the option values of the individual patents would lead to a useless result for the portfolio value in the case of interrelated options.

33 Reitzig (2001b) describes that for the evaluation of a corporate patent portfolio of 90 semiconductor patents various ‚established' indicators did not turn out to be significantly correlated with the patents' values. Forward citations were significant, family size and backward citations were not.

own purposes. Obviously, this imposes various additional problems the most dominant of which may be to assess the value of the test portfolio and to find a representative sample.

2.*2.3.2.2. Assigning the different indicators to the input parameters of a real option assessment*

Despite the variety of empirical studies that have been carried out (see 2.2.2.1) very little is actually yet known on the multitude of effects that are reflected by certain indicators. None of the studies mentioned in 2.2.2.1 validates indicators of patent value within a structural model that would allow to separate out the correlations between certain indicators and the present value of patent cash flows from those between the indicators and the volatility of the underlying. Nevertheless there is good reason to believe that a substantial amount of indicators is correlated with both, cash-flows and volatility.[34] Thus as of today it appears scientifically questionable to assign indicators to the different input parameters of the Black and Scholes formula.

2.2.3.2.3. Functional form and weights of indicators

A comparable problem to the assignment of indicators to the different input parameters of the Black and Scholes (1973) formula takes place at a different step of the valuation process, too. As of today little is known whether indicators add up linearly in their explanatory power to predict the present value of the cash-flows or not. Most of the studies described in 2.2.2.1 validated indicators in the reduced form. This does not mean, however, that a simple addition of the indicators will be the most convenient way to assess the input parameters for the real option assessment. Besides, weights of indicators may vary substantially across industries and companies. Little is known on what one forward citation, on backward citation or an opposition may reveal about the economic value of a patent. The following extract from the empirical results is incomplete and is meant to convey a general impression only.

The study by Albert, Avery et al. (1991) suggests that the 'marginal returns' of an additional forward citation to a patent are increasing more than linearly. On a ordinal scale an increase from 7 to 13 forward citations is associated with an increase in the value of the patent roughly by factor 6. Lanjouw and Schankerman (1999) suggest that weights for indicators have varying importance for the patent quality index across industries. From their factor analysis using US patents they deduct that forward citations enter the patent quality index with a weight of 39% in chemistry and drugs but only 26% in mechanics. Family size enters with a relative weight of 11% in drugs and chemistry and 18% in electronics and mechanics. Backward citations enter with a relative weight of 35% in drugs, 28% in chemicals, and 18% in electronics and mechanics. In another study, Harhoff, Scherer et al. (1999) find that DE patents of the 1977 cohort that were renewed to full term were on average 11.2 times more valuable when they received (and survived) an opposition by a third party.

2.2.3.2.4. Portfolio effects

34 Take the following as an example: Family size may operationalize the breadth of a patent and it may therefore be positively correlated with the present value of the cash-flows. At the same time patent breadth may be positively correlated with a patent's probability to be invalidated or amended (legal volatility)

Finally, when trying to assess a portfolio's value with indicators referring to individual patents it seems hardly possible to model interrelations between the option values of the individual patents at this stage. For example: to the best of my knowledge nothing is known on the impact of the average number of backward citations of the patents in one sample on the value of an additional forward citation of one individual patent in the same sample.

2.2.3.3. Existing practice

To the best of my knowledge, for the time being indicator assessments in practice are carried out in the following way.

- Indicators are compiled for each patent within the portfolio that is subject to valuation.
- A weight is assigned to each indicator.
- The values of the individual patents are calculated by adding up linearly the weighted size of each indicator.

In the case of a portfolio evaluation:

- The portfolio value is calculated as the sum of the individual patents' values.

In practice, indicator assessments differ with respect to the number and types of indicators chosen for the assessment and with respect to the assignment of the weights. In some cases, the weight of certain indicators is determined by calibrating them at a test portfolio of patents whose value is known from other sources. In other cases, a factor analysis of indicators yields the weights of each proxy.

Obviously, assessments of this type show tremendous shortcomings from a scientific standpoint. The obstacles to a proper application of a real option framework as mentioned above made this point very transparent. The existing obstacles do in fact define various future research tasks (see below for a summary).

Still, I argue that there are several scenarios in which even the existing indicator valuation approaches offer an interesting alternative to other methods from a corporate perspective.

Even though indicators of patent value have not yet been validated in structural models that would allow to assign the indicators optimally to profound valuation algorithms, the validity of those indicators as patent value correlates in general can hardly be doubted. Recalling section 2.2.2.2 it becomes clear that many of them can be recommended for the assessments of portfolios comprising "young" property rights (i.e. property rights which were granted only shortly before the evaluation). Finally, the indicators can be compiled at low costs.

Thus, existing indicator assessments can preferably be considered an interesting alternative in cases when:

- Large portfolios of patents need to be valued

- Here, the cost advantage of an indicator assessment over other types of valuations increases.
- Besides, the relative evaluation error for the entire portfolio decreases compared to the relative error of each individual patent.

- The evaluated portfolios are not subject to high legal or market uncertainty
- The evaluated portfolios consist of rather interrelated patents
- It is difficult to find comparable traded IP portfolios.

3. Summary and future challenges

This paper started from the premise that from an strategic management perspective valuations of patents using real options should theoretically yield the most suitable assessment results. Consistent with Pithelky (1999) it argued that in practice real option valuations of patents impose problems because it is especially difficult to assess the present value of cash-flows from the patent and the volatility of the cash-flows. The paper tried to lay out that according to a series of criteria determining the suitability of patent assessments from a management perspective market benchmarking may not always be a convenient way to assess the input parameters for a real option assessment. It was argued that problems using market benchmarking might particularly occur in cases where it becomes costly to find spanning traded IP assets. This might especially be the case for portfolio valuations when several different spanning IP assets need to be found for the individual patents within the portfolio. The paper tried to show that alternative approaches to the assessment of the present value of the cash-flows and the volatility of the cash-flow could offer interesting alternatives in cases where market benchmarking falls short. Reviewing the literature on the determinants of patent value (value drivers) it was shown that a patent's present value of cash-flows is driven by the patent's novelty, its inventive activity (non-obviousness), breadth, disclosure, difficulty in inventing around, and the availability of complementary assets. Equally, it was argued that the volatility is determined by technical, market, and legal uncertainty. Reviewing the empirical literature on patent indicators the paper then presented existing knowledge on how the present value of cash-flows may become subject to an assessment by indicators (that correlate directly with expected cash-flows or operationalize latent value drivers). An overview over the best-known and scientifically validated indicators was presented in 2.2.2.2. Referring to the actual state of the art in assessing patents using indicators from the patent system the article presented the existing shortcomings of current practice as of today, such as the problem of assigning weights to indicators or assigning indicators correctly to the input parameters of a real option valuation. Despite their shortcomings, however, simplistic indicator evaluation as carried out in practice today already provide a value added to the management in various cases. They are especially appealing in scenarios where large portfolios of patents need to be evaluated quickly on a regular basis.

As mentioned before, several future challenges exist for researchers and practitioners seeking to improve existing valuation approaches from a management perspective. Some of the points had already been touched in the section 2.2.3..

Refining indicator evaluations provides challenges to econometricians working with patent data. From an applied point, I would consider research projects "useful" that address the question of how different indicators from the patent system can be validated either as indicators of the present cash-flows of a patent and/or the volatility of the cash-flows.

Extending our empirical knowledge on the validity of certain indicators across industries and patent uses might be another rewarding task for researchers working in the field.

The use for additional indicators accessible from public data sources would be a third task for researchers trying to enhance the power of prediction tools for patent valuations. Here, special attention should be paid to validating indicators that operationalize latent value drivers. With an eye on related future issues (such as IP accounting) it might be especially rewarding to uncover indicator variables that are not endogenous from the perspective of the patent holder.

A fourth issue to be addressed by researchers is the question of valuing synergies between individual patents within portfolios. To the best of my knowledge, as of today most of the portfolio valuation approaches sum up the values of the inherent individual patents (or subgroups of patents). Obviously, in that way synergistic effects between individual patents that have an impact on the portfolio's value as a whole cannot be illustrated.

Along the same line of thought but on a somewhat higher level it may be a crucial (fifth) task to consider potential synergies between different types of intellectual property rights. The value of an individual patent may be significantly affected by the (lack of) support of a strong brand.

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5. Abbreviations

DE	=	German
EP	=	European
EPO	=	European Patent Office
GNP	=	Gross National Product
G3	=	France, Germany, UK
IP	=	Intellectual Property
IPC	=	International Patent Classification
PCT	=	Patent Cooperation Treaty
R&D	=	Research and Development
UK	=	United Kingdom
US	=	United States of America