Available online at www.sciencedirect.com
ScienceDirect
Int. J. Production Economics 105 (2007) 282–292
international journal of production economics
www.elsevier.com/locate/ijpe

Valuing patents on cost-reducing technology: A case study

Sander van Triest[a,*], Wim Vis[b]

[a]Department of Accounting, Universiteit van Amsterdam Business School, Room E2.77, Roetersstraat 11, 1018 WB Amsterdam, The Netherlands
[b]Department of Finance and Accounting, University of Twente, P.O. Box 217, 7500 AE Enschede, The Netherlands

Received 11 August 2005; accepted 20 April 2006
Available online 19 June 2006

Abstract

We present an approach for valuing patents on production process improvements. Specifically, we focus on valuing a patent on cost-reducing process improvements from the viewpoint of the patent holding firm. We do this by considering the relevant cash flows that result from owning the patent. The patent value is determined by (1) licensing fees and royalty income, (2) competitive advantage resulting from the patent, (3) patent maintenance costs. We discuss a case study that presents the difficulties and challenges in finding the relevant information that is needed to estimate the cash flows. We show that valuation of patents on production process improvements cannot be done without good knowledge of technology, markets and competitors.

Keywords: Patents; Patent valuation; Discounted cash flows; Case study

1. Introduction

A patent is an exclusion right. In return for disclosing the patented technology or invention, the patent owner is the only one who may use the technology or invention during the patent life. This exclusion right can be valuable, as is clear in for example the pharmaceuticals industry. A patent right on an effective medicine can generate large amounts of cash flows for the patent owner. The patent results in a monopoly position, which generates extra cash flows from higher unit sales and higher prices relative to selling the medicine in a competitive market.

However, most patents cover only a part of a product or service, and more often only a small part of a production process. Rather than conferring monopoly rights on products on a firm, they exclude others from implementing a substantial but limited feature in a product, or from using a specific process step. These exclusion rights can also be valuable. For example, in September 2004, Nikon and ASML, two producers of lithography systems used by firms such as Intel to produce computer chips, settled several patent litigation procedures. Nikon and ASML accused each other of infringing the other's patents with respect to several different aspects of their systems. The settlement called for ASML (and its main supplier) to pay Nikon a total of € 119 million.

In this paper, we present an approach to valuing patents on cost-reducing process technology. These

*Corresponding author. Tel.: +31 20 525 4163.
E-mail address: s.p.vantriest@uva.nl (S. van Triest).

0925-5273/$ - see front matter © 2006 Elsevier B.V. All rights reserved.
doi:10.1016/j.ijpe.2006.04.019

patents do not lead to monopoly positions, nor to a competitive advantage because of enhanced product quality, but they can lead to lower product costs. We focus on the practical difficulties in establishing the value of individual cost-reducing patents. The valuation of patents on such process steps is not well documented in the literature. Whereas the literature often takes an econometric approach, deriving patent values from proxies such as renewal fees and litigation costs, we discuss a case study of a single patent (portfolio) held by a chemical firm. We identify the nature and the sources of the information that is needed to value patents, as well as the discretionary choices a firm has to make in establishing and realizing patent value. Thus, we show that the patent valuation process at the firm level requires in-depth knowledge of technology, markets, and competitors, and that there is no quick fix for performing such valuations.

Valuing patents on production process improvements is useful for a number of reasons. First of all, a firm has to decide each year whether it should renew the patents, which requires yearly fees. As such, it is an operational decision. Also, patents are part of the intellectual capital of the firm. Financial reporting on intellectual capital is becoming more important, and is required in drawing up balance sheets of business combinations that result from mergers or acquisitions. In the United States, firms that donate patents to universities are allowed to deduct the value of the patents from their income, thus saving taxes. Finally, the process of patent valuation can help in discovering potential licensing income sources, and in setting the royalty rates or licensing fees.

This article is organized as follows. First, we discuss the cash flow effects of a cost-reducing patent, since all valuation requires estimates of the relevant cash flows. We also review the literature with respect to the theory of valuation, and we discuss operationalizations of patent value that are used in the empirical literature. After that, we discuss the case study, and we finish with the conclusions.

2. Valuing a cost-reducing patent: theory and literature review

2.1. Identifying the relevant cash flows

The value of any asset is equal to the future cash flows that it will generate, corrected for the risk of those cash flows. Thus, the identification of relevant cash flows is the starting point for all valuation issues, and indeed for any financial business decision (e.g. Drury, 2004, Chapter 9). In the case of a patent, we can identify the relevant cash flows by looking at the difference between the situation in which a company owns a certain patent portfolio and the situation in which the company does not own that portfolio: what cash flows will change if the firm would not own the patent? Since we are interested in the value of a cost-reducing patent, we do not have to look for cash flows that originate from unique product features.

The relevant cash flows consist of three types:

(1) *Cash flows due to competitive advantage:* Because of the patent on the cost-reducing technology, the firm operates at a lower cost level than its competitors. It can use this cost advantage to establish price leadership and thus increase its market share. Another option for the firm is to use the extra margin to offer e.g. extra services without lowering its price. A firm taking this approach does change the nature of the product offering, however. Analyzing the cash flows due to competitive advantage is difficult since they result from the patent's impact on the cost level, the price, and the volume.
(2) *Licensing income:*
   (a) *Current licensing fees and royalty rates:* These are current cash flows, which can be attributed directly to the patent.
   (b) *Potential licensing fees and royalty rates:* To adequately establish the value of the patent, it is important to identify remaining licensing opportunities. This is important, since value is a future-oriented construct. It is imperative to examine all licensing opportunities, since they can contribute to the cash flows originating from the patent.
(3) *Maintenance costs of the patent:* The renewal fees that have to be paid to keep the patent valid. This could also include any legal costs in the case of litigation.

Note that the lower cost price level at which the firm operates does not lead to relevant cash flows as such. The cost reductions are due to the technology, not the patent. If the firm would not have patented the technology, but would have developed and applied it, it would also realize the cost savings. Therefore, the cost savings cash flows do not

contribute to the patent value. This also implies that a cost-reducing patent does not create value if it is not licensed, or used to create a competitive advantage. The mere fact that competitors are prohibited from using the patented technology does not lead to extra cash flows for the patent holding firm.

2.2. Valuation

Valuation is straightforward in theory: it has long been established that the value of any asset is equal to the future cash flows that it will generate, corrected for the risk of those cash flows—the discounted cash flow approach or DCF (see any finance textbook, e.g. Brealey and Myers, 2003). In the patent (and technology) valuation literature, a number of valuation methods are presented that are mostly variations on DCF, such as the income approach and market multiples. Also, many rules of thumb are proposed, all of which have in common that they are based on a cash flow-related measure such as profit or royalty revenues, or use market values of comparable assets to come to a value (see Razgaitis (2003) for a practitioner's overview of patent valuation). However, the 'cost approach' is also regularly presented as a valid measure of value, even though this approach focuses on cash *outflows* (costs) instead of cash inflows. Since value equals discounted future cash inflows, it cannot be measured by past cash outflows.

Thus, the relevant literature on valuation is first of all the standard valuation literature to be found in corporate finance textbooks (Brealey and Myers, 2003), management accounting textbooks (Drury, 2004), or practitioner's guides (Copeland et al., 2000). They are all based on the discounted cash flow approach, where the value of a series of n cash flows subject to a discount rate k is calculated as follows:

$$\text{value} = \sum_{i=0}^{n} \frac{\text{cashflow}_i}{(1+k)^i}.$$

It is important to realize that the focus is on future cash flows. This is what makes all valuation difficult. However, it also implies that valuation requires many estimates and assumptions, both with respect to external factors such as market developments and competitor behavior, as well as choices that the patent holding firm is facing (cf. Borgonovo and Peccati, 2006).

The DCF method can be extended using the so-called real options approach to valuation. This approach is often proposed for valuing research and development projects (see e.g. Dixit and Pindyck, 1994). The real options approach allows for flexibility in pursuing or abandoning lines of research, and in the actual application of (patented) technology, since this will generally require irreversible investments. This makes it especially suitable for young patents where there is much uncertainty about the effectiveness and the rewards of the technology. It is important to note that real options analysis is truly an extension to discounted cash flow analysis, in that it requires more information, not different information: next to the expected cash flows, the essential ingredient is the standard deviation (or volatility) of these expected cash flows. The problem then is that patents on specific technology are non-traded assets, implying that there are no market-based estimates of the volatility (e.g. Miller and Bertus, 2005, p. 231). This makes an option-based approach to valuing patents difficult, as it is for most other applications, despite the substantial attention for option-based valuation methods in the literature (e.g. Copeland and Tufano, 2004; Zettl, 2002).[1]

The choice between DCF and a real options approach for valuing a cost-reducing patent is dependent on the extent to which the technology is developed. In this paper, we are studying patents on technology that is already implemented successfully. This implies that there are no substantial investments to be made by the patent holding firm: the technology is applied in existing production processes. Thus, the expected cash flows are not conditional on cash outflows, and a real options approach is not necessary.

2.3. Licensing fees and royalty rates: sharing the benefits of the patented technology

Next to the valuation issues, the cash flows from licensing fees and royalties require attention. Whereas the cash flows from competitive advantage are the result of applying the patented technology,

[1]In a survey on corporate finance practices, Graham and Harvey (2001) report that almost 30% of respondents claimed to regularly use real options analysis. However, the question was worded such that it possibly does not indicate the actual application of quantitative option valuation (respondents were asked to grade on a scale of 0–4 the statement 'We incorporate the "real options" of a project when evaluating it').

the structure of the rewards from sharing the patented technology has to be decided upon by the patent holding firm. If a firm decides to license a technology, it has to make a trade-off between licensing income and lost sales revenue. If the firm licenses its technology, competitors will be able to lower their product costs, and thus their selling price; this will impact the licensing firm's unit sales as well as the unit selling price. The literature on this is summarized by Kamien (1992). The analyses mostly center on patents on cost reducing technology, rather than new products with monopoly value resulting from either a unique product, or from increased quality. The question of interest is then whether the license fee should be in the form of fixed fees or a royalty rate. The literature provides some information on the structure of licensing agreements (see Faulí-Oller and Sandonís (2002) for an overview).

However, the literature is not clear on how to choose the actual level of the royalty rate or the licensing fee. Economic theory is not very helpful in this: while a rational economic agent would be willing to pay up to the total net present value of the cost savings in order to obtain the license, this is not likely to happen in practice. Reasons include continued uncertainty for the licensee about the effects of the new technology (even though this can be accounted for in the net present value calculation through an appropriate discount rate), and information asymmetry between patent holder and licensee, making the latter unsure about the true extent of cost savings. If we look towards the behavioral economics theory, we find a limited analogue in the ultimatum game, where one party has to split up a reward between itself and another party, without the other party having any influence on the distribution. If the receiving party does not accept the proposed distribution, nobody gets anything. This setting also occurs in patent licensing: the reward to be split up is the cost savings, which can be realized only if the patent holder and the licensee agree upon the distribution of the reward. Experimental results from the ultimatum game suggest that the party proposing the split up typically chooses to offer 30–50% to the other party, and the receiving party rejects offers of less than 20% (Camerer and Thaler, 1995). An extension of the ultimatum game includes taking input costs into account, and splitting up the rewards accordingly (e.g. Gantner et al., 2001). The problem then becomes how to value the input of both parties: is the patented technology more important as input than the realized savings? In all, the literature offers little guidance for the actual choice of royalty rates (or licensing fees), neither theoretically nor from empirical data. Any publicly available data consists of royalty rates on sales or lump-sum fees, without any relation to the cost savings that are the reason for licensing (see Razgaitis (2003) for an overview of licensing agreements, rules of thumb, and typical royalty rates on sales that are used in practice).

2.4. Empirical operationalizations of patent value

The empirical literature on patent valuation is dominated by an econometric approach. A substantial part of this literature is based on cash outflows from renewal fees, sometimes in combination with legal costs related to the upholding of patents, while value estimates by respondents through questionnaires are also used. Empirical studies based on cash inflows that are attributable to the patent are rare, however. Typical operationalizations of patent value are:

- *Firm market value:* '… this paper investigates the dynamic relationships among the number of successful patent applications of firms, a measure of the firm's investment in inventive activity (in R&D expenditures), and an indicator of its inventive output (the stock market value of the firm).' (Pakes, 1985, p. 390).
- *Renewal fees:* 'This paper presents and then estimates a model which uses observations of the proportion of different cohorts of patents which are renewed at alternative ages, and the relevant renewal fee schedules, to estimate the distribution of the returns earned from holding patents'. (Pakes, 1986, p. 755).
- *Renewal fees and cost of legal actions to uphold patents:* 'This paper presents quantitative estimates of both the magnitude and the distribution of the private value of the protection received by inventors... The value of protection derives from the additional returns that an inventor is able to capture given that he has a patent on his innovation...' (Lanjouw, 1998, p. 671).
- *Granting of patents:* 'Two factors suggest that the patents granted have a higher value than the ones that are withdrawn or refused ... The search and examination procedures have to confirm that the invention (...) surpasses the skills of a

professional confronting the problem concerned (grant reflects value) ... The exclusive exploitation of the invention induces a potentially higher return (grant generates value).' (Guellec and Van Pottelsberghe de la Potterie, 2000, p. 110).

- *Grading on Likert scales from questionnaires:* 'the propensity to buy the patent on a scale ranging from 1 (no interest, no value) to 7 (superior interest, superior value)...' (Reitzig, 2003, p 18).
- *Profit estimate from interviews:* 'The [profit] flow value estimates were computed from annual sales and profit ratio data multiplied by a correction factor ... To obtain this factor, we asked respondents to estimate the share of total profits that could not have been earned without having ownership of the patent right.' (Harhoff et al., 2003, p. 1349).
- *Opposition to patents:* '... the probability of an opposition is correlated with the value of the valid patent for the patent owner.' (Reitzig, 2004, p. 946).

The patent values estimated in the econometric literature are used to identify the determinants of patent value, such as patent lifetime, novelty, and difficulty to invent around, and to identify indicators of patent value, such as renewal information, backward and forward citations, and legal arguments (see e.g. Reitzig, 2003). Furthermore, the estimated values lead researchers to conclude that there exists a 'patent paradox': the econometric estimates of patent values often are very low, yet firms are patenting their technology more frequently (see e.g. Hall and Ziedonis, 2001).

However, the estimates using econometric approaches do not necessarily coincide with the value of individual patents, or of a portfolio of patents active on a specific process. This is the type of value that needs to be known to make licensing decisions, in performing purchase price allocations, or in case of donating patents to universities in return for a tax write-off. The probability of opposition to a patent, or the probability of granting a patent, will not help in valuing a patent. The estimates from renewal fees provide a lower bound to patent values, but do not take into account possible higher returns to patenting. An exception in the literature is the data set in Harhoff et al. (2003), who use estimates of the value of individual patents by the patent holders (although in another study relying on the same data, Scherer and Harhoff (2000) refer to several other data sets that establish patent values using profit or cash flow data). Accurately estimating the value of individual patents requires identification of all cash flows associated with those patents. These cash flows not only consist of maintenance outflows in the form of renewal fees, but also of inflows as a result of monopoly positions, or production cost advantages.

3. Calculating the value of a cost-reducing patent: a case study in commodities production

As is often the case with valuation problems, the theory is straightforward, yet the actual implementation is difficult. Identifying the required data is not always easy, and actually obtaining them presents even more problems. For example, the potential licensing income can be a major part of the patent value. Estimating this potential requires identifying firms that possibly are interested in the technology, and accurately estimating the benefits that they can achieve from applying this technology. It is clear that this requires in-depth knowledge of markets, competitors, and technology. After all the relevant information is gathered, the actual impact of the patent has to be established. In a differentiated industry, where price and quality are marketing instruments, this requires estimates of the part of the sales that is due to the higher price–quality ratio, either from the lower price or from the increased quality resulting from the patent.

The analysis of patent value is simplified if we consider cost-reducing patents that work on processes producing commodities. For example, the market price of ethylene and propylene behave more like the oil price, in that it is largely independent of the number of producers and the profit margins of these producers. The price is set at the world market, and a single producer will not be able to influence this price. Cost reductions in the exploration of oil provide another setting in which the effects on a firm's cost structure will not influence price or quantity. Thus, cost-reducing patents in commodities production have no cash flows associated with them as a result of competitive advantage, and the value of the patent becomes an analysis of licensing income and maintenance costs. Furthermore, the potential licensing income is determined solely by the effects on the cost structure of potential licensees, since the price and (to a lesser extent) volume are not variables that market participants can set. This allows for a relatively straightforward estimate of patent value.

3.1. Case setting

We present an anonymized case study, performed at ChemCo, a company active in the chemical industry. During a 5-month period, one of the authors worked at the intellectual property department of ChemCo to develop a valuation procedure for patents. This issue had been studied several years before, but this first try did not result in a satisfactory model, and the model was never tested or implemented. With hindsight, the main problem seemed to be that no one outside of the intellectual property department was involved. This led us to broaden the scope of the model to include aspects related to technological and marketing functions within ChemCo. We talked to many employees from these functions: people with knowledge of the technology of the production process, of market behavior, of competitors. Next to this, we used many internal information sources, such as the patent database of ChemCo and reports on the technology and the costs of production processes, but also external sources such as (commercially available) competitor evaluation reports drawn up by third parties.

We studied a patent related to the production of a commodity that is subsequently used in the production of plastics (we denote the commodity Prep, preplastic). The market price for Prep is largely independent from the production and price levels of the producers. Producing Prep can be done using a number of technologies, but the end result is an identical commodity product, so quality is not a competitive issue. Furthermore, since the main input material for producing Prep is an oil-based commodity, all producers are faced with the same cost of raw material. Thus, any effects of the patent can be identified with considerable accuracy. As indicated previously, the problem in valuation is not in the calculations, but in generating the input for the calculations: the relevant cash flows.

3.2. Input data

Ultimately, the information that was needed to perform the valuation was grouped into six categories, but this emerged during the case study and was not clear from the outset. The categories are (1) production process, (2) patent, (3) market, (4) competitors, (5) existing fees, (6) discount rate. We discuss the valuation of the case patent by identifying the type and source of information required in each of these categories.

3.2.1. Production process

We start with describing the actual production process, both in terms of technology as well as physical characteristics such as capacity. ChemCo has a number of plants producing Prep. Production of Prep takes place in a continuous process, which requires substantial investments. There are several different process technologies that can be used in producing Prep; all of ChemCo's plants operate the same technology in the production process.

3.2.2. Patent

The content and the life of the patent have to be described. What is it exactly that the patent covers? What is the nature of the technology that others are prohibited from using? And when can competitors use the technology? ChemCo owns several patent series on its production technology. Of these series, one in particular is important with respect to the production costs of Prep. This patent series covers a specific step, and it leads to a higher yield as well as a longer maintenance interval, thus reducing downtime and maintenance costs. The patent series has a remaining life of several years.

3.2.3. Market

The market analysis is based on input from the marketing department, or from commercially available marketing reports. It has three aspects:

(a) Number of players: In general, the chemical industry has a limited number of large players. In the case of the Prep market, six major production companies (including ChemCo) can be identified. These are the companies that have to be analyzed in detail in the technological analysis.
(b) Market volume expectations: The market for Prep is growing moderately. The marketing department does not think it likely that there will be large shocks in the demand for Prep. The market shares of the large producers are also stable.
(c) Market price expectations: The nature of Prep is such that the market determines the price. As indicated, this implies that there will be no cash flows resulting from competitive advantages. Therefore, there is no need for an estimate of the market price.

3.2.4. Competitors

It is necessary to thoroughly understand the processes that produce the same products with other technologies. One has to know which technologies

are available, as well as the advantages and disadvantages of the different technologies. Patented technology is not easily applied to other processes, that have been developed over the years. Which competitors have a process where the patented technology can be implemented to yield positive results (so cost savings)? Obviously, this is the most difficult part of the valuation process.

Estimating production costs of competitors requires modeling their production processes, by using as much data as possible. Sources of these data can be commercially available reports providing descriptions of market participants, the plants and the technologies they use, and estimates of financial performance. More often, however, it will require an effort by the patent holding firm to model their competitors' processes, using data from the scientific literature and patent filings. The patents have to be quite detailed with respect to key modeling variables such as temperature, pressure, and concentrations. Publicly available environmental permits can offer information on process details. Also, meetings from industry groups and associations can help: competitors have to market their products and processes, and they need to provide basic information on the workings of the technology to do this. Sometimes, firms are actively promoting the licensing opportunities they offer, which will offer even more insight into their processes.

Since modeling a chemical process is quite straightforward for industry experts, only limited data is needed to do this. The result of the technological competitor analysis is that of the five major competitors one company (Company A) operates at a lower cost price, one company (Company B) is actually licensing ChemCo's technology, and the other three are operating at a higher cost price level.

Company A uses patented technology which is completely different from ChemCo's. It leads to a lower cost price, but the difference with ChemCo's cost price is not very large. Certainly, there is no gain for ChemCo in switching to Company A's technology. It would require a whole new plant, since Company A's technology cannot be introduced by modifications of the existing processes.

Company B licenses ChemCo's technology. No technological analysis of Company B is needed.

Company C produces Prep using a substantially different technology. This technology has been operational since before ChemCo developed its patented process. Company C's process to produce Prep is integrated with the production of another chemical product. ChemCo's patented technology cannot be implemented in this integrated process without incurring substantial costs. Thus, Company C is not expected to be interested in licensing ChemCo's technology.

Company D uses a technology that is related to ChemCo's, but with certain differences, probably due to the patent portfolio of ChemCo. From presentations by company D at industry association meetings, ChemCo's technological experts concluded that Company D is facing problems comparable to those ChemCo faced when developing its own technology several years back. The patented technology could be applied to company D's processes with limited switching costs. According to ChemCo's technological experts, there is a possibility that Company D ultimately will achieve a cost price at the same level as ChemCo, but this is not yet clear.

Company E has a production process that is almost identical to ChemCo's process, but the process step to which the patent of ChemCo applies does not perform as well. Company E's cost price could decrease if it used ChemCo's patented technology, and implementation of ChemCo's technology would require little extra costs. It is possible to estimate the savings that company E can realize by using the patented technology. This is not straightforward, since the improved performance that would result will still require adjustments in the process with respect to e.g. the heat balance in the plant, and the volume changes. Nevertheless, a good estimate of the cost savings can be made.

3.2.5. *Existing fees*

The current patent-related cash flows are readily identified. The cash outflows as a result of renewal fees can be estimated accurately. Cash inflows resulting from existing licensing agreements may be subject to more uncertainty if licensing is in the form of royalty rates instead of fixed fees. The licensing income from Company B is the result of a royalty rate on Company B's production. The maintenance costs of renewing the patents can be estimated based on archival data from the past and the known renewal fees.

3.2.6. *Discount rate*

Determining the correct discount rate is difficult. Formally, the discount rate should be based on the

risk associated with the cash flows. The maintenance cash outflows are relatively certain. For the inflows, the riskiness differs per category: fixed fee licensing agreements are less risky than royalty rates, whose risk is comparable to the cash flows resulting from competitive advantage. Potential licensing fees carry the risk of not being agreed upon. However, as an approximation, the firm's cost of capital can be taken (according to Graham and Harvey (2001), this is the rate most used in practice when evaluating project proposals). Therefore, ChemCo's firm wide cost of capital is taken as the discount rate.

3.3. Calculation of patent value

Using the input described above, we can now calculate the patent value. Since there are no cash flows due to competitive advantage, the patent value consists of actual and potential licensing income, minus the maintenance costs. As described in Section 2, these cash flows can be valued using a DCF valuation. The use of a real options approach is not necessary: ChemCo does not need to invest in capital expenditures, since the patented technology is up and running.

With respect to the current cash flows, Company B's royalty payments in year i are estimated to be rb_i, and the renewal fees for the patents per year are m_i. With a remaining life of n years, and a discount rate k, the discounted values of the actual cash flows are

$$RB = \sum_{i=1}^{n} \frac{rb_i}{(1+k)^i}$$

with RB the value of the royalty payments of Company B, and

$$M = \sum_{i=1}^{n} \frac{m_i}{(1+k)^i}$$

with M the value of the maintenance costs. Thus, the current value of the patent series is $RB - M$.

The technological analysis showed that the potential licensees are Company D and E. Because of the substantial differences between their technology and that of Company A, there is no possibility for Company D and E to use Company A's patented technology. Thus, we do not take this option into account in estimating the possible licensing fees. The returns for each company from applying ChemCo's technology are estimated from the savings in operating costs per year minus any switching costs (mainly capital investments to modify the processes). For Company D switching requires a one-time outlay of CD, and the savings in operating costs are sd_i per year. Then the value of the savings by Company D SD are

$$SD = \sum \frac{sd_i}{(1+k)^i} - CD.$$

The same procedure is to be followed for Company E, leading to a value of SE.

As indicated in Section 2.3, there is little guidance in the literature on how to distribute the cost savings over the two parties. The game-theoretic analyses of patent licensing suggest that a fixed-fee contract or an auction of the patent license is optimal, but this does not reflect practice, where royalty rates are prevalent. This can be partly the result of unrealistic assumptions in developing the analytical models. For example, analyzing the setting in which licenses are auctioned requires an identical cost reduction for each licensee (Kamien, 1992; Faulí-Oller and Sandonís, 2002). With the potential licensees of ChemCo, this is not the case. Also, even if the ultimate variable (marginal) cost per unit is the same for Company D and E as it is for ChemCo, there will be substantial capital investments required to implement the technology, and these investments will be much larger for Company D than for Company E.

In practice, the basis for determining a licensing fee (either fixed or in the form of a royalty rate) should be the present value of the relevant cash flows of the licensee: the increased margin because of the cost-reducing technology, minus the required capital investments to implement the technology, as well as any output losses during the switch and the start-up period required to optimize the performance of the processes again. Any ultimate contract is the result of a bargaining process. Practical experience suggests that the rewards for the patent holder will be well below 50%. Razgaitis (2003, p. 152) states that a reward for the patent holder of 25% of cost savings as a general rule 'is widely recognized in the licensing community'. Given that the estimated savings (corrected for investments and other switching costs) for both companies are SD and SE, and their estimated royalty rates are r_D and r_E, we get the following potential value for the patent series of ChemCo: $RB + r_D SD + r_E SE - M$.

We have not discussed taxes explicitly in the analysis. This is because it is not likely that there

will be specific tax-deductible costs associated with the royalty incomes, other than the patent renewal fees: in general, research and development costs are not recorded as assets and depreciated for tax purposes, so they will have been expensed in the past. Thus, the taxable royalty streams will be equal to the cash flows that have been identified. Royalty and licensing income can be treated differently from ordinary income, depending on the country, but in general it is treated as a normal revenue stream. In that case, tax effects can be incorporated using the firm level pre-tax discount rate.

The final question is which value is the correct patent value: should the potential cash flows from licensing be included? This depends on the likelihood of realizing these cash flows. The valuation procedure can stimulate the firm to try and make more licensing deals. If, however, there is no action undertaken to license the technology, the patent value will continue to consist only of the current cash flow streams. The question whether the current or the potential value is the 'true' value of the patent depends on decisions to be made by ChemCo, as well as the potential licensees: if for example Company D chooses to develop its own technology because it believes this will lead to cost prices at the same level as that of ChemCo's technology, the potential licensing value $r_d SD$ will not be realized. Note that it is possible to use the likelihood of realizing the licensing opportunities to come to an expected value for the licensing cash flows, in which case there is a single value for the patent. If we take p_D as the probability of Company D licensing the technology, and p_E the same for Company E, the value of the patent becomes $RB+p_D r_D SD+p_E r_E SE-M$.

3.4. Outcome of patent valuation process

For the patent series of ChemCo, the patent value that was established consisted mostly of current licensing fees. The remaining life of the patent series was such that the potential licensing income was limited. Confidentiality agreements do not allow us to disclose the actual or relative values.[2] However, we can indicate that the renewal fees are negligible (well below 1%) compared to the current and potential licensing values. Ultimately, ChemCo did not pursue the potential licensing opportunities, because of the limited value contained in them. Thus, the patent value consists of the current licensing income minus the maintenance costs. The methodology of estimating potential licensing income is used as an input in other licensing processes. In the case example, the estimated value of savings for Company D times the royalty rate r_D would be ChemCo's starting point in the negotiations on the licensing fee.

Comparisons with other valuation techniques are difficult. There are no suitable rule of thumb approaches available, since the effects of cost-reducing patents are specific for each process, and indeed each competitor. Estimates from a cost approach are not feasible in this case, since the costs involved in developing the patented technology have not been recorded separately. Thus, the only available value is the cost of renewal fees (maintenance costs), as used in the econometric literature. As is clear, this value substantially underestimates the actual patent value.

3.5. Illustrative example

To clarify the calculations, we go through the case setting using hypothetical data. Before doing this, we stress once more that the essential step in valuing cost-reducing patents is the estimation of the potential licensing income, rather than performing the calculations on the cash flows.

The remaining life of the patent series is 10 years. The current licensing agreement with Company B also runs for 10 years, with yearly royalties of $ 10 million. Renewal fees are $ 0.1 million per year. The pre-tax discount rate is 15%.[3] This leads to a value of $ 49.7 million for the current cash flows, consisting of $ 50.2 million in licensing income and $ 0.5 million in renewal costs.

Company D produces at a cost price of 125% of ChemCo's cost price. Yearly production costs of Company D are $ 50 million. Thus, using ChemCo's technology would result in yearly savings of $ 10

[2]ChemCo refused to disclose even relative valuation results, since these reflect its understanding of competitors' processes. Although this is not ideal for the paper, the value that ChemCo attaches to the outcome increases our trust in the methodology and the results from the valuation process.

[3]Formally, the discount rate is determined by the riskiness of the cash flows. Therefore, both the licensing company and the potential licensees will value the savings using the same discount rate. Taking ChemCo's firm wide discount rate can result in distortions. However, the licensees will generally be comparable firms, active in the same sector, so their firm level discount rates will also be comparable.

million. Switching costs will be $ 5 million. If Company D starts licensing now, the value of the cost savings is

$$-5+\sum_{i=1}^{10}\frac{10}{1.15^i}=45.2.$$

The distribution of the cost savings follows the 25% rule of Razgaitis (2003). Since Company D is still developing its technology, the probability of licensing to Company D is not very high: it is estimated at 30%. This leads to a value of .3 * .25 * $ 45.2 million = $ 3.4 million.

Company E produces at a cost price of 115% of ChemCo' cost price with yearly production costs of $ 60 million. Applying ChemCo's technology leads to a cost reduction of $ 7.8 million per year. Switching costs will be $ 1 million. If licensing would start now, Company E's savings have a value of $ 38.3 million. Since Company E's process is almost identical and switching costs are limited, the probability of licensing is set at 80%. With a reward of 25% of the savings, the value is .8 * .25 * $ 38.3 million = $ 7.7 million.

Thus, in this example, the patent value is 50.2 + 3.4 + 7.7 − .5 = $ 60.8 million.

4. Conclusion

We have presented a general model for valuing cost-reducing patents using a relevant cash flow approach. This approach leads to the economic value of a patent for the patent holding firm. Rather than taking indicators of patent values from the econometric literature, we suggest identifying the actual cash flows that can be attributed to the fact that a firm has a patent. The valuation process requires input from six categories: (1) production process, (2) patent, (3) market, (4) competitors, (5) existing fees, (6) discount rate. Of these, estimating the market development and especially analyzing competitors' technology and cost prices are the most difficult steps in the valuation procedure.

Our case study shows that there is no easy way of valuing patents. The problems involved in patent valuation are similar to those in any valuation exercise. For example, in firm valuation, analysts spend considerable time on getting to know and understand companies, in order to make a reasonable and informed estimate of the firm value. Patent valuation also requires detailed input, and detailed knowledge of markets and technology. An extra complication is that it is difficult to perform without competitors' proprietary data on e.g. cost prices.

Furthermore, it should be realized that cost-reducing patents as such do not add value to a firm. The benefits of applying the patented technology accrue to the firm because of the technology, not the patent. There is no gain (certainly no direct gain) of 'hurting' your competitor by forcing him to produce at a higher cost price. If a firm wants to create value from its patents on commodities processes, it is essential to license. The analysis would be different if the cost savings could be used to change prices or price-quality ratios, and thus change the competitive relationships.

Acknowledgment

The authors thank the anonymous reviewers and Marc Wouters for helpful comments.

References

Borgonovo, E., Peccati, L., 2006. The importance of assumptions in investment evaluation. International Journal of Production Economics 101, 298–311.

Brealey, R.A., Myers, S.C., 2003. Principles of Corporate Finance, seventh ed. McGraw-Hill, Boston.

Camerer, C., Thaler, R.H., 1995. Anomalies: Ultimatums, dictators and manners. Journal of Economic Perspectives 9 (2), 209–219.

Copeland, T., Tufano, P., 2004. A real-world way to manage real options. Harvard Business Review 80 (3), 90–99.

Copeland, T.E., Koller, T., Murrin, J., 2000. Valuation: Measuring and Managing the Value of Companies, third ed. Wiley, New York.

Dixit, A.K., Pindyck, R.S., 1994. Investment under uncertainty. Princeton University Press, Princeton.

Drury, C., 2004. Management and Cost Accounting, sixth ed. Thomson, London.

Faulí-Oller, R., Sandonís, J., 2002. Welfare reducing licensing. Games and Economic Behavior 41, 192–205.

Gantner, A., Güth, W., Königstein, M., 2001. Equitable choices in bargaining games with joint production. Journal of Economic Behavior & Organization 46, 209–225.

Graham, J.R., Harvey, C.R., 2001. The theory and practice of corporate finance: evidence from the field. Journal of Financial Economics 60 (2-3), 187–243.

Guellec, D., van Pottelsberghe de la Potterie, B., 2002. Applications, grants and the value of patent. Economics Letters 69, 109–114.

Hall, B.H., Ziedonis, R.H., 2001. The patent paradox revisited: An empirical study of patenting in the U.S. semiconductor industry, 1979–1995. RAND Journal of Economics 32 (1), 101–128.

Harhoff, D., Scherer, F.M., Vopel, K., 2003. Citations, family size, opposition and the value of patent rights. Research Policy 32, 1343–1363.

Kamien, M.I., 1992. Patent licensing. In: Aumann, R.J., Hart, S. (Eds.), Handbook of game theory, vol. 1. North-Holland, Amsterdam, pp. 331–354.

Lanjouw, J.O., 1998. Patent protection in the shadow of infringement: Simulation estimations of patent value. Review of Economic Studies 65, 671–710.

Miller, L., Bertus, M., 2005. License valuations in the aerospace industry: A real options approach, Review of Financial Economics 14, 225–239.

Pakes, A., 1985. On patents, R&D, and the stock market rate of return. Journal of Political Economy 93 (2), 390–409.

Pakes, A., 1986. Patents as options: some estimates of the value of holding European patent stocks. Econometrica 54 (4), 755–784.

Razgaitis, R., 2003. Valuation and Pricing of Technology-based Intellectual Property. Wiley, New York.

Reitzig, M., 2003. What determines patent value? Insight from the semiconductor industry. Research Policy 32, 13–26.

Reitzig, M., 2004. Improving patent valuations for management purposes—validating new indicators by analyzing application rationales. Research Policy 33, 939–957.

Scherer, F.M., Harhoff, D., 2000. Technology policy for a world of skew-distributed outcomes. Research Policy 29, 559–566.

Zettl, M., 2002. Valuing exploration and production projects by means of option pricing theory. International Journal of Production Economics 78, 109–116.