MODERN METHODS

FOR THE VALUATION

OF INTELLECTUAL PROPERTY

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MODERN METHODS FOR THE VALUATION OF INTELLECTUAL PROPERTY

I. INTRODUCTION

It is tempting to imagine that ownership of a patent automatically leads to riches. The chain of reasoning that sometimes misleads people to this conclusion is: "Patent=Monopoly; Monopoly=Riches; therefore, Patent=Riches." Unfortunately, for the patent owner, having a patented product or process doesn't automatically guarantee that the patent will have market value. Even a monopolist has to be able to sell his product in order to get rich from it.

Ultimately, market forces determine economic value. This is as true in markets for technology as it is in markets for goods and services. Market value in a goods market comes from the demand-fulfilling characteristics of the product. Similarly, in a technology market, it is the demand-fulfilling (or cost-saving) characteristics of the innovation that create the economic value of the innovation.

A further important determinant of economic value is the availability of economic substitutes. When we think of a valuable good in a product market we generally think of one with few close substitutes. The same condition is necessary for high value in the market for production processes. This does not necessarily equate to the so-called "monopoly" granted by ownership of a patent. A patent for a technologically novel mousetrap may give the inventor a right to exclude others from making a similar mousetrap. It does not, however, imply a monopoly in any meaningful economic sense. This is because the new mousetrap will likely compete with older, unpatented designs. People will only pay extra for features deemed to be more desirable than those available in unpatented mousetraps. Likewise, a process patent may give the inventor the right to be the sole user of a particular production process but if there are other economically equivalent processes, and if the patent doesn't substantially reduce the costs of production compared to the next best alternative, the patent will have little economic value.

A patent can sometimes enable a firm to exclude rivals. When a patent prevents competitors from entering a market, it can literally confer monopoly power upon the owner. Such situations, however, are rare. More common is the circumstance where a variety of technical alternatives exist in competition with one another. This can apply to both product and process innovations. Similarly, even in circumstances where there are no clear **technical** substitutes for a product or process, technologically diverse **economic** substitutes may undermine a patent's potential for creating market power. It is a commonplace in the modern economy that technologically dissimilar products or processes serve as close competitive alternatives.

Market power—which means an ability to set price above cost and earn profit greater than the cost of capital invested—stems from an absence of economic substitutes for the patented product or process. For example, a pharmaceutical firm may patent a new chemical entity that is distinctly different from other molecules. If, however, that product treats a condition for which there are many other adequate treatments, the patent is likely to confer little, if any, market power. If, on the other hand the drug treats a condition that heretofore had no cure, then the patent is likely to confer substantial market power. If a patented product has many close economic substitutes, is the patent valueless? Not necessarily: To the extent that the patent allows its owner to produce in the market, albeit at a price that is only slightly above cost, then this weak patent has some slight value. If, alternatively, the patent allows the patentee to just cover its opportunity costs, i.e., setting the price equal to incremental cost, then that patent has no market value. In other words, the patent has no commercial value vis-à-vis the next best alternative product or process.

Some patents confer competitive advantage by keeping a cost saving invention from being imitated. In a competitive market, cost savings will accrue to the patent holder in the form of a higher profit margin or increased market share as a result of being able to price a good below those of competitors. The choice between converting a cost saving advantage into higher unit profitability or increasing sales and market share will depend upon the conditions of demand.

In either case, the patent holder will ultimately obtain economic rents from the exploitation of the cost advantage.

This paper provides an illustration of how familiar methods of asset valuation may be used to value intellectual property. The methods described are routinely used in licensing, transfer pricing and ordinary valuation, as well as in the course of patent infringement litigation. Newer asset valuation methods can also be used to determine the value of intellectual property while it is still in the development stage. This sort of valuation can help a firm determine whether it is worthwhile to continue to invest in an ongoing project.

Part II of this paper describes some recent empirical findings on patent value. Part III then describes widely used methods of valuing a process patent that are often misused. Part IV introduces discounted cash flow analysis to determine the value of intellectual property embedded in a production process. This method directly estimates a manufacturer's maximum willingness to pay for the right to practice a patent by measuring the contribution of the patent to profitability of the final product. Part V considers the issue of the bargaining range in licensing negotiations. Finally, Part VI considers the question of how a research firm should evaluate its investments in R&D. We illustrate how asset valuation methods can be used to help determine whether it is worthwhile to continue to invest in a particular R&D project. By treating an investment in R&D like an investment in a stock option, we are able to adjust the value of continued investment in R&D for the risks associated with R&D.

II. EVIDENCE ON PATENT VALUES

Some recent scholarship sheds light on an important question that ought to precede a consideration of valuation techniques: What do we know about the value of patents generally? We suppose that a patent must be valuable, if for no other reason than that inventors devote time, effort and expense to obtaining patent protection. Nevertheless economists who study such things are remarkably consistent in their opinions that the majority of patents are not worth much and that only a relatively small number of patents are very valuable. The underlying reasons for this rest with considerations of demand and supply such as those discussed in the previous section. Only inventions that fulfill a need that producers or consumers are willing to pay to fulfill can be valuable. Even then, it is also necessary that the need cannot be cheaply met by other means.

Even when there are no close substitutes in the market, patents are not an absolute barrier to entry. Competition—and with competition, the erosion of a patent's value—depends upon the scope of the patent and the ability of others to design around it or to leapfrog it in product or process design.

Empirical studies of patent value generally conclude that only a very few patents yield high returns. In an empirical study dating from 1965, F.M. Scherer found that "…a few outliers accounted for nearly all of the profits. In a sample of 74 patents, only six had profits (or rents) exceeding $1 million."[1]

In 1986, Ariel Pakes estimated the value to the patent holder of maintaining proprietary rights to their patent with data from countries where patent holders must pay an annual renewal fee to maintain their patent.[2] According to Pakes' estimates, the value of the proprietary rights of the patent is typically low. On average 50 percent of patents in France, Germany, and the U.K. have a value that is less than $2,189.[3]

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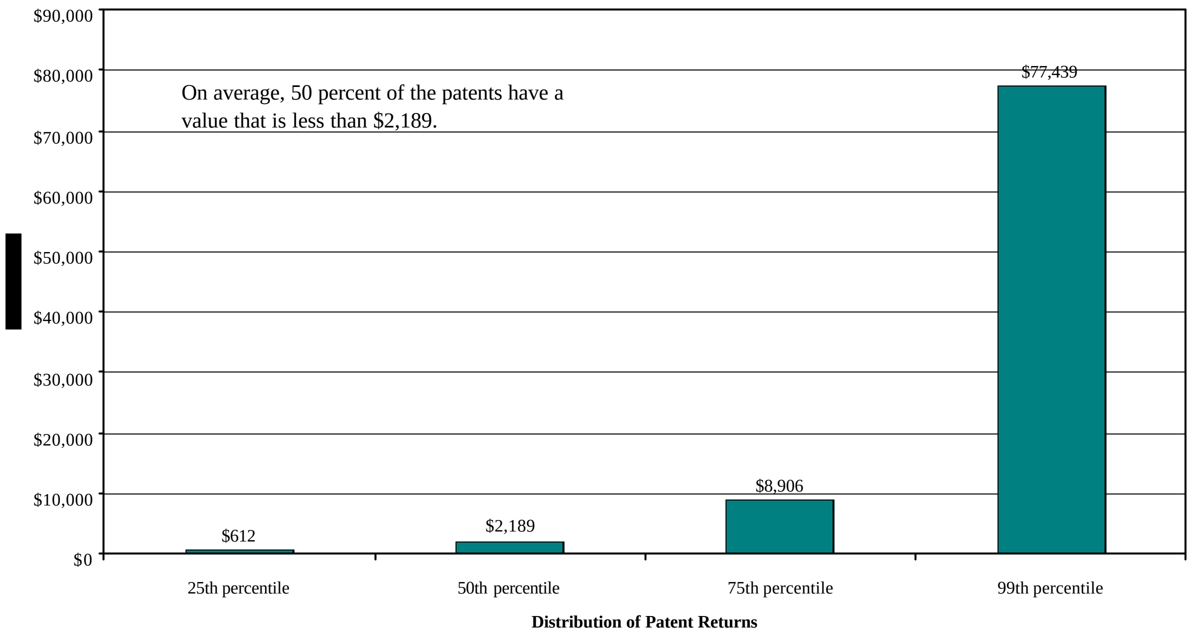
[1] See F. M. Scherer, "Firm Size, Market Structure, Opportunity, and the Output of Patented Inventions," *The American Economic Review*, Vol. LV, No. 5, Part 1 (December 1965) pp. 1097-1125.

[2] Pakes, Ariel (1986). "Patents as Options: Some Estimates of the Value of Holding European Patent Stocks." *Econometrica*, Vol. 54, No. 4, pp. 755-784. July.

[3] Weighted average of the 50 percentile patent value in France, Germany and the U.K. 1980 U.S. dollars.

Figure 1
Most Patents Yield Low Returns



Source: Pakes, Ariel (1986). "Patents as Options: Some Estimates of the Value of Holding European Patent Stocks," in *Econometrica*, Vol. 54, No. 4, p. 777. Values of patent returns are the weighted average of the values obtained for France, Germany and the U.K. Dollar values are $1980.

Pakes also finds that the distribution of patent values is highly skewed. While 99 percent of patents are valued at less then $77,000, this figure is far from representative. Ninety percent of patents have a value that is less than $25,000. Figure One shows the distribution of patent returns presented in Pakes' paper.

In a more recent paper, Mark Schankerman uses patent renewal data from France to estimate the value of patent protection in various technological fields including pharmaceuticals, chemicals, mechanics and electronics.[4] Like Pakes, he concludes that the distribution of the value of patent rights is highly skewed. Schankerman estimates the median patent values across technology fields at $1,631, $1,594, $2,930 and $7,933 for pharmaceuticals, chemicals, mechanical and electronic patents respectively. In Schankerman's sample, pharmaceutical patents have the lowest mean valuation ($4,313) and electronic patents have the highest mean

[4] Schankerman, Mark (1998). "How Valuable is Patent Protection? Estimates by Technology Field," RAND Journal of Economics. Vol. 29, No. 1, p. 94. Spring.

valuation ($68,502). Less than five percent of electronics patents have a value greater than $1 million.[5]

These findings are significant but it is possible to overstate their importance in the context of valuation. While it may be true that most patents have little value, it is also true that worthless patents are unlikely to be the subject of licensing or litigation. There is not much to be said about the value of any specific patent based on inferences from broad averages.

III. CONVENTIONAL VALUATION APPROACHES

A. Profit Splitting

Some conventional methods for intellectual property valuation mistakenly do try to infer specific patent values from broad generalizations. This is hard to justify either in theory or by empirical means. For example, in his "Litigation Backgrounder for Licensing," Robert Goldscheider proposes that in determining the value of an infringed technology, 25 percent of the realized profit from sales should be credited to the invention. The infringer would retain 75 percent of the profits based on the reasoning that "they assumed the greater risk in these operations, inasmuch as they had made substantial investments in plant and machinery, and faced vigorous competition from companies selling similar products."[6] For products with gross profits in the range of 30 to 40 percent, the 25 percent rule would yield running royalty rates of 7.5 to 10 percent.

This profit-splitting rule-of-thumb for assigning a value to an invention does not take into account what we know about the distribution of patent values. The so-called "LES method"

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[5] All values in 1980 U.S. dollars.

[6] Goldscheider, Robert (1994). "Litigation Backgrounder for Licensing," in *les Nouvelles*. Vol. 29, No 1. March, p. 25.

and others like it assign the same relative importance to any patent, failing to consider the number or value of economic alternatives or the incremental value of using the patented technology over other viable alternatives. The profit splitting rule also has the peculiar feature of requiring a low-cost producer to pay more for a particular patent than a competing producer with higher costs even if the patented technology is not related to the difference in production costs.

In addition to the methodological problems with a profit splitting rule, the proposed 25 - 75 percent split seems generous in light of a perhaps equally suspect generalization—this time from a survey reported by Degnan and Horton. The respondents to the Degnan-Horton survey indicated that they would be willing to pay no more than 15 percent of gross profits even for a license to a product or service that yields more than 80 percent gross profits. If the gross profit ratio were less than 60 percent, the licensees would only be willing to pay a royalty rate equal to10 percent of gross profits.[7]

The authors also list the willingness to pay of survey respondents for cost-saving technologies. Forty-four percent of the respondents indicated that they would only pay between 1 and 10 percent of the costs saved for the invention. An additional 44 percent of respondents indicated that they would be willing to pay between 11 and 25 percent of the cost saved for the invention. Since the saved costs will only be a portion of total profits, even paying 25 percent of costs saved will be less than 25 percent of total profits. This means that 88 percent of the

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[7] Degnan, Stephen A. and Corwin Horton (1997). "A Survey of Licensed Royalties," in *les Nouvelles*. June, p. 95. In their survey of 428 members of the Licensing Executives Society, Degnan and Horton asked respondents to rank the patents they had licensed on an "innovativeness scale" and indicate the royalty rate paid for the patent. "Revolutionary patents earned running royalty rates between 7 and 13 percent on average. Patents representing "major improvements" earned running royalty rates between 4 and 8 percent on average and patents representing "minor improvements" earned rates between 2 and 5 percent on average.

It should be noted that the authors rightly recognize that "reducing this data to generalized ranges is a further dilution of it" and that "the relevance of a prior negotiation…depends crucially on the comparability of the issues and the economics."

respondents to this survey would be unwilling to pay 25 percent of total profits for a process license.

These generalizations should be classed in the category of nearly worthless information alongside the following:

1) The average annual wage of a professional baseball player is X.

2) The typical American corporation has assets of Y.

It's not worth the effort to find out what either of these two numbers actually is. X and Y stand for the averages of distributions with wide dispersions. The average wage of a baseball player doesn't tell you much useful about the wage of any particular player because the distribution of players consists of many at the lower and middle ranges and a few superstar multimillionaires. The same is true of the assets of American corporations. Trying to apply industry averages or rules of thumb to particular patents can lead to errors of great magnitude for exactly these reasons.

B. Comparison to Another Technology

A second, more sensible, conventional method of valuing intellectual property is through the use of comparables. A "comparable" technology is one that is used in the same industry, performs a similar service or function, and is of similar importance to the final product being sold as the intellectual property we are trying to value. An approximation to the value of the intellectual property at issue is the royalty paid for the comparable technology (adjusted for any substantive differences between the two).

A drawback to the use of comparables is that even if an appropriate benchmark technology can be found, the license for the benchmark will have been negotiated under different economic circumstances than currently exist. Market conditions including the demand for the final product and the number of close substitutes may have changed since the benchmark license was negotiated. We would expect there to be differences between the buyers of the intellectual property at issue and the buyers of the benchmark intellectual property. Differences in their willingness or ability to pay for a license will influence the outcome of a royalty negotiation.

IV. DISCOUNTED CASH FLOW ANALYSIS

The value of an intangible asset such as a technology covered by a patent is the lump-sum, present value of the future income stream associated with the product or process. This income stream is simply the sum of annual net profit from the use of the asset, discounted to present value. In the case of a cost-saving process patent, the extra profit arising from the saving of costs is the basis of the patent's value. For a patented product, the incremental profitability of making and selling the product are the basis of value.

A fundamental method of determining the value of a patent that accounts for the actual contribution of the intellectual property to the profitability of the product is the discounted cash flow method. This method is used for valuation of all types of income producing assets. The discounted cash flow method evaluates the future stream of revenue net of the relevant incremental costs from using the intellectual property, and compares that to the present discounted value of cash flow from using the next best alternative. This yields the maximum royalty that a manufacturer would be willing to pay for the right to use the patented technology.

Suppose that we are considering the value of intellectual property embedded in a newly discovered production process for a popular consumer product. The value of the intellectual property comprising the new technology is equal to the increase in profits that could be gained in manufacturing using the new technology compared with manufacturing using the old technology. The value therefore depends not only on the profits generated by the final product but also on the alternative production methods that are available to the manufacturer.

Table One illustrates an example of using the discounted cash flow method to value a process patent. The first panel of the table shows the net present value of sales revenues that the manufacturer can earn from selling his product. Over the next 10 years, the manufacturer expects to make over $200 million dollars in sales. In order to produce at all, however, the manufacturer needs access to a production technology. Alternative One on Table One shows the manufacturer's discounted cash flow if the manufacturer chooses to use the currently available "tried and true" technology. This "tried and true" technology is available by paying a royalty rate to the patent owner equal to 2.5 percent of net sales. Using this technology and paying a 2.5 percent royalty rate, the manufacturer's net cash flow is $24 million dollars.

Once the "new-improved" technology has been invented, the manufacturer has the option of sticking with the tried-and-true technology or switching to the new-improved method. The new improved technology lowers the manufacturer's costs of production. We want to know the value of the new, efficiency-enhancing methodology to the manufacturer. This value will tell us the maximum amount the manufacturer would be willing to pay for a license to use the technology.

Table 1
Discounted Cash Flow Analysis
($ Thousands)

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Expected Sales Revenues										
Expected Sales (Thousands of Units)	45,000	50,000	55,000	60,000	62,000	64,000	65,000	65,000	65,000	65,000
Expected Price	$ 0.53	$ 0.55	$ 0.56	$ 0.58	$ 0.60	$ 0.61	$ 0.63	$ 0.65	$ 0.67	$ 0.69
Expected Revenues (Thousand Dollars)	$ 23,850	$ 27,295	$ 30,925	$ 34,749	$ 36,984	$ 39,323	$ 41,135	$ 42,369	$ 43,640	$ 44,949
Discount Factor	1.00	0.88	0.78	0.69	0.61	0.54	0.48	0.43	0.38	0.33
Discounted Value of Sales	$ 23,850	$ 24,155	$ 24,219	$ 24,083	$ 22,683	$ 21,343	$ 19,758	$ 18,009	$ 16,416	$ 14,963
Net Present Value of Sales	**$ 209,478**									
Alternative One: Licensing the "Tried and True" Technology										
Expected Revenues	$ 23,850	$ 27,295	$ 30,925	$ 34,749	$ 36,984	$ 39,323	$ 41,135	$ 42,369	$ 43,640	$ 44,949
Costs of Production										
Royalty Payments	$ 596	$ 682	$ 773	$ 869	$ 925	$ 983	$ 1,028	$ 1,059	$ 1,091	$ 1,124
Physical Production Costs	$ 20,511	$ 23,474	$ 26,596	$ 29,884	$ 31,806	$ 33,817	$ 35,376	$ 36,437	$ 37,531	$ 38,657
Total Expected Costs	$ 21,107	$ 24,156	$ 27,369	$ 30,753	$ 32,731	$ 34,800	$ 36,405	$ 37,497	$ 38,622	$ 39,780
Net Cash Flow	$ 2,743	$ 3,139	$ 3,556	$ 3,996	$ 4,253	$ 4,522	$ 4,731	$ 4,872	$ 5,019	$ 5,169
Discount Factor	1.00	0.88	0.78	0.69	0.61	0.54	0.48	0.43	0.38	0.33
Discounted Value of Cash Flow	$ 2,743	$ 2,778	$ 2,785	$ 2,769	$ 2,609	$ 2,454	$ 2,272	$ 2,071	$ 1,888	$ 1,721
Total Net Present Value of Option One	**$ 24,090**									
Alternative Two: Licensing the "New-Improved" Technology										
Expected Revenues	$ 23,850	$ 27,295	$ 30,925	$ 34,749	$ 36,984	$ 39,323	$ 41,135	$ 42,369	$ 43,640	$ 44,949
Costs of Production										
Royalty Payments	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Physical Production Costs	$ 20,273	$ 23,201	$ 26,286	$ 29,536	$ 31,437	$ 33,424	$ 34,965	$ 36,014	$ 37,094	$ 38,207
Total Expected Costs	$ 20,273	$ 23,201	$ 26,286	$ 29,536	$ 31,437	$ 33,424	$ 34,965	$ 36,014	$ 37,094	$ 38,207
Net Cash Flow	$ 3,578	$ 4,094	$ 4,639	$ 5,212	$ 5,548	$ 5,898	$ 6,170	$ 6,355	$ 6,546	$ 6,742
Discount Factor	1.00	0.88	0.78	0.69	0.61	0.54	0.48	0.43	0.38	0.33
Discounted Value of Cash Flow	$ 3,578	$ 3,623	$ 3,633	$ 3,612	$ 3,402	$ 3,201	$ 2,964	$ 2,701	$ 2,462	$ 2,244
Total Net Present Value of Option Two	**$ 31,422**									

Alternative Two demonstrates that by using the new-improved technology the manufacturer's net discounted cash flow could be $31 million if the manufacturer did not have to pay any royalty rates.

Table Two calculates the maximum royalty rate the manufacturer would be willing to pay for a technology that at the most, could yield him $31 million in profits. The true value of the technology to the manufacturer is the difference between what he can earn using the new technology and what he could earn by using the next-best alternative. The incremental value of the new technology is approximately $7 million. This means that the maximum value of the new technology to the manufacturer is $7 million or 3.5 percent of net sales. This is the maximum because at higher royalty rates, the manufacturer would earn higher profits using the old technology. The maximum willingness to pay for the new technology is bound by the existence of a viable alternative.

Table 2
Hypothetical Discounted Cash Flow Analysis

A. **Net Present Value of Cash Flow From New Intellectual Property:**	**$31,421,760**
B. **Net Present Value of Cash Flow From Next Best Alternative:**	**$24,090,016**
C. **Net Present Value From Using the New Intellectual Property minus Net Present Value From the Alternative: (A-B)**	**$7,331,744**
D. **Net Present Value of Sales:**	**$209,478,401**
E. **Royalty Rate that Extracts the Maximum Willingness to Pay of the Licensee: (C/D)**	**3.5%**

Table Three illustrates what happens to the value of the new technology if there is no viable alternative. In this case, the manufacturer’s only choices are to produce using the new technology or not to produce at all. Here the incremental value of the patented technology is the total profits earned in this industry. The manufacturer would be willing to pay up to $31 million (or 15 percent of net sales) for access to the technology. Of course a 15 percent royalty rate would leave the manufacturer with zero operating profits, so while it represents the full value of the technology to the manufacturer, it is unlikely that he would be willing to pay this amount.

Table 3
Hypothetical Discounted Cash Flow Analysis

The Importance of Available Substitutes

	Acceptable Alternative	No Acceptable Alternative
A. **Net Present Value of Cash Flow From New Intellectual Property:**	**$31,421,760**	**$31,421,760**
B. **Net Present Value of Cash Flow From Next Best Alternative:**	**$24,090,016**	**$0**
C. **Net Present Value From Using the New Intellectual Property minus Net Present Value From the Alternative: (A-B)**	**$7,331,744**	**$31,421,760**
D. **Net Present Value of Sales:**	**$209,478,401**	**$209,478,401**
E. **Royalty Rate that Extracts the Maximum Willingness to Pay of the Licensee: (C/D)**	**3.5%**	**15.0%**

The discount rate used to bring an income stream to present value is also an important factor in the valuation process. A high discount rate reduces the value of the asset by reducing the present value of future cash flows. A low discount rate has the opposite effect. The right discount rate is the rate of return appropriate to the expected risk of the enterprise employing the asset.

V. WILLINGNESS TO PAY AND WILLINGNESS TO SELL

The discounted cash flow method allows us to measure the full incremental value of a patented technology to a licensee but if the licensee were actually required to pay the full value of the technology for the right to use it, he would be no better off than he was before the technology was invented. Most licensing negotiations will involve "gains from trade" to both the licensee and the licensor. That is, the licensor and the licensee can usually agree on a royalty rate that leaves the licensee better off for using the new technology and leaves the licensor better off for having licensed the technology. Unless there are many manufacturers competing for the right to an exclusive license for the new technology, it is unlikely that a negotiated royalty rate would be at the licensee's maximum willingness to pay. It is possible though, that there could be no price that the licensee would be willing to pay and the licensor would be willing to accept. Some licensing deals never happen for that simple reason.

In the example in the previous section, suppose a manufacturer with a viable alternative is only willing to pay up to 3.5 percent of sales ($7 million) for an improved technology, even though his total profits from manufacturing using the improved technology are $31 million (15 percent of sales). How do we know whether or not the owner of the intellectual property would be willing to license the technology for maximum royalty earnings of $7 million? The purchaser of a technology evaluates all of his alternatives and is willing to pay, at most, the incremental value of the technology over his next best alternative. Similarly, the seller of the technology will evaluate his alternatives and be willing to accept any payment that is at least as high as his next best selling alternative.

Among the options available to the technology owner are: maintaining his unique right to use his patented technology; licensing a competitor to practice the patent as well as using the technology to produce himself; or, if the technology owner is an inventor but not a manufacturer, she can license the technology to the highest bidder.

In the last case, where the licensor is not also a manufacturer, it is likely that the licensor would be willing to accept the royalty rate offered by the highest bidder. The costs of developing the patent are in the past, and since she can make no use of the patent herself, she is better off licensing the technology to anyone who is willing to pay for it. Her cost of licensing to one party is the opportunity cost of licensing to another. If many firms are competing for the right to manufacture using the new technology, it is likely that the patent owner will be able to sell his technology for the highest possible price of $7 million in the example above.

If there is only one firm which can really make any use of the technology, then that firm will also have some bargaining power and it is unlikely that the patent owner will be able to extract the manufacturers' full willingness to pay. The manufacturer knows that if he refuses to purchase the technology, the patent owner has no one else to whom he can turn to sell his invention. In this case, the final selling price of the technology isn't easily predicted. The bargaining range is set by the manufacturer's maximum willingness to pay and the technology owner's minimum acceptable selling price. Any royalty rate within this range leaves both parties better off.

Suppose though, that the owner of the patent is also a manufacturer. In this case, if he licenses his technology to other manufacturers, he is helping a competitor. Even though the licensee might be willing to pay up to $7 million, the technology owner would not be willing to license his technology for this amount. If the technology owner licenses a competitor, it is likely that he will lose some sales to the competitor that he would have been able to make profitably himself. These lost profits represent a cost to the licensor of licensing his technology. If the costs of licensing (lost profits) are greater than the benefits (the willingness to pay of the other manufacturer), the technology owner may not be willing to license his technology at any price that another competitor is willing to pay. In this instance we say that there is no bargaining range. There is no royalty rate that the licensee is willing to pay and the licensor is willing to accept.

To recapitulate:

- Ordinary discounted cash flow analysis is the clearest window on intellectual property valuation available. It is a means for finding the opportunity cost of not using an invention by measuring the profit consequences of defaulting to the next best alternative.
- DCF describes the gains from licensing a technology—it doesn't go to the sharing of the gains between the licensor and the licensee, however.
- If there are gains from trade, then bargaining power—not industry rules of thumb—will determine the sharing of these gains. Bargaining power, briefly stated, is the ability to hurt your counterparty by walking away from the negotiating table.

VI. Option Value Method

The discounted cash flow method is useful in determining the value of intellectual property once it has been invented. A remaining question of interest is: How would an R&D-based firm determine the value of a new technology that it is still in the process of developing? The cost-saving or demand-fulfilling characteristics of the technology have yet to be fully determined. In addition, it may be many years before any product is brought to market and market conditions could change considerably in the time that it takes to develop a new technology or invent a new product. Knowing the likely value of the technology would help the firm decide whether or not it was worthwhile to continue the development project.

The discounted cash flow analysis outlined above assumes that future earnings arise from decisions already taken. It assumes that no managerial volition is involved in bringing the project to its conclusion. This contrasts with many real world situations where projects characteristically involve a series of "go-no-go" decisions along the way. For R&D-based firms in particular, projects in the early stages of their lifecycle may be thought of as options.

Investor choice about whether to proceed with a project is akin to the decision about whether to buy an option. Because it is typically costly to proceed with a project, the decision involves comparing the net expected gains from proceeding with the savings associated with terminating the project (or not exercising the option). As good textbooks in corporate finance teach, many projects involving managerial decisions may properly be viewed as options.[8]

Investing in R&D is like buying an option to market an as-yet-to-be-developed product. The purchase price of the option is the amount the investor must pay today in order to continue the research. The value of the option is the discounted profit stream the investor expects to receive once he can use or sell his technology. As long as the value of the option exceeds the purchase price, the investor should continue to invest in R&D. If the current price of investing in R&D exceeds the likely value of the technology, the investor should abandon that project and devote his research funds to different projects. When the development of a particular product or technology is expected to take several years, the firm can perform this valuation at decision points about funding. With the passage of time the firm will have more information regarding future market conditions and the likely costs of completing the development of the product. The firm can use this new information to update its analysis of the likely value of the R&D.

Investment in R&D can be evaluated in nearly the same manner as one would evaluate a stock option in the stock market. An investment in R&D is conceptually similar to purchasing an option to sell a product at some point in the future. If the firm decides not to continue the R&D, it has lost the option of eventually selling a marketable product. If it continues to invest in R&D, it has maintained the option of seeing the product through to development or at the

[8] Brealey, Richard A., Myers, Stewart C. (1996). *Principles of Corporate Finance*, McGraw-Hill., Chapter 21, pp. 589-610.

very least, keeping the project going for another year, during which it will have gained more information of the likely costs and benefits of continuing development.

A. Valuing a Stock Option

The method by which one values a stock option is familiar but we will include an example here to build upon in the discussion that follows. Suppose we were going to evaluate a call option: the option to buy one share of stock one year from today. In order to determine the value of the option we would consider the price of buying the option, the exercise value of the option (the strike price) and the current price of the stock. Table Four outlines the elements that we would consider in evaluating an option. Since we would only exercise the option if the price of the stock rose above the strike price, the option only has value when the future price of the stock is higher than the strike price of the option. If that were the case we would exercise the option, buy the stock at the strike price and resell it at the (higher) market price of the stock. We are better off as long as the difference between the market price of the stock and the strike price of the option exceeds what we originally paid for the option.

Table 4

Option Valuation

Evaluating an Option to Buy One Share of Stock One Year from Today

Option Price	$1.00
Strike Price	$11.00
Current Price	$10.00

Example 1. Low Spread of Returns (low volatility)

				Expected Price of Stock
Potential Stock Prices in one year:	$7.50	or	$12.50	$10.00
Probability of Each Price:	50%		50%	
				Expected Value of Option
Potential Value of Option in one year:	$0.00		$1.50	**$0.75**

Since the expected value of the option is less than the price: ⇒ Do Not Buy Option

Example 2. High Spread of Returns (high volatility)

				Expected Price of Stock
Potential Stock Prices in one year:	$5.00	or	$15.00	$10.00
Probability of Each Price:	50%		50%	
				Expected Value of Option
Potential Value of Option in one year:	$0.00		$4.00	**$2.00**

Since the expected value of the option is greater than the price: ⇒ Buy Option

Moral of the Story: The value of the option depends on the volatility of share prices

Since it is not possible to know with certainty what the future price of the stock will be, the simplified example we are using requires some hypothetical knowledge of all possible future prices and the likelihood of any particular price occurring. Example One in Table Four calculates the value of the option if there are only two possibilities for the future price of the stock. The value of the stock can go up or it can go down. Furthermore, it can only increase or decrease by a constant proportion (25% in Example One). We also assume that there is an equal probability either happening. In this example, we would only choose to exercise the option if the stock price increases to $12.50. At that price we would exercise our option to buy the stock at $11.00 and we would have made $1.50 (or $0.50 after considering the purchase price of the option).

However, we have to consider that there is only a 50% chance that the stock increases to a price at which we would want to exercise the option. There is also a 50% chance that the price will fall and we would be stuck with a worthless option. Since there is only a 50% chance of the option having a value to us of $1.50 and a 50% chance of the option having no value, the *expected value* of the option is only $0.75. Since the current purchase price of the option is higher than the expected payoff value, we would not choose to purchase this particular option.

Suppose though we were to consider a similar option with a greater volatility of stock prices. Example Two illustrates a similar option to that in Example One but now there is greater volatility in the future stock price. Where before the stock could only increase or decrease by 25%, now the price could increase or decrease by 50%. By following the same logic as outlined above, the expected value of the option is now $2.00. Since the expected payoff is greater than the purchase price we would buy the option.

Consider one more extension to this example. Example Three (on Table Five) shows the identical option as in Example One (the one we didn't want to buy) but now pushes the strike date off until two years into the future rather than one year in the future. As before, at the end of one year, the stock price could have increase or decreased by 25%. Now at the end of the second year, the stock price as the opportunity to increase or decrease again by 25%. Again, assuming that all outcomes are equally likely, the expected value of the option is $1.16 which is now greater than the purchase price. Increasing the length of time until the strike date increases the value of the option.

At this point we have determined two things: First, the value of an option increase with the

Table 5

Option Valuation

Example 3. Evaluating an option with a longer time horizon

Price of Stock today:	$10.00						
Potential Stock Prices in one year:	$5.00	or	$15.00				
Potential Stock Prices in two years:	$2.50	or	$7.50	or	$22.50	Expected Price of Stock	$10.00
Probability of Each Price:	25.0%		50.0%		25.0%		
Potential Value of Option after two years:	$0.00		$0.00		$11.50	**Expected Value of Option**	**$2.88**

Moral of the Story: The value of the option increases with the length of time until the strike date

Option Price	$1.00
Strike Price	$11.00
Current Price	$10.00
Strike Date	2 years from today

volatility of the value of the stock. This is simply because the down side is always zero. Since the most we can lose is what we paid for the option, if the potential upside increases, then the value of the option also increases. This is why the value of the investment in R&D will increase with the volatility of the potential returns (or revenue) generated from the intellectual property. The researcher is developing a product that could have no market value, intermediate value or be a big winner.

Second, the value of the option increases with the length of time until the strike date – this is simply because the more time you have, the more chances the stock has to hit a high note. Since, as noted above, the down side is bounded by the price of the option, we are better off if we increase the possibility that the price will go higher.[9]

B. Valuing an Investment in R&D

We can use this same method to evaluate an investment in R&D. Tables Six and Seven lay out the necessary elements to evaluate an investment in R&D as a stock option. The option is the right to sell the new product once it is developed. This option will only be exercised if the R&D were successful in producing a product that has market value. Of the many possible selling prices of the developed product, we also have to consider the possibility that the research will not produce any useful technology or desirable new product and all of the dollars spent in the development process will be lost.

[9] The example outlined in this section is oversimplified in order to illustrate the method by which one values an asset whose return is subject to uncertainty. Since in the real world there are many possible future prices of a particular stock and many periods in which the price of the stock can change, we need a more complex (but conceptually similar) method of determining the value of a real world stock option. The Black-Scholes formula is a method of valuing a stock option when there are essentially an infinite number of prices that the stock can take by the strike date. The Black-Scholes formula accounts for the fact that the stock price can change at any time between now and the strike date and can take on essentially any value. See for example Brealey & Myers.

Table 6

Option Valuation

Sample Spreadsheet

Parameters	
Discount Rate	13%
Risk Free Rate	5%
Standard Deviation	50%
Years to Launch	4
Units	$'000

		Phase I 1997
A.	**Current Investment Requirement**	(3,800)

		Pre-Launch Costs		
		Phase II 1998	Phase III 1999	Phase IV 2000
B.	**Cash Flows**	(6,000)	(7,500)	(12,000)
C.	**Discount Factor (13%)**	0.885	0.783	0.693
D.	**Cash Flows in $1997**	(5,310)	(5,874)	(8,317)
E.	**Probability of Reaching Future Phase**	35%	20%	20%
F.	**Probable Costs**	(1,858)	(1,175)	(1,663)
G.	**Expected Pre-Launch Costs ($1997)**	(4,696)		

		Cash Flows After Launch									
		2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
H.	**Expected Revenue**	$23,850	$27,428	$31,226	$35,257	$37,708	$40,286	$42,348	$43,830	$45,364	$46,952
I.	**Expected Costs of Production**	$21,465	$23,313	$24,981	$26,443	$26,395	$26,186	$27,526	$28,490	$29,487	$30,519
J.	**Net Cash Flows**	$2,385	$4,114	$6,245	$8,814	$11,312	$14,100	$14,822	$15,341	$15,877	$16,433
K.	**Discount Factor (13%)**	0.613	0.543	0.480	0.425	0.376	0.333	0.295	0.261	0.231	0.204
L.	**Net Present Value of Cash Flow**	$1,463	$2,233	$3,000	$3,747	$4,255	$4,694	$4,366	$3,999	$3,663	$3,355

M.	**Total Net Present Value**	$34,775
N.	**Probability of Launch**	30%
O.	**Asset Value**	$10,432
P.	**Black-Scholes Value of Option**	$7,077

Research Value		
Initial Investment	**Option Value**	**Invest if Positive**
($ Thousands)		
($3,800)	$7,077	$3,277

The option price is the cost to initiate or continue funding R&D. This is the expenditure necessary to continue development of the product. If we buy the option, we are buying the possibility of profiting from the invention at a future date. If we don't buy the option, the project is abandoned and we will never have the possibility of profiting from a future invention but we have saved the remainder of its development costs. The strike date of the option is the date at which we expect to be able to launch the product. The exercise price is conceptually equivalent to all of the R&D costs that will have been incurred between today and the launch date and the possible stock prices are conceptually equivalent to the discounted stream of future revenues generated by the product.

The expected value of the option to continue product development is the probability weighted discounted stream of future revenues once the development stage has been completed. If the expected value of the discounted stream of future revenues were greater than the anticipated costs of developing the product through to market launch, we would choose to continue development. That is, we would buy the option and invest in R&D on this project.

Table 7
Option Valuation

Evaluating An Investment in R&D

Investing in R&D is like buying an option to make sales of the potentially profitable new product.

The Option: The right to sell the new product if R&D is successful

Option Price	=	Cost to Initiate R&D	=	$3,800,000
Strike Date	=	Product Launch	=	4 Years from Today
Exercise Price	=	R&D costs incurred by strike date (in current $)	=	$4,696,000
Standard Deviation of Asset Earnings			=	50%
Risk Free Interest Rate			=	5%
Discounted Value of Total Potential Earnings from sales of the new product			=	$34,775,000

The Value of the Research and Development

Potential Outcomes	R&D Not Successful	or	R&D Successful
Probability of Outcome	70%		30%
Potential Value of Investment	$0		$34,775,000
Expected Value of Asset	$10,432,500		

Black-Scholes Value of the Option

The Black-Scholes method of valuing an option takes account of the fact that there are many possible prices the asset could take, and many time periods in which the price could change.

Black-Scholes Option Value = $7,076,682

Investment Decision

If:	Option Value	>	Option Price	⇒	Buy the Option
Since:	$7,076,682	>	$3,800,000	⇒	Buy the Option

VII. CONCLUSION

The techniques described in this note are methods by which to determine the value of intellectual property both when it is embedded in a finished production process and when it is still being developed.

Rule of thumb or profit sharing methods assign values to intellectual property without considering the “willingness to pay” of the intellectual property user. They are therefore unlikely to approximate the true value of the intellectual property. Comparables can usefully inform intuition about valuation but their use is not in any strict sense a “method.” The discounted cash flow methodology outlined above directly estimates the true contribution of the patented technology to the manufacturing process. Option valuation is preferable when the technological and economic outcome is uncertain but the distribution of probable outcomes is known.