Teaching Patents as Real Options

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As a framing device for an introductory course in patent law, the study of patent valuation can deepen students' understandings of patents as business assets and as instruments of industrial policy. In particular, the real options approach to patent valuation highlights patent owners' strategic postures toward future income opportunities in the face of legal uncertainty and change. This Article describes the author's experience with teaching patent valuation in connection with a show-and-tell exercise in which students consider the economic role of patents in markets for products they have purchased. The exercise utilizes an online calculator designed by the author to foster student intuitions regarding the financial implications of characterizing the option to commercialize a patent as an American call option.

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INTRODUCTION

Although the decision to seek a patent is ultimately a business decision,[1] entrepreneurs with new technological ideas are prudent to seek legal advice early regarding whether to patent and what is worth patenting. Successful technology startups must focus their limited time and resources on acquiring a relatively small number of patents that will create enough long-term value to justify their short-term costs.[2] Once this patent portfolio has been acquired, it must be strategically managed in the face of changing market, technological, and legal conditions.[3] The ability to advise a client regarding the economic value of its existing and prospective patent rights should be considered an essential part of every patent attorney's skill set.

Typically, however, law students have little opportunity to receive training in the economic valuation of patents before entering the practice of patent law. The topic is not covered on the patent bar examination or in leading patent law casebooks.[4] While the largest patent law firms may have sufficient expertise to provide in-house training in valuation issues and methodologies,[5] most attorneys must

1. *See* Certain Optical Disk Controller Chips and Chipsets and Prods. Containing Same, Including DVD Players and PC Optical Storage Devices II, USITC Pub. 26, Inv. No. 337-TA-523, 2005 WL 482887, at *16 (Feb. 22, 2005) ("[A] decision whether or not to seek a patent, even if based partially on legal advice, is generally abusiness [sic] decision and, as such, is not privileged.").

2. *See* Jeff Seul, *Current Business and Legal Trends in the Organization, Funding, and Operation of Emerging Technology Companies*, *in* REPRESENTING EMERGING TECHNOLOGY COMPANIES: LEADING LAWYERS ON GUIDING BUSINESSES AND INVESTORS THROUGH THE TECH START-UP PROCESS 7, 19–20 (2014) ("Patents are competitive business assets and legal tools, and not everything that could be patented is strategic enough from a business perspective to justify the costs (money and personnel time) to a resource constrained start-up . . . . A good patent attorney is someone who not only has a relevant technical background and great legal credentials and experience, but is also someone who can see the forest for the trees and can help clients recognize which inventions, if protected by patents, will create long-term value by helping keep potential competitors out of the company's technology and/or market space.").

3. *See generally* Martin A. Bader, *Strategic Management of Patent Portfolios*, 42 LES NOUVELLES 552, 552–54 (2007) (describing a leading approach to strategic patent portfolio management).

4. *See* MARTIN J. ADELMAN, RANDALL R. RADER & JOHN R. THOMAS, CASES AND MATERIALS ON PATENT LAW, at vii–xv (4th ed. 2015) (table of contents); F. SCOTT KIEFF ET AL., PRINCIPLES OF PATENT LAW, at xix–xxviii (6th ed. 2013) (same); ROBERT PATRICK MERGES & JOHN FITZGERALD DUFFY, PATENT LAW AND POLICY, at iii–xv (5th ed. 2011) (same); CRAIG ALLEN NARD, THE LAW OF PATENTS, at xi–xix (3d ed. 2014) (same); *Manual of Patent Examining Procedure (MPEP)*, USPTO.GOV (Nov. 2015), https://www.uspto.gov/web/offices/pac/mpep/ [https://perma.cc/GMS5-G4CZ] (same).

5. *See, e.g.*, *Patent Portfolio Management*, FISH & RICHARDSON, http://www.fr.com/services/patent-law/patent-portfolio-management/ [https://perma.cc/82LN-CFJQ] (listing

develop a working understanding of patent valuation from their own intuitions and practice experiences. A patent law course that guides students through the logic of patent valuation in a practice setting could thereby introduce future attorneys to a versatile set of tools for diverse client counseling tasks.

This Article provides rationales and resources for covering the topic of patent valuation, with particular attention to the real options valuation approach, as part of the intellectual property curriculum in law school. Part I discusses the motivation for a classroom exercise involving patents that elicits and uses the students' perspectives as consumers of patent products as motivation for patent valuation analysis. Part II describes the basic financial model that analogizes the valuations of patents to those of real options and some of the legal insights that may emanate from this model. Part III documents the features of a web-based calculator that can support student intuitions and classroom discussions throughout the semester regarding the determinants of patent valuation under the real options approach.

I. CURRICULUM

The bulk of the patent law course is devoted to teaching the legal requirements for a valid patent in painstaking detail.[6] I have found it pedagogically worthwhile to preface this sequence with an appeal to a more fundamental motivation for studying the law of patent validity. Patent law students are perennially drawn to what I refer to as the alchemy of patent practice: the possibility of putting words to paper in such a way as to create an instrument conferring new and valuable rights. As consumers and observers of patented products in the marketplace, students begin the course ready to explore the economic dimensions of patent valuation. This Part describes some of the approaches I have taken to facilitate that exploration.

A. Patents in the Classroom

Ever since I started teaching Patent Law at the University of North Carolina School of Law in 2001, I have begun the course with a show-and-tell exercise in which students bring in patented products and their

thirty-eight principal attorneys and ten associate attorneys as members of Fish & Richardson's patent portfolio management team as of January 22, 2017).

6. *See generally, e.g.*, ADELMAN ET AL., *supra* note 4, at 67–550 (covering statutory requirements for patent validity); KIEFF ET AL., *supra* note 4, at 149–792 (same); MERGES & DUFFY, *supra* note 4, at 67–796 (same); NARD, *supra* note 4, at 59–500 (same).

associated patents to discuss in small groups.[7] The exercise provides a hands-on introduction to the components of a patent document and the role of patent claims, as well as an early opportunity for classmates to meet and interact with each other in a practice setting. The students' inherent interest in the technologies underlying their own household items and the market forces influencing their own consumer behavior ensures a high level of engagement.

In observing these small group conversations over the years, I have increasingly seen my students show a particular interest in valuation issues. Discussions about the products' commercial successes have led to vigorous debates about the extent to which patented features contributed to the students' purchase decisions. Group members have informed each other about similar products that could compete with their patented products. Some students have noted that their patents were nearing expiration (or had already expired), while others have wondered whether emerging technologies might render their patents obsolete before their respective expiration dates. Several have reported that their inventions have seemed obvious, and many have acknowledged difficulties when asked to distinguish their patents from examples of patents that were allowed to expire for failure to pay maintenance fees.[8] In critically assessing their patents' strengths and weaknesses with their small groups, students have expressed sophisticated economic intuitions about patents in the marketplace and called into question the popular notion that patent rights inherently confer monopoly power.[9]

7. I ask the students to inform me of their choices a day in advance so that I can prepare materials to supplement the discussion.

8. The most recent examples of patents allowed to expire due to failure to pay a maintenance fee can be found in the notices section of the Official Gazette of the U.S. Patent & Trademark Office. *See Official Gazette Notices–2016*, USPTO, http://www.uspto.gov/learning-and-resources/official-gazette/official-gazette-notices-2016 [https://perma.cc/SYG2-KG5E]; *cf.* Kimberly A. Moore, *Worthless Patents*, 20 BERKELEY TECH. L.J. 1521, 1525, 1531 (2005) (using a patentee's failure to pay maintenance fees as an "objective and systematic way to identify worthless patents" and showing that worthless patents on average have fewer claims, fewer prior art references, fewer related applications, and shorter prosecution times).

9. *See* Ill. Tool Works Inc. v. Indep. Ink, Inc., 547 U.S. 28, 39–45 (2006) (reappraising presumption that patents confer market power); Mark A. Lemley, *The Economics of Improvement in Intellectual Property Law*, 75 TEX. L. REV. 989, 996 (1997) ("In economic terms, intellectual property rights prevent competition in the sale of the particular work or invention covered by the intellectual property right, and therefore allow the intellectual property owner to raise the price of that work above the marginal cost of reproducing it."); *id.* at 996 n.26 ("This does *not* mean that intellectual property rights automatically confer market power or create 'monopolies' in an economic or antitrust sense, as some courts have erroneously presumed."); *see also* Simone A. Rose, *Patent "Monopolyphobia": A Means of Extinguishing the Fountainhead?*, 49 CASE W. RES. L. REV. 509, 530–34 (1999) (providing a historical survey of judicial hostility to the "monopoly" power conferred by patent rights).

B. Patent Valuation as a Frame for Class Discussions

After the students have reported back from their small groups to the full class, I have used their comments as the basis for further discussions throughout the semester on the legal and economic principles underlying patent valuation. Using patent valuation as a framing device for the patent law course provides many significant pedagogical benefits. It motivates discussions regarding strategic decisions in patent prosecution and litigation. It deepens the students' understanding of patents as business assets and as instruments of industrial policy. It provides an auxiliary gateway into patent law and policy for students with nontechnical business backgrounds, aptitudes, and interests. It highlights the role of patent law in business counseling and planning. It suggests ways attorneys can create and demonstrate added value for clients in an increasingly competitive landscape for patent practice. It facilitates teaching of the important, but often omitted, topic of patent damages. It could even provide students of patent law with comparative expertise over valuation practitioners who lack legal training in the analysis of patent claims.[10]

Additionally, eliciting student interest in patent valuation with a show-and-tell exercise at the beginning of the semester provides a further benefit: it provides the students with an early "law in action"[11] perspective on the patent system as consumers of patented products. This serves as an immediate practical application of their introductory readings on the economic justifications for patents and the exclusionary nature of patent rights.

C. Approaches to Patent Valuation

The value of a patent derives from the exploitation of the right it confers: namely, "the right to exclude others from making, using, offering for sale, or selling the invention throughout the United States or importing the invention into the United States[.]"[12] This right is "nothing but a negative right of exclusion"[13] and therefore does not necessarily

10. *See* Malcolm T. Meeks & Charles A. Eldering, *Patent Valuation: Aren't We Forgetting Something? Making the Case for Claims Analysis in Patent Valuation by Proposing a Patent Valuation Method and a Patent-Specific Discount Rate Using the CAPM*, 9 NW. J. TECH. & INTELL. PROP. 194, 196 (2010) (observing that most patent valuation techniques fail to conduct "an analysis of the most important part of a patent—its claims").

11. *See generally* Roscoe Pound, *Law in Books and Law in Action*, 44 AM. L. REV. 12 (1910) (coining the phrase "law in action" and providing the classic statement of the distinction between the formal sources of law and the social practices of legal administration).

12. 35 U.S.C. § 154(a)(1) (2012).

13. Chi. & A. Ry. Co. v. Pressed Steel Car Co., 243 F. 883, 890 (7th Cir. 1917) ("[A] patent conveys nothing but a negative right of exclusion. It is the right to exclude others, but

permit an inventor to commercialize the invention in the United States market.[14] Despite this, patent valuations often estimate not only the value a patent owner might derive from suing for infringement or selling immunity from suit in the form of a license,[15] but also the rents associated with the patent owner's power to exclude competition from the market for a commercial embodiment of the invention.[16]

There are three basic approaches to patent valuation, generally referred to as cost methods, market methods, and income methods.[17] Cost methods infer the value of a patent from the cost of developing the patented technology and the cost of obtaining and maintaining the patent.[18] Market methods utilize valuation information from the price-setting activities of buyers and sellers in competitive markets for the patent itself, for comparable assets, or for shares of stock or other indicators of the patent's value in the context of the firm's other assets.[19] Income methods estimate the total present value of the net economic benefits the patent will generate over time, including profits from market power attributable to the patent rights and royalties from patent assertion or licensing.[20]

Accessible introductions to the cost, market, and income approaches can be found in any of the leading surveys on patent

not the natural right to make, use, and sell, which the patentee obtains from his general ownership of the materials employed, not from the government."); *see also* Giles S. Rich, *The Relation Between Patent Practices and the Anti-Monopoly Laws*, 14 FED. CIR. B.J. 21, 26–27 (2004) (explaining that the right to make, use, and sell is "the 'natural' right of man" and that the government can therefore grant no more than "*the right to exclude others from making, using or vending the patented invention*").

14. *See* Adam Mossoff, *Exclusion and Exclusive Use in Patent Law*, 22 HARV. J.L. & TECH. 321, 330 (2009) (explaining that blocking patents or administrative regulations may prevent a patent owner from commercializing the patented invention).

15. *See Chi. & A. Ry. Co.*, 243 F. at 890 ("[T]he licensee does not obtain [a] right to make, use and sell from the license, but only immunity from suit by the licensor.").

16. *See* WILLIAM J. MURPHY, JOHN L. ORCUTT & PAUL C. REMUS, PATENT VALUATION: IMPROVING DECISION MAKING THROUGH ANALYSIS 107 (2012) ("Patent rights provide the patentee with what economists refer to as market power."); *id.* ("When valuing the patent rights for an invention under the classic incentive theory, the valuator is trying to calculate the value of the extra profits that come from excluding competitors.").

17. *See id.* at 16. This taxonomy of the basic approaches to patent valuation has been credited to Russell Parr and Gordon Smith. *See* Robert Pitkethly, *The Valuation of Patents:A Review of Patent Valuation Methods with Consideration of Option Based Methods and the Potential for Further Research* 6 (Judge Inst. of Mgmt. Studies, Judge Inst. Working Paper No. 21/97, 1997) (citing Russell L. Parr & Gordon V. Smith, *Quantitative Methods of Valuing Intellectual Property*, *in* THE NEW ROLE OF INTELLECTUAL PROPERTY IN COMMERCIAL TRANSACTIONS 39, 49–61 (Melvin Simensky & Lanning Bryer eds., 1994)), http://users.ox.ac.uk/~mast0140/EJWP0599.pdf [https://perma.cc/T8BV-U3YV].

18. *See* MURPHY ET AL., *supra* note 16, at 19, 225.

19. *See id.* at 18, 189–91.

20. *See id.* at 16–18, 131–34.

valuation[21] and assigned as supplemental reading. With this background in hand, students are able to brainstorm about readily accessible sources of information that might be relevant to each approach. Concerning the cost approach, students have generally struggled to obtain historic data on the costs of research and development associated with a patented technology. Some students have found the market approach more promising. While transaction data involving similar patents usually is not readily available,[22] these students have determined the market capitalization of publicly traded patent owners and perused recent press releases and annual reports for information regarding the relative financial significance of the patent in question. Overall, however, students have found the income approach the most amenable to calculation, using diverse information sources as inputs to estimate the earnings attributable to the patent covering their product.[23] Following one of these approaches, each student is asked to formulate low and high estimates of their patent's present (i.e., postcommercialization) valuation, together with an estimate of the probability that the actual value ultimately derived from the patent before expiration will fall between the two estimates.

While students find this introduction to the valuation research process informative and productive, they conclude the exercise with varying degrees of confidence in their own calculations. They might be

21. *See, e.g.*, CHRISTIAN GRUBE, MEASURING THE IMMEASURABLE: VALUING PATENT PROTECTION OF KNOWLEDGE-BASED COMPETITIVE ADVANTAGES 119–29 (2009); MURPHY ET AL., *supra* note 16, at 16–19; Heinz Goddar & Ulrich Moser, *Traditional Valuation Methods: Cost, Market and Income Approach*, *in* THE ECONOMIC VALUATION OF PATENTS 109, 109–13 (Federico Munari & Raffaele Oriani eds. 2011); Shigeki Kamiyama, Jerry Sheehan & Catalina Martinez, *Valuation and Exploitation of Intellectual Property* 26–28 (OECD Directorate for Sci., Tech. and Indus., Working Paper No. 2006/5, 2006), https://www.oecd.org/sti/sci-tech/37031481.pdf [https://perma.cc/C4W7-F5C2]; Pitkethly, *supra* note 17, at 5–8; Liina Tonisson & Lutz Maicher, *Patents, Their Importance and Valuation Methods* 10–16 (Fraunhofer MOEZ, Working Paper No. 3/2012, 2012), https://www.imw.fraunhofer.de/content/dam/moez/de/documents/Working_Paper/Working-Paper-3.pdf [https://perma.cc/U9VD-KATY].

22. *See* MURPHY ET AL., *supra* note 16, at 194 ("One of the greatest information problems for market-based patent valuation methods is the dearth of publicly disclosed patent transactions."); Krista F. Holt, Brian P. O'Shaughnessy & Thomas B. Herman, *What's It Worth? Principles of Patent Valuation*, LANDSLIDE, Sept.–Oct. 2015, at 33, 35; Kamiyama et al., *supra* note 21, at 27 ("Given the uniqueness of patents, third party arm's length transactions involving similar patents are infrequent."); *see also* Mark A. Lemley & Nathan Myhrvold, *How to Make a Patent Market*, 36 HOFSTRA L. REV. 257, 257–58 (2007) (proposing legislation to require publication of patent assignment and license terms after noting that a patent licensee often has no idea if it is "getting a good deal" because "[e]ven if that patent or ones like it have been licensed dozens of times before, the terms of those licenses, including the price itself, will almost invariably be confidential").

23. *See infra* Section III.A (presenting examples of student calculations).

reassured to know that experts are typically retained to produce more sophisticated and detailed patent valuation reports,[24] and even expert calculations are subject to uncertainty[25] and the "garbage-in, garbage-out" principle.[26] At the same time, an acquaintance with the valuation process can help an attorney not only in deciding whether to retain a valuation expert[27] and in interpreting an expert's findings,[28] but also in a host of other strategic decisions regarding patent acquisition, assertion, and management.[29]

Most students will recognize, and often a student will spontaneously point out, that the class's selective sample of successfully commercialized patents is not representative of the more than two million patents in force.[30] I confirm this observation with statistics showing that nearly two-thirds of patents are allowed to expire for failure to pay maintenance fees,[31] and then invite the students to attempt to discern facial differences between their show-and-tell patents and a comparison group of lapsed patents. This exercise highlights the extent to which the class's income-based valuations of the show-and-tell patents relied on postcommercialization information about markets for the patented products,[32] and calls into question whether the students' analytical

24. MURPHY ET AL., *supra* note 16, at 86 (noting that the authors frequently recommend forming a valuation team including a financial expert, an industry expert, and a technology expert); Nils Omland, *Valuing Patents Through Indicators*, *in* THE ECONOMIC VALUATION OF PATENTS, *supra* note 21, at 169 (noting that the income approach to patent valuation "generally builds on expert knowledge of the technology, markets, production facilities, legal effectiveness of the patents, and so on" and might involve "different experts, possibly even from different organizations").

25. *See* MURPHY ET AL., *supra* note 16, at 53 (describing patent valuation as "an inherently inexact undertaking").

26. *See id.* at 131 ("While the clean mathematical calculations of [an income-based valuation] analysis can convey an aura of precision, the quality of the analysis is entirely dependent on the quality of the inputs that are used in the calculation. If the inputs are substantially wrong, the answer that comes from the . . . analysis will be substantially wrong.").

27. *See* Holt et al., *supra* note 22, at 33 (noting that a sense of the valuation process can help attorneys "make informed decisions as to how and when to engage an expert").

28. *See* MURPHY ET AL., *supra* note 16, at 13 ("A user who understands the limits and implications of the inputs used to feed her chosen valuation method will be better suited than others to interpret and employ the resulting valuation effectively.").

29. *See id.* at 3–4.

30. *See* Mark A. Lemley, *Rational Ignorance at the Patent Office*, 95 NW. U. L. REV. 1495, 1506–07 (2001) ("There is certainly a strong sense in the patent community that many issued patents, even potentially valuable ones, sit around collecting dust."); Alan C. Marco et al., *The USPTO Historical Patent Data Files: Two Centuries of Innovation* 32 (USPTO Econ., Working Paper No. 2015-1, 2015) (graphing annual count of patents in force), https://www.uspto.gov/sites/default/files/documents/USPTO_economic_WP_2015-01_v2.pdf [https://perma.cc/WKZ4-7PMY].

31. *See* Lemley, *supra* note 30, at 1503–04.

32. *See infra* text accompanying notes 88–105 (describing examples).

approaches can be extended to address precommercialization counseling scenarios.

At this point, it should be apparent to the students that patent valuations are more typically grounded in predictions about future income opportunities than in extrapolations of existing income streams. Specifically, what is needed is a valuation methodology that incorporates the *ex ante* value of future opportunities to try to generate income from the patent in light of these uncertainties. This is the promise of the real options approach to patent valuation.

II. THEORY

Despite the extensive economics literature characterizing patents as real options, to date relatively few legal scholars and practitioners have attempted to utilize this formulation for patent valuation purposes.[33] This Part briefly describes the potential applicability of real options theory to patent valuation and some of the pedagogical benefits of bringing its associated financial tools and perspectives into the law school classroom.

A. Real Options and Financial Options

"A real option is the right, but not the obligation," to pay a predetermined price to undertake a potentially profitable action in the future.[34] The notion of a real option bears a close analogy to a financial options contract based on an underlying security, such as a share of stock.[35] The analogy extends to call and put options, or rights to purchase or sell a share of stock at a predetermined strike price, respectively.[36] Real options also follow the terminology of financial options in distinguishing between European and American types. A European option can be exercised only on the expiration date, while an American option can be exercised at any time up to and including the expiration date.[37]

33. *See* Christopher A. Cotropia, *Describing Patents as Real Options*, 34 J. CORP. L. 1127, 1128 (2009) (describing the "fairly robust economics literature" on patents as real options and noting that "[t]he legal literature is a bit behind in using this analogy").

34. *See* TOM COPELAND & VLADIMIR ANTIKAROV, REAL OPTIONS: A PRACTITIONER'S GUIDE 5 (2001); *see also* Raffaele Oriani & Luigi Sereno, *Advanced Valuation Methods: The Real Options Approach*, *in* THE ECONOMIC VALUATION OF PATENTS, *supra* note 21, at 141, 142–43.

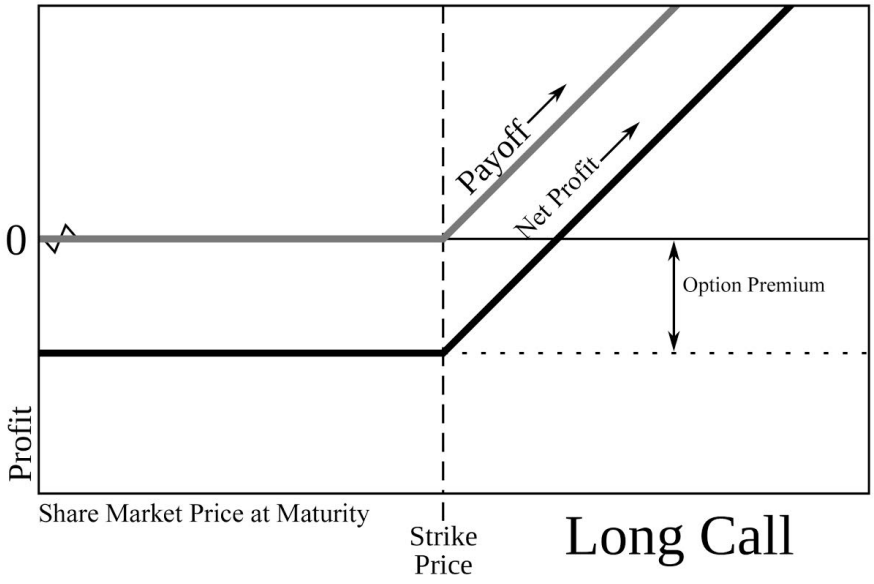
35. *See* Stewart C. Myers, *Determinants of Corporate Borrowing*, 5 J. FIN. ECON. 147, 147–49 (1977) (coining the term "real options" and developing the analogy between real options and financial options).

36. JANA SACKS, ELEMENTARY FINANCIAL DERIVATIVES 107 (2016).

37. *Id.* at 107–08.

An unexpired financial option can have present value even if it would not be profitable to exercise it, because the underlying stock's price movements may make it profitable to exercise the option at some time in the future.[38] The market price for an option reflects this present value and is referred to as the option premium.[39]

Figure 1. Net Profit from Purchasing a European Call Option at the Option Premium, as a Function of the Market Price of the Underlying Stock at Maturity.[40]



38. *See* BRIAN COYLE, RISK AWARENESS AND CORPORATE GOVERNANCE 119 (2004).

39. *See id.*

40. *Cf.* ASWARTH DAMODARAN, DAMODARAN ON VALUATION app., at 444 fig. A12.1 (2006).

As illustrated in Figure 1, a person who pays the option premium to purchase a European call option—thereby obtaining a "long position" in call options—will have the right to purchase a share of the underlying stock at the strike price when the option matures.[41] It will be rational for the option holder to do so if the share's market price at maturity is higher than the strike price, because the holder can exercise the option to purchase a share at the strike price, immediately sell the share at the higher market price, and keep the difference as the payoff. If this payoff exceeds the option premium, the holder will earn a positive net profit.

B. Valuation in Theory and Practice

The analogy to financial options is useful for understanding real options because there is a considerable business literature to explain and predict the valuation of financial options.[42] Most of this research has focused on the Black-Scholes-Merton model of option pricing,[43] which expresses the premium on a European call option as a function of six variables: the current price of the underlying stock (S), the strike price (X), the time to expiration (T), the standard deviation of returns on the underlying asset (σ, also known as the asset's volatility), the riskless interest rate (r), and the dividend yield (ρ).[44]

41. SACKS, *supra* note 36, at 107–08.

42. For a survey of empirical option pricing research, see generally David S. Bates, *Testing Option Pricing Models*, *in* 14 HANDBOOK OF STATISTICS 567–611 (G.S. Maddala & C.R. Rao eds., 1996).

43. *See* David S. Bates, *Empirical Option Pricing: A Retrospection*, 116 J. ECONOMETRICS 387, 387 (2003) (noting that until recently "the overwhelming bulk of the empirical literature [on option pricing] was set within the BSM paradigm, with relatively few papers that tested alternative models"). *See generally* Fischer Black & Myron Scholes, *The Pricing of Options and Corporate Liabilities*, 81 J. POL. ECON. 637 (1973) (describing the model); Robert C. Merton, *Theory of Rational Option Pricing*, 4 BELL J. ECON. & MGMT. SCI. 141 (1973) (extending the model, *inter alia*, to incorporate dividend payouts).

44. *See* TIMOTHY FALCON CRACK, BASIC BLACK-SCHOLES: OPTION PRICING AND TRADING 41 (3d ed. 2014). The value of a European call option in the Black-Scholes-Merton model is given by the function

$$c(S, X, T, \sigma, r, \delta) = Se^{-\rho T} N(d_1) - e^{-rT} XN(d_2),$$

where

$$d_1 = \frac{\ln(S/X) + \left(r - \rho + \frac{1}{2}\sigma^2\right)T}{\sigma\sqrt{T}},$$

$$d_2 = d_1 - \sigma\sqrt{T}, \text{ and}$$

N is the cumulative density function for the standard normal distribution. *See id.* at 142–43.

The Black-Scholes-Merton model is based on several simplifying assumptions about the statistical movement of stock prices and the efficiency of markets. First, all investors in the options market must have sufficient liquidity to conduct certain hedging strategies on a continuous basis.[45] Second, the market must have sufficient efficiency and liquidity to allow investors to complete all of the trades necessary for these strategies at fair market value, with no transaction costs and no possibility of arbitrage.[46] Finally, the price movement of the underlying stock must have the statistical properties associated with geometric Brownian motion.[47]

Because of these "severe" simplifying assumptions, there are substantial differences between option pricing in the Black-Scholes-Merton model and in the real world.[48] Even so, one of the model's key predictions, that high stock volatility would be reflected in high options prices, has been confirmed in empirical studies of financial options markets.[49]

In contrast to the financial literature, there have been relatively few empirical studies on the valuation of real options,[50] but the real options literature reflects many of the same basic insights that emerge from the Black-Scholes-Merton model.[51] Thus, the value of waiting to decide whether to undertake an action tends to increase with the volatility of the outcome.[52] Other recognized drivers of real option value are also consistent with the partial derivatives of the Black-Scholes-Merton

45. *See* NEIL A. CHRISS, BLACK-SCHOLES AND BEYOND: OPTION PRICING MODELS 201–03 (1997).

46. *See id.*

47. *See id.* at 203–04. For a brief explanation of why the Black-Scholes-Merton model's use of Brownian motion is a simplifying assumption, see, for example, NICO VAN DER WIJST, FINANCE: A QUANTITATIVE INTRODUCTION 224–26 (2013) (noting that "stocks do not only vary randomly," but "are expected to move upwards").

48. *See* CRACK, *supra* note 44, at 189 (providing a lengthy list of aspects in which real-world options markets deviate from the assumptions of the Black-Scholes-Merton model, including the prevalence of American options, the existence of bid-ask spreads and commissions, and the partial predictability of stock price movements in response to news).

49. *See* Fischer Black & Myron Scholes, *The Valuation of Option Contracts and a Test of Market Efficiency*, 27 J. FIN. 399, 416 (1972); Henry A. Latané & Richard J. Rendleman, *Standard Deviations of Stock Price Ratios Implied in Option Prices*, 31 J. FIN. 369, 369–75 (1976).

50. *See* COPELAND & ANTIKAROV, *supra* note 34, at 75 ("There have been only a few empirical studies that compare [net present value accounting] with real options methodology.").

51. *See id.* at 86–87 (describing the fact that the value of waiting to decide whether to undertake an action tends to increase with the volatility of the outcome, a consequence of the Black-Scholes-Merton model, as a "general result for [real] options").

52. *See id.* at 86–87 (describing this proposition as a "general result for [real] options").

valuation formula[53]: *ceteris paribus*, an increase in the present value of the opportunity, a decrease in the strike price, an increase in the time to expiration, an increase in volatility, an increase in the risk-free interest rate, and a decrease in the dividend rate will each lead to an increase in the real option value.[54]

C. Benefits of Teaching the Real Options Approach

If the real options literature is basically correct in its approach to valuation, then its central insight—that flexibility has value[55]—has considerable significance for patent valuation. The real options embedded in a patent may have significant value that is systematically neglected by income approaches to patent valuation.[56] One commentator suggests that a real options approach to patent valuation would have helped Xerox recognize the potential value of many undeveloped ideas it discarded as "worthless[,]" such as the personal computer, laser printing, the Ethernet, and graphical user interfaces.[57] As Xerox's tragic tale vividly illustrates, an attorney counseling a client on what to patent needs more than valuation methods based on postcommercialization income. The real options approach is well-suited to the precommercialization counseling scenario, in which income-based valuation methods can be used to calculate a probabilistic distribution of proceeds from exercising the option to commercialize.

The real options approach to valuation provides new economic intuitions that can reframe classroom discussions of patent law and policy. In a 2009 article,[58] Chris Cotropia shows how "macro patent elements," or clusters of interrelated rules of patent law, affect various determinants of a patent's value as a real option.[59] First, a patent's option premium consists of the total cost of acquiring the patent, including creating and developing the underlying invention, drafting,

53. *See supra* note 44.

54. *See* COPELAND & ANTIKAROV, *supra* note 34, at 5–7.

55. *See* DAMODARAN, *supra* note 40, at 19 (explaining suitability of option pricing models for promising new technologies and other kinds of assets impacted by exogenous contingencies for "risk can be an ally and can be exploited to generate additional value").

56. *See* COPELAND & ANTIKAROV, *supra* note 34, at 24 ("Why use real options for evaluating investment decisions? Because Real Options Analysis values the flexibility to respond to uncertain events—net present value techniques do not and consequently undervalue everything.").

57. *See* A. Tracy Gomes, *Intellectual Property Economics on Real Options in Patent and Intangible Valuation*, *in* JOHNATHAN MUN, REAL OPTIONS ANALYSIS 50, 51 (2d ed. 2006) (citing KEVIN RIVETTE & DAVID KLINE, REMBRANDTS IN THE ATTIC: UNLOCKING THE HIDDEN VALUE OF PATENTS 58–59 (2000)).

58. Cotropia, *supra* note 33.

59. *See id.* at 1144–45.

filing and prosecuting the patent application, and losing trade secret protection.[60] Second, a patentee may try to obtain supracompetitive profits by opting to commercialize the invention during the period of exclusivity provided by the patent grant.[61] The possibility of earning such profits will depend on the patent's valid scope relative to the relevant product market[62] and should be discounted to the extent that market exclusivity is attributable to the inventor's first-mover advantage rather than the legal exclusivity afforded by the patent.[63] The patent's strike price in this context consists of the total cost of exclusive commercialization, including the costs of developing and marketing the product,[64] policing the market against infringement by competitors,[65] and obtaining freedom to operate.[66] Alternatively, a patentee may try to obtain damages or royalties by opting to assert the patent against another company that has commercialized the invention.[67] In this context, the strike price consists of the cost of litigation or licensing

60. *See id.* at 1135–37.

61. *See id.* at 1137.

62. *See* Richard A. Posner, *Intellectual Property: The Law and Economics Approach*, J. ECON. PERSP., Spring 2005, at 57, 68 ("A legal monopoly is not necessarily an economic monopoly; if close substitutes exist for a patented product, the patent may confer little power over price."). Thus, the patentee will be able to obtain supracompetitive profits only if the patent covers all close economic substitutes for the commercialized embodiment of the invention, which is not always the case. *Id.*

63. *See, e.g.*, Oskar Liivak, *Maintaining Competition in Copying: Narrowing the Scope of Gene Patents*, 41 U.C. DAVIS L. REV. 177, 212 (2007) (noting that an inventor in a new technological market may have a first-mover advantage that allows abnormal profits).

64. *See* Cotropia, *supra* note 33, at 1137–38.

65. *See id.*

66. *See id.* It must be remembered that a patent does not confer a positive right to practice the invention; thus, the patentee may need to obtain licenses to blocking patents or meet regulatory approvals before commercializing a patented invention. *See supra* note 14 and accompanying text.

In light of these and other complications, Ted Sichelman has suggested that it is more logical to analogize patents to put options, wherein a patent's value subsists in the right to force an infringer to purchase a license, pay damages, or cease infringement. *See* Discussion with Ted Sichelman, Professor, University of San Diego School of Law (Aug. 15, 2016) (on file with author). While this is a valid and important critique of the call option characterization, it is far from clear that the put option analogy fully captures a patent's economic value. *See, e.g.*, Alan C. Marco, *The Option Value of Patent Litigation: Theory and Evidence*, 14 REV. FIN. ECON. 323, 325 (2005) (characterizing a patent as a portfolio consisting of the option to sue together with an asset that pays a stochastic profit flow); Oriani & Sereno, *supra* note 34, at 150–52 (describing the patentee's option to sue as a put option, but also enumerating several other potentially valuable real options held by the patentee). Valuing a patent as a put option would also entail the estimation of patent damages, a topic that would not be appropriate to cover in connection with the introductory activity described in this Article. Oriani & Sereno, *supra* note 34, at 152.

67. *See* Cotropia, *supra* note 33, at 1138.

negotiations.[68] Third, whereas the real options conferred by patent rights expire with those rights, technological or market changes may effectively terminate the patentee's de facto ability to exercise those options even before the patent expires.[69] Finally, while patent rules operate in principle without regard to the value of the underlying invention, scope-limiting doctrines such as novelty, nonobviousness, and adequate disclosure serve in practice to limit a patent's real option value.[70]

Cotropia highlights two potential discussion topics in patent law that can helpfully be reframed from a real options perspective. The first of these concerns the controversy over whether non-practicing entities, often referred to as "patent trolls," help or harm the patent system.[71] To the extent that the assertion of patents by non-practicing entities tends to chill potentially beneficial entrepreneurial activities,[72] this problem could be attributed to the low costs of acquiring and asserting a patent relative to the much higher costs of commercialization.[73] A patent's low acquisition costs can in turn be attributed to the legal rules comprising the "macro patent element" of the patent's option premium, such as the constructive reduction to practice doctrine allowing a filed patent application to stand in for the acts of making and using the claimed invention.[74]

Cotropia finds a second discussion topic in the Supreme Court's 2007 decision *KSR International Co. v. Teleflex Inc.*,[75] which appears to have elevated the nonobviousness standard for patentability.[76] To the

68. *See id.* at 1138–39.

69. *See id.* at 1139–40.

70. *See id.* at 1141–42.

71. *See, e.g.*, Cotropia, *supra* note 33, at 1145–47; John F. Duffy, *Reviving the Paper Patent Doctrine*, 98 CORNELL L. REV. 1359, 1362–64 (2013) (providing a concise survey of the controversy).

72. *See* Duffy, *supra* note 71, at 1363 ("The practices of [nonpracticing entities] are least justifiable where the patents have never been practiced by any entity in the chain of patent ownership and are asserted against entrepreneurial firms that not only developed the technology independently but also took the risks associated with bringing the technology to market.").

73. *See* Cotropia, *supra* note 33, at 1146–47.

74. *See id.* at 1146.

75. 550 U.S. 398 (2007); Cotropia, *supra* note 33, at 1147–48.

76. *See, e.g.*, Ali Mojibi, *An Empirical Study of the Effect of* KSR v. Teleflex *on the Federal Circuit's Patent Validity Jurisprudence*, 20 ALB. L.J. SCI. & TECH. 559, 572–73, 596 (2010) (finding district courts "over seven times more likely to find patents obvious as a result of *KSR*" and the Federal Circuit "more likely . . . to find a patent obvious on review"); Jennifer Nock & Sreekar Gadde, *Raising the Bar for Nonobviousness: An Empirical Study of Federal Circuit Case Law Following* KSR, 20 FED. CIR. B.J. 369, 407 (2011) (concluding that since *KSR*, "the bar has indeed been raised for finding an invention nonobvious"); Jason Rantanen, *The Federal Circuit's New Obviousness Jurisprudence: An Empirical Study*, 16

extent that a higher patentability standard raises the costs and risks associated with patent acquisition,[77] the *KSR* decision provides an example of a legal change that has served to raise the option premium for many patents.[78] When viewed from this real options perspective, *KSR* can be identified as a patent law development that might ameliorate the patent troll problem.[79]

Beyond the potential reframing of specific topics in the patent law course, the real options perspective primes students to recognize flexibility as a strategic consideration in patent doctrine and case law. For example, the question of whether an invention has been put "on sale" (so as to bar it from patentability after one year[80]) often turns on the public policy "allowing the inventor a reasonable amount of time following sales activity to determine the potential economic value of a patent[,]"[81] even if the invention has not been fully commercialized.[82] After relying heavily on future projections from postcommercialization data in their own patent valuations,[83] students can better understand why the emergence of such data from an on-sale event might be an appropriate point from which to measure the maximum lifetime of the patent option.[84]

III. EXPERIENCE

The real options approach to patent valuation can provide law students with new analytical tools for precommercialization counseling and new perspectives on patent law and policy. It is challenging to teach, however, because it involves quantitative techniques beyond the usual scope of the law school curriculum. Of course, students do not need to know or understand the Black-Scholes-Merton formula to appreciate

STAN. TECH. L. REV. 709, 764 (2013) ("[T]he Federal Circuit has indeed found patents and applications to be obvious at a higher rate than it did prior to *KSR* . . . .").

77. *See* Cotropia, *supra* note 33, at 1148.

78. *See id.*

79. *See id.* at 1145 (describing *KSR*'s nonobviousness standard as "an arguable solution" to the problem of patent trolls).

80. *See* 35 U.S.C. § 102(a)(1), (b)(1) (2012) (post-America Invents Act); 35 U.S.C. § 102(b) (2006) (pre-America Invents Act).

81. *See* Cont'l Plastic Containers v. Owens Brockway Plastic Prods., Inc., 141 F.3d 1073, 1077 (Fed. Cir. 1998).

82. *See* Pfaff v. Wells Elecs., Inc., 525 U.S. 55, 63 (1998) (finding no statutory basis for requiring that an invention be reduced to practice before an "on sale" event can occur).

83. *See supra* text accompanying note 32.

84. *But see* Amelia S. Rinehart, *Patents as Escalators*, 14 VAND. J. ENT. & TECH. L. 81, 102–03 (2011) (arguing that the real options perspective may deter patent owners from "full commercialization" of patents they have been pressured to obtain early because of the on-sale bar).

that strategic flexibility has value to an entrepreneurial client facing technological, market, and legal uncertainty. Still, the practical exercise of estimating the value of a patent as a real option can suggest possibilities for, and limitations of, quantitative insights into the option value of patents at the precommercialization stage, and can lead students to consider how they might apply such insights in counseling scenarios.

This Part suggests some pedagogical tools and approaches for equipping law students to apply the real options approach to patent valuation. The main cognitive challenge lies in the mathematical sophistication of the models involved: the leading methodologies for valuing real options presuppose that the uncertain future value of an underlying asset can be modeled according to a lognormal probability distribution.[85] For students to use the real options approach in practice, Section A describes a simple, intuitive way to specify valuation estimates that uniquely determine the parameters of the associated lognormal distribution; Section B then describes a dedicated software application that will calculate these parameters and use them as inputs in the appropriate formula for real options valuation.

A. Generating the Data

As described in Part I, the small group exercise provided the students with an introduction to the methodologies and practices of patent valuation research. Importantly, the exercise also yielded all of the necessary inputs for the real options approach to patent valuation. In particular, the students were asked to provide low and high estimates of their patent's postcommercialization valuation. They were also asked to give a confidence level, stated as an estimate of the probability that the actual value ultimately derived from the patent before expiration would fall between the low and high estimates.[86] These data are sufficient to pick out a unique lognormal distribution whose geometric mean is equal to that of the two estimates. This specification approach is an attempt to avoid cognitive errors observed when students express uncertain beliefs in terms of subjective probability distributions, as well as students' likely unfamiliarity with lognormal distributions.[87]

85. *See, e.g.*, COPELAND & ANTIKAROV, *supra* note 34, at 122–23 (explaining the choice of the lognormal distribution as a "reasonable approximation" of the probability distribution of future common stock prices for options valuation purposes).

86. *See supra* text following note 23.

87. *See* Anders Winman, Patrik Hansson & Peter Juslin, *Subjective Probability Intervals: How to Reduce Overconfidence by Interval Evaluation*, 30 J. EXPERIMENTAL PSYCHOL. LEARNING, MEMORY & COGNITION 1167, 1167 (2004).

The following discussion describes some of the students' calculations as reported from their small groups to the full class.

Example 1. "Audio Earbud Headphone with Extended Curvature," U.S. Patent No. 8,515,115, assigned to Skullcandy Inc.

The student found Skullcandy's annual report online,[88] stating a gross profit of $109.9 million for 2015.[89] The student also located a page on the Skullcandy web site listing all of the design and utility patents covering each of Skullcandy's headphone products.[90] According to the web page, Skullcandy's "Fix," "Fix In-Ear," and "Method" lines of headphones are covered by two utility patents, including the '115 patent, and five design patents.[91] This provided an opportunity to discuss the virtual marking provisions of the America Invents Act,[92] as well as the difficulty of attributing a product's profitability to each of several patents covering the product. The student did not have time to review the other patents in detail, but concluded that one year of actual profits would represent a reasonable high-end estimate of Skullcandy's future earnings attributable to the '115 patent over the remaining fourteen years of the patent term.

Example 2. "Ink Cartridges," U.S. Patent No. 7,222,950, assigned to Brother Kogyo Kabushiki Kaisha

The student noted that in 2012, Brother had moved to a "universal-type" shape and configuration for its black and color inkjet cartridges, which appeared to be covered by the claims of the '950 patent.[93] After reviewing online articles on the inkjet cartridge industry,[94] the student

88. For all of Skullcandy's annual reports, see *Annual Reports*, SKULLCANDY, http://investors.skullcandy.com/annuals.cfm [https://perma.cc/JUF4-PM4J].

89. *See* Skullcandy, Inc., Annual Report (Form 10-K) Item 6, at 20 (Mar. 4, 2016), http://files.shareholder.com/downloads/ABEA-5FMQI8/4425980030x0x879697/18E48AD1-5244-4C63-AEFD-576DC0F1AF23/SEC-ABEA-5FMQI8-1423542-16-112.pdf [https://perma.cc/4TV5-AY3Z].

90. *See Patent Information*, SKULLCANDY, http://www.skullcandy.com/customer-service/patent-information/patents-page.html [https://perma.cc/T9R2-MLHB] (last updated Oct. 5, 2016).

91. *Id.*; *see also* U.S. Patent No. D761,760 (filed Mar. 19, 2015); U.S. Patent No. D728,533 (filed Mar. 31, 2014); U.S. Patent No. 9,0555,365 (filed Aug. 15, 2013); U.S. Patent No. D656,129 (filed June 3, 2011); U.S. Patent No. 8,515,115 (filed Aug. 20, 2010); U.S. Patent No. D624,057 (filed Jan. 6, 2010).

92. *See* 35 U.S.C. § 287(a) (2012) (allowing a patentee to inform the public that an article is patented by affixing "patent" or "pat." on the article together with an Internet address to a posting "associat[ing] the patented article with the number of the patent").

93. U.S. Patent No. 7,222,950 col. 10 l. 21–col. 12 l. 52 (filed Sept. 29, 2006).

94. *See, e.g.*, *Complex OEM Inkjet Cartridge Structures Pose a Challenge for Compatible Makers*, ACTIONABLE INTELLIGENCE (Dec. 5, 2013), http://www.action-intell.com/2013/12/05

estimated Brother's United States sales at 119 million units over the effective life of the patent and attributed approximately $1 to $2 of Brother's profit per unit to the market exclusivity conferred by the '950 patent. The student noted that Brother had not pursued as active a litigation strategy as Hewlett-Packard and some other competitors and thus had been susceptible to parallel importing of compatible ink cartridges.[95] Even though Brother had priced its original equipment manufacturer ("OEM") cartridges at $10 to $12, the student was able to obtain acceptable equivalents online in bundles of six for $13. The student suggested that the patent valuation would increase if Brother adopted a more aggressive litigation posture in the future. Finally, the student noted the potential for consumer harm if patents broadly covering compatible cartridge configurations were allowed to extinguish price competition in the aftermarket for Brother inkjet cartridges.[96]

Example 3. "Tape Locking Device for Tape Measure," U.S. Patent No. 6,595,451, assigned to Komelon Corp.

In light of the crowded field of functionally interchangeable tape measures, the student reasoned that purchasers of Komelon's tape measure would select it primarily, or even exclusively, for its patented self-locking mechanism.[97] Prior art tape measures automatically retract unless the user actively pushes a button to lock the tape, which may be inconvenient for the user and damaging to the tape. The student stated that Komelon's annual report identifies measuring tapes as one of seven product groups, but does not itemize its profit reporting by product group.[98] The student estimated that measuring tapes constituted one-seventh of Komelon's sales, and that one-third of Komelon's measuring tapes included the patented feature, so that 1/21 of Komelon's net

/complex-oem-inkjet-cartridge-structures-pose-a-challenge-for-compatible-makers/ [https://perma.cc/UJ3B-EM2V].

95. *See* Charles Brewer, *OEMs Keep Pressure on Vendors Marketing Infringing Ink and Toner Supplies*, ENX MAG. (Feb. 23, 2015), http://www.enxmag.com/twii/news-briefing/2015/02/oems-keep-pressure-on-vendors-marketing-infringing-ink-and-toner-supplies/ [http://perma.cc/7FHT-LFSY].

96. *See* Larry F. Darby & Stephen B. Pociask, *Inkjet Prices, Printing Costs and Consumer Welfare*, AM. CONSUMER INST. (Nov. 19, 2007), http://www.theamericanconsumer.org/2007/11/inkjet-prices-printing-costs-and-consumer-welfare/ [https://perma.cc/7CCQ-M5YK].

97. *See* U.S. Patent No. 6,595,451 abstract (filed Jan. 29, 2002).

98. *See* Audio recording: Patent Law, Law 286, Fall 2016, University of North Carolina School of Law (Sept. 6, 2016) (on file with author); *see also Komelon Corp: 049430 Financial Summary*, INVESTING.COM, http://www.investing.com/equities/komelon-corp-financial-summary [https://perma.cc/87DL-CJN9 (staff-uploaded archive)] (last updated Apr. 14, 2017).

annual profits, or $522,000, could be attributed to the patented feature.[99] He then applied a ten percent discount rate over the 5.5-year life of the patent to estimate a range for the patent's valuation.

Example 4. "Smart Light Bulb," U.S. Patent No. 6,528,954, assigned to Color Kinetics Inc.[100]

The student presented a third-party iPhone-controllable LED light bulb that apparently fell within the scope of the '954 patent.[101] The student reviewed PowerPoint slides from a presentation on Philips's LED light bulb patent licensing program[102] and concluded that the third-party bulb had likely been manufactured under license from Philips. From a world industry report for LED manufacturing,[103] the student found that the total profit for the industry was $82.5 million with a projected annual growth rate of 3.4%.[104] Philips is estimated to have a market share of 43.1%.[105] From these numbers, the student estimated Philips's profits from LED manufacturing over the remaining two years of the patent term and used these estimates as the range for the '954 patent's valuation.

99. *See* Audio recording, *supra* note 98; *see also Komelon Corp: 049490 Financial Summary*, *supra* note 98.

100. Royal Philips Electronics acquired Color Kinetics in 2007. *See Color Kinetics Announces Acquisition By Philips*, PR NEWSWIRE (June 19, 2007), http://www.prnewswire.com/news-releases/color-kinetics-announces-acquisition-by-philips-58151087.html [https://perma.cc/6USY-BY7F].

101. *See* U.S. Patent No. 6,528,954 abstract (filed Dec. 17, 1998).

102. Philips Intellectual Property & Standards, *LED Luminaires and Retrofit Bulbs Licensing Program*, PHILIPS (June 21, 2016), http://www.ip.philips.com/data/downloadables/1/5/2/5/philips-led-luminaire-licensing-program-_final_20160621.pdf [https://perma.cc/28FF-25VZ].

103. *See generally* JUSTIN MOLAVI, IBISWORLD INDUSTRY REPORT OD4456, LED MANUFACTURING IN THE US (2011) (detailing the state of the LED chip and component manufacturing industry in 2011).

104. *See id.* at 3; *see also* Jennifer Kho, *New Partnership Aims to Make LEDs Cost Competitive*, FORBES (Nov. 7, 2012), http://www.forbes.com/sites/jenniferkho/2012/11/07/new-partnership-aims-to-make-leds-cost-competitive [http://perma.cc/MTG2-C7YL].

105. *See* MOLAVI, *supra* note 103, at 3; *see also* Kho, *supra* note 104.

Table 1. Summary of Example Student Valuations of Show-and-Tell Patents Using the Income Approach

Description	Patent No.	Life	Low	High	Confidence
Headphone	8,515,115	14 yrs.	$70m	$109m	85%
Ink cartridge	7,222,950	9 yrs.	$100m	$250m	60%
Tape measure	6,595,451	5.5 yrs.	$1m	$2m	50%
Light bulb	6,528,954	2 yrs.	$36m	$44m	50%

Students commonly attributed a company's entire profits for a patented product to the patent itself, as exemplified by those in Examples 3 and 4.[106] This tendency might be due in part to the students' lack of previous exposure to patents and to cases on patent remedies calling for a more nuanced apportionment of profits.[107] In this regard, the students are not alone. Patent owners may be subject to endowment effects that lead them to systematically overestimate the value of their patent holdings.[108] Courts also often overestimate the contribution of a patented invention to the success of a product in the market when valuing patents in the infringement context.[109] The Patent Act allowed the owner of a utility patent to recover an infringer's entire profits until 1946,[110] and continues to allow the owner of a design patent such a remedy to this day.[111]

106. *See supra* text accompanying notes 97–105.

107. *See, e.g.*, Ga.-Pac. Corp. v. U.S. Plywood Corp., 318 F. Supp. 1116, 1119–20 (S.D.N.Y. 1970) (providing multifactor analysis for determining reasonable royalty), *modified and aff'd*, 446 F.2d 295 (2d Cir. 1971).

108. *See* Christopher Buccafusco & Christopher Sprigman, *Valuing Intellectual Property: An Experiment*, 96 CORNELL L. REV. 1, 32–34 (2010) (finding a significant endowment effect in a market for copyrights, and raising concerns about related inefficiencies resulting from initial entitlements in the patent context).

109. *See, e.g.*, John W. Schlicher, *Patent Damages, the Patent Reform Act, and Better Alternatives for the Courts and Congress*, 91 J. PAT. & TRADEMARK OFF. SOC'Y 19, 22 (2009) ("Patents that make available an entirely new type of product are rare. Nonetheless, the courts frequently find that some patented variation of an old product is the basis for an infringing company's entire revenue and profits.").

110. Act of Aug. 1, 1946, ch. 726, § 1, 60 Stat. 778, 778 (codified as amended at 35 U.S.C. § 289 (2012)). *See* Roger D. Blair & Thomas F. Cotter, *An Economic Analysis of Damages Rules in Intellectual Property Law*, 39 WM. & MARY L. REV. 1585, 1595–96, 1596 n.45 (1998).

111. *See* 35 U.S.C. § 289 (2012); *see also* Mark A. Lemley, *A Rational System of Design Patent Remedies*, 17 STAN. TECH. L. REV. 219, 219 (2013) (criticizing the continuing availability of the "entire profit" remedy for design patent infringement).

B. Processing (and Tinkering with) the Data

To aid students in estimating the value of their patents as real options, I developed a beta version of a web-based "Patent Valuation Calculator"[112] that uses numerical methods to estimate the value of the option to commercialize as an American call option. As shown in Figure 2, the calculator asks for an estimated range for the postcommercialization profits attributable to the patent, together with an estimate of the probability that the actual value derived from the patent ultimately will fall within this estimated range. It also asks for an estimate of the cost of commercializing the invention, the time to expiration and the riskless interest rate. The calculator uses sliders for its input interface, with the aim of inviting the students to test different input values. The students can use the estimated patent valuations that they obtained using the income approach as starting points[113] and then experiment to observe the effect of changing each parameter.

Since the option to exploit a patent through commercialization can be profitably exercised only before the patent expires,[114] it is appropriate to regard patents as American options for valuation purposes.[115] In finance, binomial models are used to account for the profits attributable to exercising an American option at different points in time prior to the expiration of the option.[116] Since a decision to commercialize can take place at any time, a binomial model of patent value should divide the patent term into many short time steps, so that the numerical calculation approaches a continuous-time analysis.[117] The calculation can be computationally intensive, as more time steps necessitate more nodes in the binomial tree from which the option value must be calculated.[118] The Patent Valuation Calculator allows the user to trade off speed for precision by selecting the number of nodes in the binomial model.

112. Andrew Chin, *Patent Valuation Calculator*, ANDREW CHIN, http://unclaw.com/chin/valuation/ [https://perma.cc/7EZF-5D76].

113. *See supra* text accompanying note 23.

114. To some extent, this is a simplifying assumption, since patent rights may confer indirect benefits such as goodwill and economies of scale after expiration. See MURPHY ET AL., *supra* note 16, at 126–27.

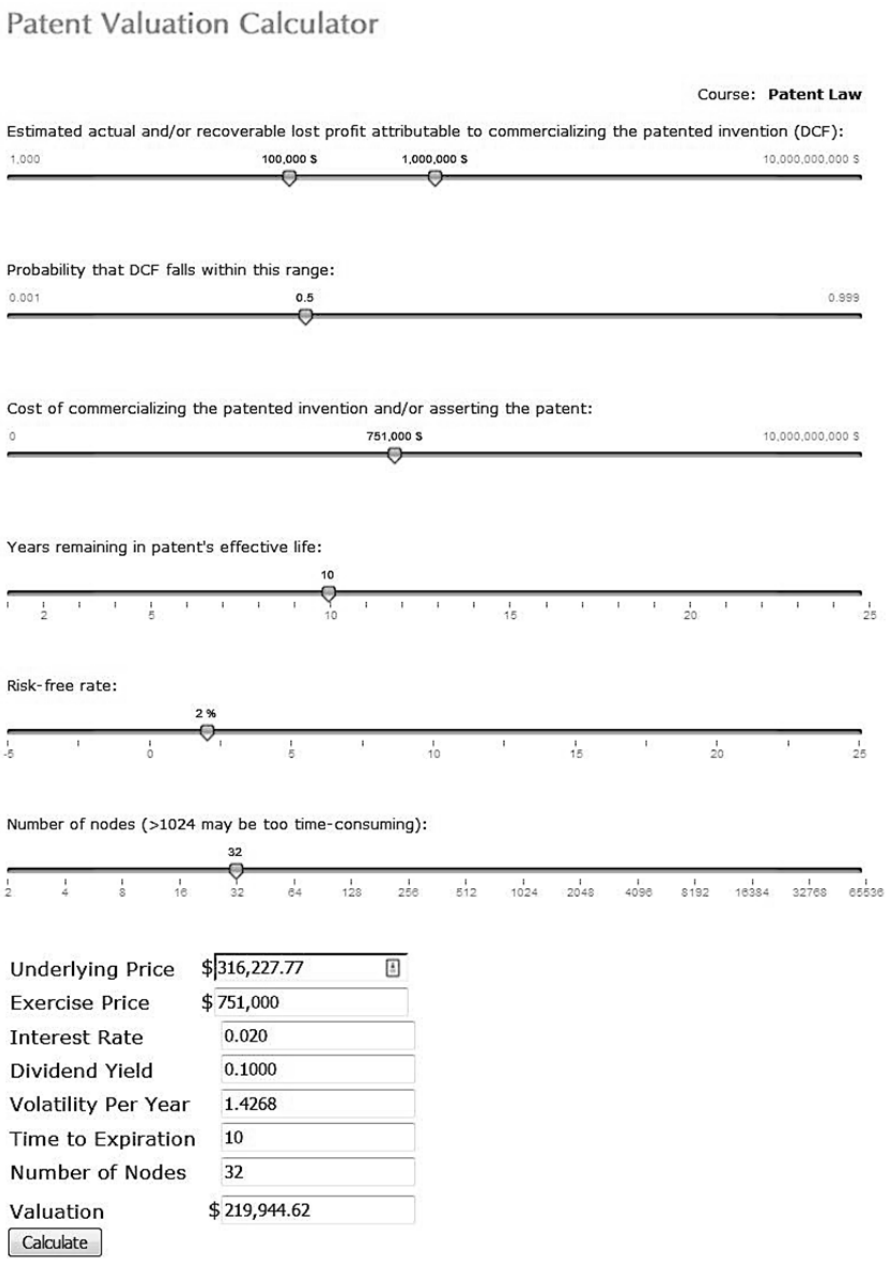
115. *See supra* note 37 and accompanying text (explaining European and American options). The opportunity cost of delaying commercialization is modeled as an annual dividend rate equal to the reciprocal of the number of years in the effective patent term.

116. *See* KERRY BACK, A COURSE IN DERIVATIVE SECURITIES 89–91 (2005) (introducing binomial models and explaining their applicability to American options pricing).

117. *See* John C. Cox, Stephen A. Ross & Mark Rubinstein, *Option Pricing: A Simplified Approach*, 7 J. FIN. ECON. 229, 250–54 (1979) (proving convergence).

118. *See* VAN DER WIJST, *supra* note 47, at 216–17 (explaining convergence of binomial model to Black-Scholes model as the number of nodes approaches infinity).

Figure 2. Web-Based Calculator for Estimating Patent Valuation Using the Real Options Approach[119]



119. Chin, *supra* note 112.

As students observe the effects of changing each input on the valuation of their patent as a real option, they can begin thinking through the logic of the real options perspective and its implications for patent acquisition, commercialization, and assertion. They can immediately see that a patent may have significant value even when immediately exercising the commercialization option would have a negative expected net value (in financial terms, the option is "out of the money").[120] They can also see that longer patent terms and lower interest rates marginally enhance the real option value of a patent.

Further experimentation with the Patent Valuation Calculator's sliders eventually leads most students to recognize that the real options approach to patent valuation relies heavily on the estimated profits attributable to commercializing the patented invention over the effective life of the patent, the level of uncertainty regarding these profits, and the estimated cost of commercialization. Specifically, the students should observe that, *ceteris paribus*, wider ranges for estimated profits from commercialization and lower levels of confidence with respect to these estimates result in higher calculated valuations.

The observation that uncertainty may enhance the value of a patent warrants a brief cautionary discussion with the students. I explain that the Patent Valuation Calculator is based on a model that assumes the uncertainty in commercialization profits is due to random, incremental changes in the expectation of those profits that accrue over the patent's remaining lifetime (i.e., the same Brownian motion assumption underlying the Black-Scholes-Merton model[121]). Under this assumption, greater uncertainty implies a greater probability of very high or very low profits, and a greater value in waiting to learn which state of the world will obtain.[122] Perceptive students should acknowledge that the uncertainty in their income forecasts may not be of the kind that implies a greater likelihood of very high profits, but may simply reflect a lack of available data. Despite the efforts of some scholars to square the circle,[123] the second kind of uncertainty cannot be justifiably used as a

120. JOE DUARTE, FUTURES AND OPTIONS FOR DUMMIES 58 (2006) ("Calls are out of the money when the strike price is greater than the market price of the underlying security.").

121. *See supra* note 47 and accompanying text.

122. *See supra* text accompanying note 52.

123. *See* F. Russell Denton & Paul J. Heald, *Random Walks, Non-Cooperative Games, and the Complex Mathematics of Patent Pricing*, 55 RUTGERS L. REV. 1175, 1213–14 (2003) (arguing that an analogy between patent license prices and photon positions, together with "recognizing a wave-particle duality in pricing[,]" implies that "the uncertainty of future profits provides a perfect substitute for past trading history" as a proxy for the market volatility of patent value).

proxy for volatility in the market value of the patent.[124] Unfortunately, entrepreneurial clients characteristically operate under this second kind of uncertainty, as Gordon Smith's contribution to this Symposium Issue emphasizes.[125]

Despite the difficulties facing the valuation of patents as real options in practice, the small group and calculator exercises can helpfully guide students toward a critical evaluation of their own and their peers' strategic analyses of their show-and-tell patents. As with other online calculators I have developed for use in my law teaching,[126] I hope that practitioners will also find the Patent Valuation Calculator helpful in developing their own understandings of the real options approach to patent valuation.

CONCLUSION

Students of patent law can benefit from an early encounter with the entrepreneurial perspective on the value of patents. One or two class sessions centered on a practice group discussion of show-and-tell patents suffice to convey most of the useful concepts of patent valuation and a

124. Denton and Heald's concept of "wave-particle duality in pricing" does not appear elsewhere in the finance literature, and the analogy is offered without any apparent foundation in statistics or physics. *See id.* (conceding that "[u]pon first exposure this approach might appear to be alien, untenably ambiguous, or altogether fantastic, but no other viable alternatives have emerged"). *See generally* MURPHY ET AL., *supra* note 16, at 174 ("Currently, there is nothing that constitutes a usable measurement for the cash flow volatility associated with an individual patent.").

125. *See* D. Gordon Smith, *Insider Trading and Entrepreneurial Action*, 95 N.C. L. REV. 1507, 1509–10 (2017) (noting the distinction between "situations in which the distribution of potential outcomes is quantifiable" and "situations in which the distribution of potential outcomes is unquantifiable" and arguing that the role of the entrepreneur is to navigate into the second kind of situation). The original formulation of this distinction in the economics literature is attributed to Frank Knight. *See* FRANK H. KNIGHT, RISK, UNCERTAINTY AND PROFIT 232 (1921) (distinguishing "measurable uncertainties" from "that higher form of uncertainty not susceptible to measurement and hence to elimination").

126. *See* Andrew Chin, *Gibrat Market Simulator*, ANDREW CHIN, http://unclaw.com/chin/teaching/antitrust/gibrat.htm [https://perma.cc/VE9D-D9AQ] (modeling market concentration under assumptions of lognormally distributed firm growth); Andrew Chin, *Herfindahl-Hirschman Index Calculator*, ANDREW CHIN, http://unclaw.com/chin/teaching/antitrust/herfindahl.htm [https://perma.cc/ZR8Y-ELVC] (calculating a measure of market concentration used in antitrust analysis of mergers); Andrew Chin, *Monopoly and Market Performance*, ANDREW CHIN, http://unclaw.com/chin/teaching/antitrust/monopoly.htm [https://perma.cc/95QS-8KYJ] (modeling supply, demand, and market-clearing prices in a commodity market under conditions of monopoly and perfect competition); ANDREW CHIN, *Short-Swing Profit Liability Calculator*, ANDREW CHIN, http://16b.law.unc.edu/ [https://perma.cc/83NU-8X9J] (calculating short-swing liability under section 16(b) of the Securities Exchange Act under the Smolowe "lowest-in, highest-out" formula and under the more accurate simplex algorithm for linear programming).

sense of its inexactness.[127] An introductory unit on patent valuation, including the consideration of the real option value of patents, can open up opportunities to discuss business perspectives on cases and topics throughout the patent law course, and can bring future patent attorneys into a closer engagement with valuation practice throughout their careers.[128]

127. *See supra* notes 25–26. *But cf.* David H. Goldenberg & Jonathan D. Linton, *The Patent Paradox—New Insights Through Decision Support Using Compound Options*, 79 TECH. FORECASTING & SOC. CHANGE 180, 180 (2012) (concluding that $556,000 is the minimum real option value a patent must have to be worthwhile at the time of filing).

128. *See supra* text accompanying note 10.