

University of Colorado Law School

Colorado Law Scholarly Commons

Publications

Colorado Law Faculty Scholarship

2006

The Unexpected Value of Litigation: A Real Options Perspective

Joseph A. Grundfest
Stanford Law School

Peter H. Huang
University of Colorado Law School

Follow this and additional works at: <https://scholar.law.colorado.edu/faculty-articles>



Part of the [Law and Economics Commons](#), and the [Litigation Commons](#)

Citation Information

Joseph A. Grundfest and Peter H. Huang, *The Unexpected Value of Litigation: A Real Options Perspective*, 58 STAN L. REV. 1267 (2006), available at <https://scholar.law.colorado.edu/faculty-articles/369>.

Copyright Statement

Copyright protected. Use of materials from this collection beyond the exceptions provided for in the Fair Use and Educational Use clauses of the U.S. Copyright Law may violate federal law. Permission to publish or reproduce is required.

This Article is brought to you for free and open access by the Colorado Law Faculty Scholarship at Colorado Law Scholarly Commons. It has been accepted for inclusion in Publications by an authorized administrator of Colorado Law Scholarly Commons. For more information, please contact rebecca.ciota@colorado.edu.

HEINONLINE

Citation: 58 Stan. L. Rev. 1267 2005-2006

Provided by:

William A. Wise Law Library



Content downloaded/printed from [HeinOnline](#)

Fri Apr 7 15:56:21 2017

- Your use of this HeinOnline PDF indicates your acceptance of HeinOnline's Terms and Conditions of the license agreement available at <http://heinonline.org/HOL/License>
- The search text of this PDF is generated from uncorrected OCR text.
- To obtain permission to use this article beyond the scope of your HeinOnline license, please use:

[Copyright Information](#)

ARTICLES

THE UNEXPECTED VALUE OF LITIGATION: A REAL OPTIONS PERSPECTIVE

Joseph A. Grundfest* and Peter H. Huang**

In this Article, we suggest that litigation can be analyzed as though it is a competitive research and development project. Developing this analogy, we present a two-stage real option model of the litigation process that involves sequential information revelation and bargaining over the surplus generated by early settlement. Litigants are risk-neutral and have no private information. The model generates results that, we believe, have analytic and normative significance for the economic analysis of litigation.

From an analytic perspective, we demonstrate that negative expected value (NEV) lawsuits are analogous to out of the money call options held by plaintiffs and that every NEV lawsuit is credible if the variance of the information revealed during the course of the litigation is sufficiently large. This finding helps explain the prevalence of a class of lawsuits that has proved puzzling to traditional,

* W.A. Franke Professor of Law and Business and Director of the Rock Center on Corporate Governance, Stanford Law School; Commissioner, U.S. Securities and Exchange Commission (1985-1990).

** Member, Institute for Advanced Study, School of Social Science, and Harold E. Kohn Chair Professor of Law, James E. Beasley School of Law, Temple University; J.D., Stanford Law School; Ph.D., Harvard University; A.B., Princeton University.

The authors thank the following institutions for their support: the Institute for Advanced Study, School of Social Science; the James E. Beasley School of Law, Temple University; and the George R. Roberts Program in Law, Business, and Corporate Governance at Stanford Law School. Thanks also to Anita Allen-Castellito, Lucian Bebchuk, Robert Bone, Andy Daughety, Allan Erbsen, Claire Finkelstein, Susan Franck, Gillian Hadfield, Louis Kaplow, Leo Katz, Michael Knoll, Paul Mahoney, Mitch Polinsky, Bob Rasmusen, Jennifer Reinganum, Kathy Spier, Steven Shavell, Cathie Struve, Alan Sykes, Alex Triantis, George Triantis, Ho-Mou Wu, and members of audiences from the John M. Olin Conference on Real Options and the Law at the University of Virginia Law School; and workshops at Harvard Law School; the Hoover Institution on War, Revolution, and Peace, Stanford University; Marquette University Law School; the School of Social Science at the Institute for Advanced Study; the University of Minnesota Law School; and the University of Southern California for their helpful comments and suggestions.

Mr. ChenLi Wang, a member of Stanford University's class of 2006, constructed this Article's online calculator and graphing tool, available at <http://lawreview.stanford.edu/real-options>. We are most grateful for his creativity, diligence, and assistance.

expected value-based modes of litigation analysis. The model also suggests that risk-neutral defendants can act as though they are risk-averse and that risk-neutral plaintiffs can act as though they are risk-seeking because increases in variance can increase a lawsuit's settlement option value just as it increases a call option's value without regard to the holder's degree of risk aversion. Models that presume defendants' relative risk aversion may therefore rely on an unnecessary assumption. Our model also suggests that a lawsuit's option settlement value is not a monotonically increasing function of the variance of the information revealed during the litigation. In particular, at low levels of variance a lawsuit's option settlement value may equal its traditional expected value, but as variance increases its option settlement value can display a discontinuity after which its option settlement value becomes a monotonically increasing function of variance. NEV lawsuits can also display "dead zones"—regions of variance over which the claim is not credible even though it is credible over higher or lower levels of variance. Comparative statics analysis also quantifies the extent to which a lawsuit's settlement value increases as plaintiff's litigation expenses occur later in the litigation process, as the ratio of defendant-to-plaintiff litigation expense increases and as plaintiff bargaining power increases.

From a normative perspective, we offer an "impossibility conjecture" suggesting that the mere presence of an irreducible degree of uncertainty endemic to the litigation process can be sufficient to prevent private litigation incentives from equating to socially optimal incentives, even if one adopts all other assumptions necessary to equate private and social incentives. It follows that it may be impossible to articulate normative principles of law through substantive standards that ignore the uncertainty inherent in the litigation process and the procedural environment in which the litigation occurs.

- INTRODUCTION..... 1269
- I. REFRAMING THE ECONOMIC DESCRIPTION OF LITIGATION 1272
 - A. *Real Options, Investments, and Litigation* 1272
 - B. *Summary of Our Model* 1275
 - C. *Analytic Implications of a Real Options Approach to Litigation* 1276
 - D. *Normative Implications of a Real Options Approach to Litigation* .. 1280
- II. A REAL OPTIONS MODEL OF LITIGATION THAT INCORPORATES BARGAINING..... 1282
 - A. *An Example of Real Options Analysis Applied to a Research and Development Project*..... 1283
 - B. *The Formal Definition of Our Model* 1285
 - C. *Related Literature*..... 1289
- III. INTUITION AND EXAMPLES..... 1292
 - A. *Positive Expected Value Litigation* 1293
 - B. *An Online Calculator and Graphing Tool*..... 1297
 - C. *Negative Expected Value Litigation* 1299
 - 1. *Recapitulating Bebchuk's example: The pure divisibility value of NEV litigation*..... 1300
 - 2. *An example of a learning option that reduces settlement value*.. 1301
 - 3. *An example of a real option with a dead zone* 1302

4. *NEV litigation with a point discontinuity* 1304

IV. ANALYTIC RESULTS 1305

 A. *Credibility Conditions* 1306

 B. *Option Settlement Value, Divisibility Value, and Expected Value* 1308

 C. *Comparative Statics* 1310

V. DISCUSSION AND EXTENSIONS 1315

 A. *Analytic Implications* 1315

 B. *Normative Implications* 1317

 C. *Extensions*..... 1322

APPENDIX: PROPOSITIONS AND PROOFS 1328

INTRODUCTION

Lawsuits and investment projects have much in common.¹ Indeed, every lawsuit forces litigants to make current expenditures in order to influence future outcomes. That is the essence of investment. Lawsuits bear a particularly strong resemblance to commercial research and development projects because both involve the discovery of new information in an environment in which managers can adjust their strategies in response to those disclosures. We therefore suggest that, by modeling lawsuits as investments in competitive research and development projects, it is possible to generate valuable insights about the operation of the litigation process that are difficult or impossible to derive through the application of more traditional modeling techniques.

Commercial research and development projects involve uncertainty about whether they can be completed on budget and on schedule and about the profits, if any, that will be generated if the project succeeds. Researchers modify their strategies while they conduct their projects, and they increase, decrease, accelerate, defer, or terminate expenditures in response to new information. Because firms often race to introduce products that target similar markets, complex competitive interactions can arise as each firm’s strategies

1. By “investment projects” we refer to “real” investment projects, such as the decision to develop a new oil field, to pursue the development of a new pharmaceutical, or to write new software code. These decisions are distinguished from financial investment decisions, such as the decision to purchase or sell a financial instrument in the form of stocks, bonds, options, futures, or forwards. This distinction is common in the real option literature, which often draws analogies to and conclusions from the theory of financial call options. *See, e.g.,* Steven R. Grenadier, *An Introduction to Option Exercise Games*, in *GAME CHOICES: THE INTERSECTION OF REAL OPTIONS AND GAME THEORY* xv (Steven R. Grenadier ed., 2000) (“Essentially, the real options approach posits that the opportunity to invest in a project is analogous to an American call option on the investment opportunity. Once that analogy is made, the vast and rigorous machinery of financial options theory is at the disposal of real investment analysis.”); LENOS TRIGEORGIS, *REAL OPTIONS: MANAGERIAL FLEXIBILITY AND STRATEGY IN RESOURCE ALLOCATION* xi (1996) (describing real options as relating to “the classical subject of resource allocation or project appraisal under uncertainty, particularly with the valuation of managerial operating flexibility and strategic interactions”).

and expenditures influence its competitor's strategies and expenditures. The ability to respond to new information in a strategic manner is therefore central to the research and development process. In addition, new information may indicate that the firm should terminate its project early, which incurs shutdown costs and thereby benefits competitors who continue with their own research and development efforts.

Lawsuits can be described in essentially identical terms. They involve uncertainty about the facts underlying the plaintiff's claim and about the interpretation of the law to be applied to those facts. There is also uncertainty about the damages, if any, that will be awarded if the plaintiff's claim prevails. Litigants modify their strategies during the lawsuit and increase, decrease, accelerate, defer, or terminate litigation expenditures in response to new information. Defendants may make settlement payments to plaintiffs in order to terminate a lawsuit. Thus, just as a shutdown decision imposes costs on the exiting firm and generates benefits for its competitors, a settlement imposes costs on the defendant and benefits the plaintiff.²

Litigation also raises complex competitive interactions because each litigant's strategies and expenditures can influence an opponent's strategies and expenditures. The ability to respond to new information in a strategic manner is evidently central to the litigation process. Put another way, litigants and their lawyers are not "potted plants" who adopt a strategy at a lawsuit's inception and then watch passively as new information spills out and opponents alter their tactics.³

From an investment perspective, lawsuits are therefore largely indistinguishable from research and development projects, and it follows that the tools applied to the economic analysis of research and development projects might also be profitably applied to the economic analysis of litigation. The

2. Novartis's decision to halt development of a new cholesterol drug illustrates this phenomenon. The decision cost Novartis hundreds of millions of dollars and benefited other pharmaceutical firms who continued to develop competing cholesterol treatments. See *Novartis Ends Development of Cholesterol-Lowering Drug NKS104*, DRUG INDUSTRY DAILY, Dec. 19, 2005, available at http://www.fdanews.com/did/4_246/deals/49754-1.html. There are, no doubt, differences between the decision to settle a lawsuit and the decision to shut down a research and development project. In particular, the settlement decision generally involves a symmetry that is lacking in the shutdown decision: the payment by the defendant to the plaintiff defines a zero-sum process whereas the decision to abandon a research project confers benefits on competitors that can be larger or smaller than the firm's shutdown costs. The symmetric nature of the payments in lawsuit settlements helps simplify certain aspects of the model presented in this Article. See *infra* Part II.B.

3. The observation that lawyers are not "potted plants" is attributed to Oliver North's counsel, Brendan V. Sullivan, who, upon being instructed to remain silent during the course of his client's congressional testimony, replied, "I'm not a potted plant. I'm here as a lawyer. That's my job." *Joint Hearings Before S. Select Comm. on Secret Military Assistance to Iran and the Nicaraguan Opposition and H. Select Comm. To Investigate Covert Arms Transactions with Iran*, 100th Cong. 100-7 Pt. I, 263 (1987) (testimony of Oliver L. North); see also *Iran-Contra Hearings: Note of Braggadocio Resounds at Hearing*, N.Y. TIMES, July 10, 1987, at A7 (responding to this interchange).

literature, however, reveals a rather remarkable gap between the two fields of study. Over the last two decades or so, real options analysis has emerged as the state-of-the-art technique for the economic analysis of research and development and has generated insights that are difficult or impossible to obtain through the application of more traditional discounted cash flow or net present value techniques.⁴ Real options analysis has, however, had very little influence on the economic analysis of litigation.⁵

This Article seeks to narrow that gap. We present a real options model of litigation in which parties bargain over the allocation of litigation expenditures that are avoided when a case settles early. Ours is not the first real options model of litigation,⁶ but it is the first to incorporate bargaining behavior and the first to generate closed form solutions that define a lawsuit's settlement value with precision.⁷ Our model's bargaining component also differentiates it from standard real options models that typically involve a single decisionmaker seeking to optimize value over exogenously determined states of nature.⁸ Our model is not, however, a "complete" model of litigation because it assumes that the parties' litigation expenditures are exogenously determined.⁹

Thus, at one level, this Article constitutes a straightforward intellectual arbitrage in which we transplant insights that are well understood by students of real options theory from the world of investment analysis to the world of

4. For specific examples of real options theory applied to research and development activity, see TOM COPELAND & VLADIMIR ANTIKAROV, *REAL OPTIONS: A PRACTITIONER'S GUIDE* 322-37 (2001); TRIGEORGIS, *supra* note 1, at 341-47; Martha Amram, *The Challenge of Valuing Patents and Early-Stage Technologies*, 17 J. APPL. CORP. FIN. 68 (2005); Nancy A. Nichols, *Scientific Management at Merck: An Interview with CFO Judy Lewent*, HARV. BUS. REV., Jan.-Feb. 1994, at 89; Ralph Villiger & Boris Bogdan, *Valuing Pharma R&D: The Catch-22 of DCF*, 17 J. APPL. CORP. FIN., 113 (2005); Ram Willner, *Valuing Start-up Venture Growth Options*, in *REAL OPTIONS IN CAPITAL INVESTMENT* 221 (Lenos Trigeorgis ed., 1995). See also *infra* notes 16-22 and accompanying text.

5. See *infra* notes 23-25, 70-73 and accompanying text.

6. The distinction of being the first to apply real options analysis to litigation is generally credited to Bradford Cornell, *The Incentive To Sue: An Options-Pricing Approach*, 19 J. LEGAL STUD. 173 (1990).

7. Cornell explains that the goal of his article "is not to provide precise estimates of the value of litigation options, but to offer general insights into how such options affect the incentive to sue." *Id.* at 176. In contrast, our objective is to provide precise estimates of equilibrium settlement values, to conduct a set of comparative statics analyses, and to offer more general insights about the implications of real options theory for the study of litigation.

8. "In standard real options models, investment (exercise) strategies are formulated in isolation, without regard to the potential impact of other firms' exercise strategies." Grenadier, *supra* note 1, at xv. More recent real options models explore the implications of strategic market interactions. For a collection of some of these works, see *GAME CHOICES: THE INTERSECTION OF REAL OPTIONS AND GAME THEORY* (Steven R. Grenadier, ed., 2000).

9. In the context of a real options model of litigation, a complete model would also contain a game-theoretic component that describes how each litigant's strategy responds to changes in opposing litigants' strategies. Total litigation expenditures would then not be exogenously determined. For a discussion of these and other potential extensions to the model presented in this Article, see *infra* Part V.C.

litigation analysis where those insights are not as broadly appreciated. This arbitrage is of more than narrow, technical interest because it generates novel insights that are difficult or impossible to derive through more traditional modes of analysis. Moreover, these insights have significant analytic and normative implications for the economic analysis of litigation. The rather simple model presented in this Article also suggests that more complex applications of real options theory offer a particularly promising paradigm for further study of litigation behavior.

In Part I, we expand on the suggestion that litigation can be reframed as a real option, summarize our model, and outline the analytic and normative implications of our findings. Part II offers a simple example of real options analysis as applied to a research and development project, formally defines our model, and describes our model in the context of prior literature. Part III provides several intuitions regarding the model's equilibrium concept and offers examples of how to generate equilibrium solutions. This Part also introduces an online calculator and graphics tool that allows readers to solve for our model's equilibrium real option settlement values for any set of parameters input. Part IV summarizes a series of formal propositions about the model's equilibrium properties. (Proofs for these propositions are presented in the Appendix.) Part V expands on our model's analytic and normative implications and describes potential extensions.

I. REFRAMING THE ECONOMIC DESCRIPTION OF LITIGATION

A. *Real Options, Investments, and Litigation*

The most common economic model applied to both investment and litigation decisions involves expected value analysis based upon a discount factor that reflects the risk inherent in the project or lawsuit.¹⁰ In these models, an investment project's expected value is described as the probability of its success multiplied by the likely payoff in the event of success. The effects of risk or uncertainty¹¹ are reflected through changes in the relevant discount rate,

10. This approach is also often described as the net present value (NPV) approach, and is characterized in the real options literature of investments as the "orthodox theory" of decisionmaking. *See, e.g.*, COPELAND & ANTIKAROV, *supra* note 4, at 56 ("Net present value is the single most widely used tool for large investments made by corporations."); TRIGEORGIS, *supra* note 1. For an application of NPV analysis to litigation, see ROBERT COOTER & THOMAS ULEN, *LAW & ECONOMICS* 393-97, 410 (4th ed. 2004). *See also* sources cited *infra* note 70. We recognize that some articles adopt far more sophisticated analyses of the litigation process than the basic NPV model without expressing a real options perspective. We address that literature in Part II.

11. Analyses often draw a distinction between risk and uncertainty: risk "consists of future states in which the outcomes, though unknown, follow a known distribution, while uncertainty consists of those states for which the distributions are also unknown." Larry T. Garvin, *Disproportionality and the Law of Consequential Damages*, 59 OHIO ST. L.J. 339, 365 n.141 (citing FRANK H. KNIGHT, *RISK, UNCERTAINTY AND PROFIT* 233-34 (1921)). For

or cost of capital, with riskier projects bearing a higher discount rate or capital cost and therefore having a lower discounted expected value.¹² These models are commonly described as discounted cash flow (DCF) or net present value (NPV) models.¹³ When NPV analysis is applied to litigation, the lawsuit's expected value is typically described as the probability that the plaintiff will prevail multiplied by the likely award.¹⁴ The effects of risk or uncertainty are again expressed through changes in the relevant discount rate, with riskier lawsuits bearing a higher discount rate and therefore having a lower expected value.¹⁵

In the investment world, this expected value analysis has recently been supplemented by a "real options" approach that has "had a huge impact on academic research."¹⁶ The interest in real options theory arises, in part, because "traditional discounted cash flow (DCF) approaches to the appraisal of capital-investment projects, such as the standard net-present-value (NPV) rule, cannot properly capture management's flexibility to adapt . . . to unexpected market developments."¹⁷ Real options analysis solves this problem by integrating the investment manager's ability to adapt to new information into the model itself. While the traditional DCF and NPV approaches assume a fixed commitment to full investment at the outset, real option theory models the investment process as a series of decision points at which investors have the option of adjusting

purposes of this analysis, however, we do not distinguish between the concepts of risk and uncertainty and use the terms interchangeably.

12. See, e.g., RICHARD A. BREALEY ET AL., PRINCIPLES OF CORPORATE FINANCE 16-18 (8th ed. 2006) (describing how appropriate discount rate must reflect risk and opportunity cost of capital); TRIGEORGIS, *supra* note 1, at 38-40. Alternatively, the same result can be reached through the application of the "certainty equivalent" approach in which each period's uncertain cash flow "is replaced by . . . the certain cash flow in year t that has the same present value as the uncertain cash flow in that year." TRIGEORGIS, *supra* note 1, at 34.

13. *Id.* at 1. DCF analysis describes a process in which "[f]uture cash flows [are] multiplied by discount factors to obtain [a] present value." NPV analysis describes a "project's net contribution to wealth—present value minus initial investment." BREALEY ET AL., *supra* note 12, at 996, 1000. Both procedures lead to identical decision rules.

14. For sample applications of this formula, see A. MITCHELL POLINSKY, AN INTRODUCTION TO LAW AND ECONOMICS 136 (3d ed. 2003); Richard R.W. Brooks & Warren F. Schwartz, *Legal Uncertainty, Economic Efficiency, and the Preliminary Injunction Doctrine*, 58 STAN. L. REV. 381, 386-87 (2005).

15. Models of litigation often assume that litigants are risk-neutral and therefore do not consider variance as an explicit parameter of the model. In these risk-neutral models, the only information that can change the lawsuit's equilibrium settlement value is information that changes the expected mean of the lawsuit's outcomes. However, if a model allows for learning, then changes in the variance of outcomes can have dramatic consequences for a lawsuit's equilibrium settlement value even when litigants are risk-neutral and the new information does not affect the lawsuit's mean value. See *infra* Parts III, IV.

16. Alexander Triantis, *Realizing the Potential of Real Options: Does Theory Meet Practice?*, 17 J. APPL. CORP. FIN. 8, 8 (2005).

17. TRIGEORGIS, *supra* note 1, at 1; see also Nalin Kulatilaka & Alan J. Marcus, *Project Valuation Under Uncertainty: When Does DCF Fail?*, 5 J. APPL. CORP. FIN. 92 (1992).

their investments in response to new information.¹⁸ This perspective supports the insight that investment “[p]rojects that can easily be modified . . . are more valuable than those that do not provide such flexibility. The more uncertain the outlook, the more valuable this flexibility becomes.”¹⁹

Because of these advantages, the real options approach has “influenced research in virtually every business discipline[,] . . . promoting better understanding of the role of uncertainty on investment activity in various sectors of our economy.”²⁰ Nearly 1000 articles apply real option theory to various forms of investment activity,²¹ and leading finance texts now commonly incorporate the real options perspective.²² In contrast, while there is a small but growing literature that seeks to apply options theory to various areas of the law,²³ very few articles apply real options analysis to the study of

18. TRIGEORGIS, *supra* note 1, at 1 (“Traditional DCF approaches make implicit assumptions concerning an ‘expected scenario’ of cash flows and presume management’s passive commitment to a certain static ‘operating strategy’ (e.g., to initiate a capital project immediately, and to operate it continuously at base scale until the end of its prespecified expected useful life).” For an example of how the real options approach differs from traditional DCF or NPV analyses, see *infra* Part II.A.

19. BREALEY ET AL., *supra* note 12, at 258; see also AVINASH K. DIXIT & ROBERT S. PINDYCK, INVESTMENT UNDER UNCERTAINTY 6-25 (1994) (explaining the value in examining real investments as options); TRIGEORGIS, *supra* note 1, at 1-4, 9-20, 121-50 (same). See generally EDUARDO S. SCHWARTZ & LENOS TRIGEORGIS, REAL OPTIONS AND INVESTMENT UNDER UNCERTAINTY: CLASSICAL READINGS AND RECENT CONTRIBUTIONS (2001); 38 Q. REV. ECON. & FIN. 615 (1998) (Special Issue) (providing a collection of articles applying real options analysis to managerial issues).

20. Triantis, *supra* note 16, at 8.

21. *Id.*

22. “The subject of real options now typically comprises an entire chapter in corporate finance textbooks.” Grenadier, *supra* note 1, at xv.

23. See, e.g., IAN AYRES, OPTIONAL LAW: THE STRUCTURE OF LEGAL ENTITLEMENTS (2005) (illuminating legal rights by applying options analysis); Douglas G. Baird & Edward R. Morrison, *Bankruptcy Decision Making*, 17 J.L. ECON. & ORG. 356 (2001) (analyzing decisions by firms to shutdown as real options); Oren Bar-Gill, *Pricing Legal Options: A Behavioral Perspective*, 1 REV. L. & ECON. 203 (2005), available at <http://www.bepress.com/rle/vol1/iss2/art2> (explaining that legal rules can be interpreted as creating options and presenting a model analyzing the value of these options under optimism and overconfidence); Lee Anne Fennell, *Revealing Options*, 118 HARV. L. REV. 1399, 1401 (2005) (proposing court-awarded option entitlements as an alternative to traditional liability or property rules); Michael S. Knoll, *Put-Call Parity and the Law*, 24 CARDOZO L. REV. 61, 63 (2002) (illustrating how options theory can help circumvent legal rules); Paul G. Mahoney, *Contract Remedies and Options Pricing*, 24 J. LEGAL STUD. 139 (1995) (examining choice between money damages and specific performance by drawing upon options valuation theory); Marie Obidzinski & Bruno Deffains, *Real Options Theory for Law Makers*, (Bureau d’économie theorique et appliquee (BETA), Document de travail No. 04, 2006), available at <http://cournot2.u-strasbg.fr/users/beta/publications/2006/2006-04.pdf> (applying real options analysis to lawmaking); Franco Paresi et al., *The Value of Waiting in Lawmaking*, 18 EURO. J.L. & ECON. 131 (2004) (analyzing optimal timing of legal intervention based upon real options analysis); Robert E. Scott & George G. Triantis, *Embedded Options and the Case Against Compensation in Contract Law*, 104 COLUM. L. REV. 1428 (2004) (characterizing termination rights as embedded options allocating risk).

litigation.²⁴ In addition, the leading texts on the economic analysis of law make little or no mention of real options analysis.²⁵

This Article seeks to narrow that gap by presenting a real options model of litigation in which parties bargain over the allocation of litigation expenditures that are avoided when a case settles early. As previously observed, ours is not the first real options model of litigation,²⁶ but it is the first to incorporate bargaining behavior and the first to generate closed-form solutions that define a lawsuit's settlement value with precision.

B. Summary of Our Model

The litigants in our model are identical, risk-neutral, individually rational agents who share common knowledge about all of a lawsuit's characteristics, including its expected value, the type and value of information that might be disclosed during the litigation, the variance of the value of that information, and each party's litigation costs.²⁷ The litigants also have equal bargaining power and face equal litigation expenditures.²⁸ The claim's terminal expected value is defined as the expected value of the verdict in the event the plaintiff successfully establishes liability. The litigation proceeds in two stages. At the end of the first stage, the parties learn new information about the facts of the case or about the law to be applied to those facts. The plaintiff, having already incurred the costs of prosecuting the claim through the first stage, evaluates the newly disclosed information and then decides either to proceed with the claim, thereby incurring second-stage litigation costs and forcing the defendant to incur those costs as well, or to abandon the claim, thereby saving second-stage litigation expenditures for himself and his opponent. The litigants can settle the case at any point in time. If they settle, they also bargain over the allocation of the litigation costs avoided through the early settlement.

The traditional expected value mode of analysis suggests that this case will

See generally John M. Olin Conference on Real Options and the Law, University of Virginia Law School, Oct. 1-2, 2004, http://www.law.virginia.edu/home2002/html/academics/olin/olin_conference04.htm.

24. See *infra* notes 70-73 and accompanying text.

25. See, e.g., COOTER & ULEN, *supra* note 10 (giving no application of real options analysis to litigation); THOMAS J. MICELI, *ECONOMICS OF THE LAW: TORTS, CONTRACTS, PROPERTY, LITIGATION* 156-200 (1997) (same) [hereinafter MICELI, *ECONOMICS OF THE LAW*]; THOMAS J. MICELI, *THE ECONOMIC APPROACH TO LAW* 243-64 (2004) (same) [hereinafter MICELI, *ECONOMIC APPROACH*]; POLINSKY, *supra* note 14 (same); RICHARD A. POSNER, *ECONOMIC ANALYSIS OF LAW* (6th ed. 2003) (same); STEVEN SHAVELL, *FOUNDATIONS OF ECONOMIC ANALYSIS OF LAW* (2004) (same).

26. See, e.g., Cornell, *supra* note 6.

27. For a complete description of the model, see *infra* Part II.B.

28. The assumptions of equal bargaining power and equal litigation expenditures are relaxed later in the analysis as we perform a series of comparative statics exercises. See *infra* Part IV.C.

settle for its discounted expected value.²⁹ Further, because the litigants are risk-neutral, changes in the variance of the value of the information disclosed during the course of the litigation will not affect the lawsuit's settlement value unless those changes also affect the lawsuit's expected value.

In stark contrast, a real options analysis of precisely the same lawsuit paints a far more intriguing picture of the litigation process and suggests that litigants will rationally settle for amounts that can be far higher or lower than the claim's expected value even if that expected value is held constant. The extent to which the lawsuit's real option settlement value diverges from its expected value depends, in material part, on the variance of the information to be disclosed, even though the parties are risk-neutral and even though we constrain all changes in the variance of the disclosed information to preserve the lawsuit's expected value.³⁰ In the real options framework, variance is a critical determinant of a lawsuit's settlement value because the larger the variance, the more dramatic and potentially valuable the information waiting to be disclosed during the course of the lawsuit and the larger the value of the plaintiff's option to continue or to abandon the litigation in response to that information. Put another way, a lawsuit's variance can be important because it reflects the value of the ability to adjust to newly learned information independently of the litigants' attitudes toward risk.

C. Analytic Implications of a Real Options Approach to Litigation

From an analytic perspective, this rather simple real options model solves several "mysteries" that have vexed students of litigation and generates new insights that have not previously been appreciated in the literature. For example, negative expected value (NEV) lawsuits are defined as lawsuits "in which the plaintiff would obtain a negative expected return from pursuing his suit all the way to trial, that is, one in which the plaintiff's expected litigation costs would exceed the expected judgment."³¹ The literature views these

29. "It is clear that if the plaintiff and the defendant have the same beliefs about the trial outcome, then there should always exist mutually beneficial settlements, because they can each escape trial costs by settling." SHAVELL, *supra* note 25, at 402. Under our assumptions, the mutually beneficial settlement would be for the lawsuit's expected value because each party avoids precisely the same amount of litigation expenditures and each is equally powerful in settlement negotiations. *See infra* Part III.A.

30. We achieve this result by assuming that the underlying probability distributions are drawn from a family of distributions that display mean-preserving spreads. *See infra* note 63. The assumption of a mean-preserving spread can be abandoned in more complex models. *See infra* Part V.C. We also demonstrate that settlement values, and the very credibility of the underlying lawsuit, can depend on the sequence in which litigation expenses are incurred, differences in the parties' relative bargaining power, and a litigant's ability to impose disproportionate litigation expenses on an opponent. *See infra* Appendix, Propositions 11-13.

31. Lucian Arye Bebchuk, *A New Theory Concerning the Credibility and Success of Threats To Sue*, 45 J. LEGAL STUD. 1, 1 (1996).

lawsuits as “puzzling” and asks, “Why would a defendant be willing to pay a positive amount in settlement to a plaintiff who would not actually go through with the trial?”³² While several articles offer a range of explanations for the existence of NEV litigation,³³ real option theory offers a simpler rationale: a NEV lawsuit is merely an out-of-the-money call option that a plaintiff will rationally pursue as long as the cost of acquiring the option is less than the option’s value.³⁴ Therefore, just as it makes sense for an investor to purchase a call option to buy a share of stock for \$100 even though its current price is \$90—provided that the option’s price is low enough and its volatility (meaning the chance of some surprising good news coming to the market before the option expires) is high enough—it makes sense for a plaintiff to pursue a risky claim with a negative expected value if the cost of pursuing the claim is low enough and the possibility of uncovering some sort of smoking gun that will lead to a recovery higher than the claim’s expected value is large enough. NEV lawsuits can therefore reflect perfectly rational assessments about the implications of the learning, abandonment, and other real options embedded in the litigation process. Indeed, we formally demonstrate that every NEV lawsuit can become credible if the variance of the information to be disclosed during the litigation is sufficiently high.³⁵

The real options perspective also suggests that risk-neutral defendants can act as though they are risk-averse and that risk-neutral plaintiffs can act as though they are risk-seeking for reasons that have nothing to do with risk aversion.³⁶ Instead, in a large category of cases, increasing uncertainty over the

32. SHAVELL, *supra* note 25, at 420.

33. See, e.g., Bebchuk, *supra* note 31 (suggesting divisibility of litigation expenses as a potential explanation for NEV litigation); Lucian Arye Bebchuk, *Suing Solely To Extract a Settlement Offer*, 17 J. LEGAL STUD. 437 (1988) (suggesting imperfect information as a cause of negative expected value litigation); Avery Katz, *The Effect of Frivolous Lawsuits on the Settlement of Litigation*, 10 INT’L REV. L. & ECON. 3, 4 (1990) (proposing a model that explains NEV suits as an “asymmetric information game”); David Rosenberg & Steven Shavell, *A Model in Which Suits Are Brought for Their Nuisance Value*, 5 INT’L REV. L. & ECON. 3 (1985) (proposing a model where the ordering of the parties’ expenses leads to settlement in NEV suits); see also SHAVELL, *supra* note 25, at 420-23 (offering a summary of this literature).

34. A call option is an option to buy an underlying asset, while a put option is an option to sell an underlying asset. A call option is “out of the money” when the price of the underlying instrument is less than the option’s strike price. The fact that the option is out of the money

does not mean that the right to buy the asset . . . has no value. In fact, from a *client’s point of view*, [the price of the underlying asset] may move up during the interval [over which the option can be exercised] and end up exceeding [the strike price by the time of the option’s expiration].

SALIH N. NEFTCI, *PRINCIPLES OF FINANCIAL ENGINEERING* 199 (2004).

35. See *infra* Appendix, Proposition 3.

36. Cornell, *supra* note 6, at 179, contains a similar observation, but does not suggest that there are discontinuities in the relationship between a lawsuit’s settlement value and its underlying variance or that settlement value might not depend on variance if variance is sufficiently low.

outcome of the litigation causes the plaintiff's claim to become more valuable.³⁷ The defendant will therefore rationally pay more to settle the case for reasons that have nothing to do with risk aversion and everything to do with the value of the plaintiff's option to adjust litigation expenditures in response to new information. Thus, to the extent that the literature on the economic analysis of litigation introduces assumptions regarding the parties' relative risk aversion, those assumptions may not be necessary to derive those models' results.³⁸

Our model also suggests that litigation settlement values can behave quite differently from option values commonly derived in financial markets. A financial option's value is generally a monotonically increasing function of the variance of the underlying instrument.³⁹ In contrast, the model presented in this Article suggests that, because of sudden changes in a lawsuit's credibility, settlement values can be discontinuous, nonmonotonic functions of a lawsuit's underlying variance.⁴⁰ In particular, when variance is sufficiently low, a lawsuit can have a settlement value that initially equals its expected value, but as variance increases, the lawsuit's settlement value can suddenly drop in a discontinuous manner, and then, as variance continues to increase, settlements can continue to climb to valuations far higher than the lawsuit's *ex ante* expected value.⁴¹ The model also suggests that some NEV lawsuits can be subject to "dead zones"—regions of variance over which the lawsuit suddenly loses and then regains credibility.⁴² The presence of discontinuities and dead zones suggests that small differences in expectations as to a lawsuit's variance can cause significant differences in a lawsuit's settlement value, even when the litigants agree about the lawsuit's expected value.

37. See, e.g., *infra* Appendix, Proposition 10.

38. See, e.g., COOTER & ULEN, *supra* note 10, at 410 (discussing explanations of litigation based upon risk aversion or loss aversion); POLINSKY, *supra* note 14, at 139; POSNER, *supra* note 25, at 569. For examples of analyses based upon attitudes towards risk to explain observed litigation, see Bruce L. Hay & Kathryn E. Spier, *Settlement of Litigation*, in 3 THE NEW PALGRAVE DICTIONARY OF ECONOMICS AND THE LAW 442 (Peter Newman ed., 1998); Russell Korobkin & Chris Guthrie, *Psychological Barriers to Litigation Settlement: An Experimental Approach*, 93 MICH. L. REV. 107 (1994); Jeffrey J. Rachlinski, *Gains, Losses, and the Psychology of Litigation*, 70 S. CAL. L. REV. 113 (1996) (relying on the psychology of choice and prospect theory to suggest that defendants will adopt risk-seeking strategies and that plaintiffs will adopt risk-averse strategies); David Rosenberg, *Mass Tort Class Actions: What Defendants Have and Plaintiffs Don't*, 37 HARV. J. ON LEGIS. 393 (2000); Richard S. Markovits, *Tort Related Costs and the Hand Formula for Negligence* (Univ. of Tex. Sch. of Law, Law & Econ. Res. Paper No. 036, 2004), available at <http://ssrn.com/abstract=649724>; James B. Heaton, *Settlement Pressure* (Feb. 2004) (unpublished manuscript), available at <http://ssrn.com/abstract=300959>.

39. See, e.g., STEPHEN A. ROSS ET AL., CORPORATE FINANCE 630 (7th ed. 2005); PETER G. ZHANG, EXOTIC OPTIONS 77 (2d ed. 1998) ("[O]ption writers normally charge more for options with higher volatility, other things being equal. Therefore, vegas [the measure of how fast an option price changes with its volatility] of all options are always positive.").

40. See discussion *infra* Parts III.C.2-3, IV, Appendix.

41. See discussion *infra* Parts III.C.2-3, IV, Appendix.

42. See discussion *infra* Parts III.C.2-3, IV, Appendix.

These discontinuities have a straightforward analogue in the real world of litigation. Consider a case in which the plaintiff's claim hinges critically on the testimony of a single witness or on the outcome of a key judicial ruling. Immediately after the witness testifies or after the ruling issues, the value of the plaintiff's claim will either be sharply higher or lower than the expected value of the claim just prior to the resolution of the uncertainty. The plaintiff's willingness to pursue the lawsuit will also rationally change in response to the new information. If the information is favorable to the plaintiff, then he will be willing to pay more to continue to pursue the claim; conversely, if the information is unfavorable, he will be willing to pay much less. The act of revealing new information can thereby cause a discontinuity in settlement value, as the information can cause the price of settlement to increase or decrease, sometimes rather sharply. Moreover, as we later demonstrate, if we modify our model slightly to allow for differential expectations, small differences in expectations as to the variance of the information to be disclosed (even when the litigants agree as to the claim's expected value) can be sufficient to cause the parties to expend material sums on litigation costs just to settle the case after some uncertainty is resolved but prior to judgment.⁴³ This pattern replicates the one most often observed in actual litigation: a complaint is filed, litigation expenses are incurred, and lawsuits are settled after some uncertainty is resolved but prior to final judgment.⁴⁴

Our model further suggests that a lawsuit's settlement value can depend critically on the sequence in which the litigants incur expenses, even if the total value of each party's litigation expenditures is held constant and the sequence of expenditures is identical for both litigants.⁴⁵ For example, if a plaintiff is able to defer a larger fraction of his litigation expenditures until a sufficient degree of uncertainty has been resolved, then the value of a plaintiff's claim will increase.⁴⁶ The intuition behind this result is that a plaintiff can commit to a relatively small investment before learning most of the information about a lawsuit's value. A card game that requires a smaller ante before a player sees the cards he is dealt is, all other factors equal, worth more than the same gamble with a higher required buy-in. The same phenomenon holds true in litigation. We also demonstrate that changes in the parties' relative bargaining power and in their relative litigation costs can have dramatic and disproportionate effects on a lawsuit's equilibrium settlement value.⁴⁷

43. See *infra* Appendix, Proposition 14 and subsequent discussion.

44. See, e.g., Charles Silver, *Does Civil Justice Cost Too Much?*, 80 TEX. L. REV. 2073, 2107-09 (2002) (collecting empirical studies finding that the percentage of civil cases that result in a verdict has declined over time and is currently hovering around three percent). "Studies repeatedly show that the overwhelming majority of disputes end without trials." *Id.* at 1207.

45. See discussion *infra* Parts III.C.2-3, IV, Appendix.

46. See discussion *infra* Parts III.C.2-3, IV, Appendix.

47. See discussion *infra* Parts III.C.2-3, IV, Appendix.

Our model's ability to generate comparative statics results that describe, with precision, the implications of changes in the sequence and magnitude of litigation costs, in the uncertainty involved in a lawsuit, and in the parties' relative bargaining power, suggests that the model is additionally useful as a means of analyzing the effects of procedure *qua* procedure. More specifically, procedural rules can be described in terms of their effects on the timing and magnitude of the parties' litigation costs and on the uncertainty of the litigation process. Because the real options framework can be adjusted to incorporate several simultaneous variations to each of these parameters, it provides a robust model for the analysis of procedural reform of the litigation process.

The model also readily describes the "trade-off" between changes in procedural rules that might make lawsuits harder or easier for plaintiffs to prosecute and changes in substantive standards that might make lawsuits more or less valuable to plaintiffs if they prevail. Substantive standards are generally defined as rules of law that govern the existence of liability and the remedies imposed in the event liability is established.⁴⁸ Procedural rules are generally defined as governing the process of pleading, proof, discovery, and all other matters related to the environment in which the litigants argue as to whether the substantive standards have been satisfied.

D. Normative Implications of a Real Options Approach to Litigation

These observations suggest that the real options perspective also has normative implications for the economic analysis of litigation. Substantive rules of law generally define a lawsuit's expected value, i.e., the circumstances under which liability will be found and the magnitude of the damages to be awarded contingent on that liability. A lawsuit's expected value in our model equals its terminal value and captures the economic implications of applicable substantive standards. From a real options perspective, the difference between a lawsuit's terminal or expected value and its option value, therefore, describes the economic value of process, learning, and uncertainty. If the settlement option value exceeds the terminal value, then the procedural environment combined with the uncertainty inherent in the litigation process is pro-plaintiff relative to the governing substantive rule of law. However, if the terminal value exceeds the settlement option value, then the procedural environment combined with the uncertainty inherent in the litigation process is pro-defendant relative to the governing substantive rule of law.

48. Polinsky adopts an essentially identical distinction between substantive and procedural rules. POLINSKY, *supra* note 14, at 141-45. Examples of substantive standards include the rules of tort liability and breach of contract, together with the rules that establish damage measures for torts and contract breaches. Examples of procedural rules include the rules of evidence and of civil and criminal procedure, together with principles of substantive and personal jurisdiction, and all other matters on which the courts rely to determine how to apply substantive rules of law.

Normative principles that seek to generate socially optimal levels of compensation and deterrence through the litigation process, such as the Hand Formula, are generally expressed as substantive rules.⁴⁹ Those substantive rules, and propositions regarding their optimality, are usually derived without regard either to the litigation's procedural environment or to the ambiguity or vagueness embedded in the substantive standards themselves.⁵⁰ The assumption implied by this mode of analysis is that the procedural environment and uncertainty in the definition or application of the substantive standard itself will not, on average and over time, cause actual awards or settlement amounts to diverge from the lawsuit's expected value because litigation would then lead to a systematically biased, socially suboptimal result, even in a risk-neutral world.

It is well understood, however, that private incentives to litigate can diverge from socially optimal incentives in either direction and that a wide range of factors can contribute to these divergences.⁵¹ A real options perspective suggests another, perhaps more fundamental and pervasive cause for this divergence. Even if one constructs an expected value model in which the private and social incentives to litigate are identical, and in which litigants are risk-neutral, equally powerful, and symmetrically informed, a real options analysis demonstrates that the simple presence of uncertainty can be sufficient to cause a divergence between private and socially optimal incentives to litigate.⁵² It follows that the assumptions necessary to equate private and social incentives to litigate may be far stronger than previously recognized and may include the requirement that uncertainty is sufficiently low even if litigants

49. See, e.g., COOTER & ULEN, *supra* note 10, at 333-37; POSNER, *supra* note 25, at 167-71.

50. See, e.g., COOTER & ULEN, *supra* note 10, at 333-37; POSNER, *supra* note 25, at 167-71. Ambiguity describes "situations in which an expression can be understood in more than one distinct sense (e.g., *river bank* versus *savings bank*), while [vagueness] refers to problems of borderline cases (e.g., a piece of ceramic that is not clearly a bowl or a cup, but something in between)." Lawrence M. Solan, *Pernicious Ambiguity in Contracts and Statutes*, 79 CHI.-KENT L. REV. 859, 860 (2004). Although linguists and philosophers tend to be precise in drawing distinctions between the concepts of ambiguity and vagueness, the legal literature tends to conflate all forms of indeterminacy under either label without regard to formal distinctions between the two. Because either source of uncertainty is sufficient to drive the model's results, we follow the legal literature and do not here distinguish between the formal notions of ambiguity and vagueness.

51. SHAVELL, *supra* note 25, at 391; accord A. Mitchell Polinsky & Steven Shavell, *Economic Analysis of Law*, in THE NEW PALGRAVE DICTIONARY OF ECONOMICS (Lawrence Blume & Steven Durlauf eds., 2d ed. forthcoming 2006) (manuscript at 22, available at <http://ssrn.com/abstract=859406> (last visited Mar. 15, 2006)) (citing Steven Shavell, *The Social Versus the Private Incentive To Bring Suit in a Costly Legal System*, 11 J. LEGAL STUD. 333 (1982); Steven Shavell, *The Fundamental Divergence Between the Private and the Social Motive To Use the Legal System*, 26 J. LEGAL STUD. 575 (1997)). For a catalogue and discussion of these causes of divergence, see SHAVELL, *supra* note 25, at 391-401, 411-15. See also *infra* notes 130-131 and accompanying text.

52. See *infra* Part V.C for further discussion of this point.

are risk-neutral. Because uncertainty is, however, prevalent in the litigation process, it is far from clear that it could ever be reduced to the degree necessary to equate social and private incentives to litigate in a real options model.⁵³

These observations suggest an “impossibility conjecture” with potentially significant implications for normative analyses of the litigation process. If it is true that uncertainty cannot be reduced to a degree sufficient to equate the private and social incentives to litigate (by causing lawsuits’ option settlement values to equal their expected or terminal values), then the real options perspective suggests that no number of other heroic assumptions about the efficiency or fairness of the private litigation process will be sufficient to equate private and social incentives to litigate. Put another way, even in a risk-neutral world, uncertainty alone can be sufficient to throw a monkey wrench into the proposition that private litigation can systematically be relied upon to achieve optimal social objectives.

This “impossibility conjecture” calls into question the common assumption that it is possible to craft substantive rules of law that can reach socially optimal results without attention to the procedural environment in which those rules will be litigated, the ambiguities inherent in the rules’ articulation, and the unavoidable uncertainties of the litigation process.⁵⁴ If this perspective is correct, then substance cannot be separated from procedure in pursuit of socially optimal rules of law. This observation suggests that the pragmatic pursuit of socially optimal rules of law could benefit from more generalized models that integrate the rules of legal procedure with the definition of substantive legal standards and the uncertainty generated by each.⁵⁵ Real option theory provides just such a modeling tool and for that reason has the potential to make valuable contributions to the normative analysis of the litigation process in addition to its more technical, analytic contributions.

II. A REAL OPTIONS MODEL OF LITIGATION THAT INCORPORATES BARGAINING

Real options analysis (ROA) provides a powerful set of modeling tools that can be applied to describe and value the potential benefits of decisionmaking

53. For a discussion of various sources of uncertainty in the litigation process, including institutional factors that could make it difficult if not impossible to reduce uncertainty to a sufficient degree, see *infra* notes 132-140 and accompanying text.

54. This observation is hardly novel from the perspective of traditional legal realists who emphasize a host of nonsubstantive factors as essential in determining the outcome of the litigation process. See, e.g., Frank B. Cross, *Legal Process, Legal Realism, and the Strategic Political Effects of Procedural Rules 2* (Univ. of Tex. Sch. of Law, Law & Econ. Working Paper No. 06, 2005), available at <http://ssrn.com/abstract=837665> (“Realists argue that the apparently neutral procedural requirements are created or applied precisely for their ideological implications.”).

55. A similar observation is found in Polinsky, but without reference to the divergence between private and social incentives that can be caused by the simple presence of uncertainty. POLINSKY, *supra* note 14, at 144-45.

flexibility when managing a project. First, ROA provides a discipline that induces management to define various forms of optionality that can be inherent in an investment opportunity. This objective is typically achieved through the construction of decision trees that articulate the sequence in which a project will proceed and the nature of the uncertainty and management flexibility that arises at each step of this process.⁵⁶ Second, ROA offers a family of techniques for quantifying the often subjective uncertainty that arises in the pursuit of investment projects and lawsuits alike.⁵⁷ Third, ROA offers techniques for combining these observations to generate a single “option value” for a project that takes into account the project’s inherent uncertainty and flexibility.⁵⁸ Although many of these techniques can be quite complicated and can require a high degree of mathematical sophistication, the basic principles of ROA are easily described by way of illustration and require no mathematical sophistication beyond the ability to add and subtract.

We begin by discussing a simple example of ROA as applied to a research and development project. This example, presented in Part II.A, illustrates a situation in which the value of management flexibility leads ROA to conclusions that differ dramatically from those generated by more traditional NPV and DCF analyses. The ability to model and value management flexibility in response to new information distinguishes ROA from more traditional models of the litigation process and serves as the basis for the formal model we present in Part II.B. We discuss prior literature in Part II.C, where we draw particular emphasis to the earlier models of Bebchuk and Cornell, each of which constitutes a special case of the more general model described in this Article.

A. An Example of Real Options Analysis Applied to a Research and Development Project

To illustrate the difference between ROA and more traditional DCF and NPV analyses, consider a hypothetical venture in which a pharmaceutical company has an opportunity to develop a drug that requires an outlay of \$3 million today to support a research and development project that has only a 10% chance of success. If the research succeeds, the company will have to

56. See, e.g., BREALEY ET AL., *supra* note 12, at 257-66; Tom Copeland & Peter Tufano, *A Real-World Way To Manage Real Options*, HARV. BUS. REV., Mar. 2004, at 90, 94-95. The earliest example of which we are aware that applies rigorous decision tree analysis to litigation strategy is in Mark B. Victor, *The Proper Use of Decision Analysis To Assist Litigation Strategy*, 40 BUS. LAW. 617 (1985). See also *id.* at 617 n.1 (citing to earlier applications of decision tree analysis dating back to 1981). Victor’s analysis clearly anticipates the application of real option theory to litigation analysis but falls short of expressing a real option approach because it fails to recognize or to value any form of optionality inherent in the decision tree structure it presents for litigation decisionmaking.

57. See, e.g., Copeland & Tufano, *supra* note 56, at 94.

58. *Id.* at 95-96.

invest an additional \$80 million (discounted to present value) to build the manufacturing facilities necessary to bring the drug to market. This research project will also allow this manufacturer to determine whether the drug can be sold over-the-counter (OTC) or whether it must be sold with a prescription. If the Food and Drug Administration (FDA) approves this drug for OTC sales, it will generate net cash flow with a discounted present value of \$160 million; if the FDA approves this drug for prescription sales only, however, it will generate net cash flow with a discounted present value of \$40 million. The company estimates that these two outcomes are equally probable. Thus, if the research project is successful, the discounted present value of its net cash flow is \$100 million (a 50% probability of \$160 million in returns plus a 50% probability of \$40 million in returns).

If the company applies traditional DCF or NPV modeling techniques, it calculates that the project has a 10% chance of generating a net income stream worth \$20 million (\$100 million representing the expected value of net revenues, less \$80 million in launch costs) and would value that opportunity at \$2 million (10% of \$20 million). However, because the initial outlay would cost \$3 million, traditional DCF and NPV analyses would suggest that the project has a net negative value of \$1 million and should not be pursued.

ROA, in contrast, reaches precisely the opposite conclusion because it recognizes management's ability to abandon the project if it learns that the FDA will approve the drug for prescription sales only. In particular, if the research indicates that the FDA will approve the drug for prescription sales only, then the company will make no further investment because investing \$80 million to build a manufacturing plant for a return of \$40 million is not profitable. The project would then be abandoned with a downside equal to a sunk cost of \$3 million. However, if the research indicates that the FDA would approve OTC sales, then the company would rationally invest an additional \$80 million in manufacturing facilities to produce the drug that would generate a positive cash flow of \$160 million, for a positive return of \$80 million.

Thus, as of the end of its research and development phase, the company recognizes that if the project is successful in the sense of producing an approvable drug, there is a 50% chance that the project will simply be abandoned with no additional cost and a 50% chance that the project will generate \$80 million. The value of this project viewed from the conclusion of its research and development phase is therefore \$40 million, but only if we assume that research has already been successfully completed. The probability of success is, however, only 10%, so the expected value of those returns must be discounted to \$4 million (10% of \$40 million). Because the cost of conducting the research necessary to generate that \$4 million income stream is only \$3 million, ROA would urge that the company undertake the project.

ROA reaches a conclusion contrary to the traditional DCF and NPV analyses because it expressly models and values management's option to abandon the project if the results of the research phase indicate that the drug

will not generate revenues sufficient to cover its costs. Traditional NPV and DCF approaches suppress the value of this optionality because they calculate the project's expected value based on an implied assumption that management retains no such flexibility.⁵⁹ Indeed, as uncertainty over potential revenues increases, management's option to abandon becomes more valuable, and the divergence between the results of ROA and NPV grows.

To illustrate, we can increase the variance of the drug's expected value after FDA acceptance so that FDA review will reveal that the drug is either worthless or that it will generate net cash flow of \$200 million, each with equal probability. Because the drug still has an average value of \$100 million in sales, by the logic described above, the traditional NPV or DCF approaches would again urge that the project not be pursued. In sharp contrast, however, the ROA approach would find that the project is now even more valuable because there is a 10% chance that the project will lead to a 50% probability of a payoff of \$120 million (\$200 million in returns less the \$80 million necessary to build the manufacturing facility). That return is worth \$6 million ($\$6 \text{ million} = 10\% * 50\% * \120 million), a 50% increase over the \$4 million return observed at the lower level of uncertainty. Thus, as uncertainty increases, the value of management flexibility can also increase, and the difference between a real options perspective and the traditional DCF and NPV perspectives becomes all the more significant.

B. *The Formal Definition of Our Model*

Our model builds upon this real investment example by formalizing it into a model of the litigation process and by adding the feature that the litigants can bargain over the allocation of the surplus generated by the decision to settle a lawsuit early. When Stage 1 starts, a plaintiff must spend a fixed amount C_{p1} to initiate the lawsuit and a defendant is initially forced to spend C_{d1} to defend the lawsuit.⁶⁰ Additional information concerning the litigation is revealed to both parties at the end of Stage 1. After that information is revealed, the plaintiff has an option either to abandon the litigation,⁶¹ thereby avoiding the expenditure of the next stage's fixed litigation costs of C_{p2} , or to continue through Stage 2 in order to collect a judgment. If the plaintiff decides to continue through into Stage 2, then he incurs fixed costs of C_{p2} and the defendant is forced spend a

59. See, e.g., BREALEY ET AL., *supra* note 12, at 257-66.

60. We assume that this defendant is forced to incur this expenditure because if he fails to do so he will incur a default judgment whose consequences to him are more severe than spending Stage 1 litigation costs.

61. We recognize that a plaintiff's ability to dismiss an action voluntarily at no cost may depend on the stage of the lawsuit and on a variety of additional factors. See generally Michael E. Solimine & Amy E. Lippert, *Deregulating Voluntary Dismissals*, 36 U. MICH. J.L. REFORM 367, 376-78, app. (2003). We assume costless abandonment solely to simplify the analysis.

fixed amount C_{d2} in defense.⁶² The court announces its verdict at the end of Stage 2. Before that, both parties can settle the lawsuit at any point without incurring additional costs.

We assume the litigants share common expectations regarding the initial expected value of the court's judgment awarded to the plaintiff if the lawsuit is pursued to its conclusion. We denote this value by μ . Uncertainty regarding information revealed during the litigation is described by a binary random variable X that assumes a value we denote by A with probability p , and a value we denote by B with probability $(1 - p)$. We assume the initial expected value of μ is fixed. This assumption means that p , A , and B must satisfy this initial condition: $pA + (1 - p)B = \mu$. In other words, the information revealed at the end of Stage 1 is constrained to have an initial expected value of μ . The pair of possible outcomes, A and B , describes a family of probability distributions that differ by mean-preserving spreads.⁶³ For ease of exposition, and without any loss of generality, we assume that $A \geq B$.

Moreover, because p is a probability that is fixed in value between zero and one, the variance of any member of this family of probability distributions is uniquely defined by either A or B .⁶⁴ It also follows that if pA increases, then $(1 - p)B$ must simultaneously decrease in order to maintain the mean-preserving condition: $pA + (1 - p)B = \mu$. Further, because the litigants share common expectations regarding the variance of the uncertainty they face, they must agree on the potential values of A and B .⁶⁵

62. Again, if a defendant fails to incur this expense, he will incur a default judgment whose consequences to him are more severe than spending Stage 2 litigation costs.

63. Imprecisely speaking, probability distribution A is a mean-preserving spread of probability distribution B if A is obtained by a mean-preserving increase in risk from B . For precise discussions of mean-preserving spreads, see, for example, Josef Hadar & William R. Russell, *Rules for Ordering Uncertain Prospects*, 59 AM. ECON. REV. 25 (1969); Michael Rothschild & Joseph E. Stiglitz, *Increasing Risk: I. A Definition*, 2 J. ECON. THEORY 225, 227-29 (1970); Michael Rothschild & Joseph E. Stiglitz, *Increasing Risk: II. Its Economic Consequences*, 3 J. ECON. THEORY 66 (1971). See also Eric Rasmusen, *When Does Extra Risk Strictly Increase an Option's Value?* (Nov. 17, 2005) (unpublished manuscript), available at http://www.rasmusen.org/papers/options_rasmusen.pdf (revisiting the notion of mean-preserving spreads and introducing related notions of riskier distributions).

64. See *infra* Appendix, Proposition 9.

65. The interpretation of the model becomes significantly more complex when B has a negative value, implying that the plaintiff must make a payment to the defendant in the amount of B . Such a payment could come as the result of a counterclaim brought by the defendant. This interpretation does not, however, fit comfortably with our assumption of costless abandonment because a rational defendant would not abandon a valuable counterclaim. We are grateful to Allan Erbsen and Michael Knoll for related observations. Alternatively, negative values for B can be modeled as a form of a costly abandonment option where the additional cost of abandonment is paid to defendant. This interpretation of the model is, however, a special case of the more general problem posed by costly abandonment, which we address in future extensions of this model. See *infra* Part V.C.

Another way to interpret a negative value for B within the costless abandonment framework would be to view the payment as a court-ordered sanction that plaintiff would be required to pay to the defendant if the plaintiff continued to litigate the matter into Stage 2.

We denote the litigants' relative bargaining power by a parameter α , which defines the fraction of the surplus generated by a settlement that a plaintiff captures. We initially assume that the litigants' bargaining power is fixed and equal, so that $\alpha = 0.5$. We later relax this assumption.⁶⁶

The litigants share common knowledge about litigation costs, μ , p , A (or equivalently, B), α , and about each litigant being risk-neutral and individually rational, in the sense that each behaves so as to maximize its expected wealth.

Our model can be viewed as describing a relatively simple lawsuit in which risk-neutral litigants confront only a single uncertain variable. That variable can, for example, describe third-party witness testimony that is equally unknown to the plaintiff and to the defendant. Although the content of that third-party testimony might be unknown, the parties concur as to the testimony's implications for the expected value and variance of the ultimate judgment. Alternatively, the uncertainty can describe a particular court's choice between two potential interpretations of a statute to be applied to a set of stipulated facts. The litigants share common expectations as to the likelihood that the court will select one interpretation of the law over another and as to the implication of each choice for the ultimate judgment.

But in order to present the court with an opportunity to resolve this uncertainty, each party must first incur Stage 1 litigation costs. These costs are, for example, discovery expenses if uncertainty is fact driven or legal research and briefing costs if uncertainty derives from a pure question of law. After the uncertainty is resolved, the plaintiff has an option to continue to pursue the case in order to collect a judgment that both parties, viewing the litigation as of its inception, agree has an initial expected value of μ . However, in order to cause payment of the judgment, the plaintiff must spend an additional C_{p2} either for additional briefing on questions of law or for further factual development of the record. If the plaintiff decides to continue with the lawsuit, the defendant is forced to incur costs of C_{d2} . Alternatively, if the plaintiff views the revealed information as being sufficiently unfavorable, he can abandon the lawsuit at no

However, if the magnitude of that sanction is constrained to reflect the additional litigation costs that would arise only beyond the point of information disclosure, as is suggested by the current structure of Federal Rule of Civil Procedure 11, then the magnitude of the negative value of B would be constrained not to exceed C_{d2} . See, e.g., CHARLES ALAN WRIGHT & ARTHUR R. MILLER, FEDERAL PRACTICE AND PROCEDURE: CIVIL 3d § 1336.3 (2004).

The interpretive difficulties associated with negative values of B are an unavoidable byproduct of our assumption of a binary distribution with a mean-preserving spread. Given the constraints of such a distribution, the only possible means of generating a sufficiently large variance is, on occasion, by assuming a negative value of B . If, however, we assume different forms of probability distributions that are truncated to have no negative values, such as the lognormal, then none of these interpretive issues arise and the qualitative results of our model remain unchanged. See Joseph A. Grundfest, Peter H. Huang & Ho-Mou Wu, A Continuous Real Options Litigation Bargaining Model (Jan. 2006) (unpublished manuscript on file with the authors) (generalizing this model to lognormal probability distributions for which negative values are not possible).

66. See *infra* Appendix, Proposition 13.

additional cost.⁶⁷

Our model can thus be described as containing a compound real option⁶⁸ consisting of a learning option and a continuation or abandonment option.⁶⁹ A plaintiff can exercise a learning option by filing a lawsuit and deciding to invest a premium of C_{p1} in order to learn the information that is disclosed at the end of Stage 1. A continuation option arises after that information is revealed, because the plaintiff has an option to continue this litigation by investing a further C_{p2} .

The options generated by litigation, however, differ from standard financial market call options. When a plaintiff files a lawsuit, the plaintiff acquires a call option whose terminal value is defined by the lawsuit's judgment upon its conclusion. Legal fees and other costs constitute premiums that a plaintiff must pay to third parties, such as lawyers and experts, and not to a defendant, in order to optimize that lawsuit's value. A defendant is forced to write a plaintiff's call option and becomes contingently liable for a judgment that might be rendered at the lawsuit's conclusion. However, instead of receiving a premium in consideration of bearing this risk, a defendant must also pay litigation costs to lawyers and to other third parties in an effort to minimize the total value of the plaintiff's claim.

This is not to suggest that a defendant receives no compensation for writing a plaintiff's call option. If a defendant appreciates that his activities—whether in the form of selling a pharmaceutical, driving a car, or offering a security for sale—give rise to the risk of litigation, then he could rationally include a “litigation premium” in the price of the goods sold or action taken. So applied, our real option pricing model could in principle serve as a method for calculating the value of that litigation premium.

However, even if a defendant does charge such a premium, a distinction remains between the operation of litigation and financial call options. In particular, a financial option defines a zero-sum process in the sense that an

67. See Solimine & Lippert, *supra* note 61. We are aware that, as a descriptive matter, plaintiffs rarely abandon litigation midstream unless there is a judicial ruling, such as the grant of a motion to dismiss with prejudice or of summary judgment. A plaintiff's decision not to appeal such an adverse ruling, or to refile the action, if possible, would then be tantamount to abandonment of the claim. Thus, the model can be interpreted more narrowly so that the information disclosed at the beginning of Stage 2 is precisely the sort of information that is in fact correlated with dismissal by court order with no subsequent effort to reinstitute the claim. Alternatively, as suggested to us by Paul Mahoney, Stage 1 can be viewed as prelitigation investigation and Stage 2 as the conduct of the lawsuit itself after the complaint has been filed.

68. Compound options provide the “possibility of stopping mid-stream . . . [where] each stage completed (or dollar invested) gives the firm an option to complete the next stage (or invest the next dollar).” DIXIT & PINDYCK, *supra* note 19, at 320.

69. For a description of various forms of real options, including continuation and abandonment options and staged investment options that provide parties with the opportunity to invest specifically in order to gain additional information, see, for example, HAN T.J. SMIT & LENOS TRIGEORGIS, STRATEGIC INVESTMENT: REAL OPTIONS AND GAMES 108-09 tbl.3.1 (2004); TRIGEORGIS, *supra* note 1, at 2-3.

option holder's gain (loss) must equal that option writer's loss (gain), taking into account both the premiums that are paid for the option and the option's terminal value. In contrast, litigation options are sure to be zero-sum only in the terminal value of the judgment that the defendant might be required to pay to the plaintiff. Litigation is not zero-sum in the aggregate because the premiums paid by each party are not paid to each other and because each party must bear its own litigation expenses with no requirement that these expenses offset each other in any meaningful sense.

C. Related Literature

The literature on the economic analysis of litigation is voluminous,⁷⁰ but it has previously failed to integrate, in a single model, litigants' opportunities for learning, adaptation, and strategic interaction. Several articles consider elements of optionality in litigation,⁷¹ and some apply options perspectives to litigation.⁷² A small number of articles apply formal options analysis to litigation.⁷³ All these articles, however, differ from ours in terms of issues they

70. The traditional, early citations to the literature include: John P. Gould, *The Economics of Legal Conflicts*, 2 J. LEGAL STUD. 279 (1973); William M. Landes, *An Economic Analysis of the Courts*, 14 J.L. & ECON. 61 (1971); Richard A. Posner, *An Economic Approach to Legal Procedure and Judicial Administration*, 2 J. LEGAL STUD. 399 (1973). More recently, several books contain excellent reviews of the literature. See, e.g., ROBERT G. BONE, *CIVIL PROCEDURE: THE ECONOMICS OF CIVIL PROCEDURE* 20-40, 71-96 (2003) (presenting the basic model of litigation and settlement); COOTER & ULEN, *supra* note 10, at 388-426 (same); MICELI, *ECONOMICS OF THE LAW*, *supra* note 25, at 157-80 (same); MICELI, *ECONOMIC APPROACH*, *supra* note 25, at 243-64 (same); POLINSKY, *supra* note 14, at 135-46 (same); POSNER, *supra* note 25, at 563-609 (same); SHAVELL, *supra* note 25, at 387-470 (same).

71. See, e.g., C. Frederick Beckner, III & Steven C. Salop, *Decision Theory and Antitrust Rules*, 67 ANTITRUST L.J. 41 (1999) (presenting a multistage decision model of sequential legal procedure, which solves for the optimal standards of summary disposition that minimize the sum of information and error costs and the optimal sequence of legal and factual issues that a court should take up); William M. Landes, *Sequential Versus Unitary Trials: An Economic Analysis*, 22 J. LEGAL STUD. 99 (1993) (addressing when a court should hold separate trials for liability versus damages as opposed to just one unified trial that considers both issues); Warren F. Schwartz, *Severance—A Means of Minimizing the Role of Burden and Expense in Determining the Outcome of Litigation*, 20 VAND. L. REV. 1197 (1967) (discussing the policy considerations of severing certain issues in litigation).

72. See, e.g., Richard A. Nagareda, *Autonomy, Peace, and Put Options in the Mass Tort Class Action*, 115 HARV. L. REV. 747, 755-58 (2002); Guy Halfteck, *The Class Action as a Financial Call Option* (Harvard Univ. John M. Olin Ctr. for Law, Econ. & Bus., Discussion Paper No. 466, 2004), available at <http://ssrn.com/abstract=528043>.

73. See, e.g., William J. Blanton, *Reducing the Value of Plaintiff's Litigation Option in Federal Court: Daubert v. Merrell Dow Pharmaceuticals, Inc.*, 2 GEO. MASON L. REV. 159, 160 (1995) (evaluating the consequences of changes in evidentiary rules on plaintiffs' incentives to file lawsuits); Peter H. Huang, *Lawsuit Abandonment Options in Possibly Frivolous Litigation Games*, 23 REV. LITIG. 47 (2004) (offering a real options analysis of litigation abandonment options that is related to our analysis); Peter H. Huang, *A New Options Theory for Risk Multipliers of Attorney's Fees in Federal Civil Rights Litigation*, 73

study, their treatment of information revelation, and their analysis of strategic interactions between litigants.

Of the published works that consider the implications of divisibility or optionality in litigation, the models presented by Bebchuk⁷⁴ and Cornell⁷⁵ are the closest antecedents to ours. Bebchuk presents a model in which the plaintiff has an option to subdivide his litigation expenses into stages. The plaintiff can abandon the litigation at no cost at the end of each stage and can also bargain with the defendant over the allocation of litigation costs that can be avoided through early settlement. Bebchuk demonstrates that mere divisibility of litigation costs, coupled with costless abandonment and bargaining over avoided litigation expenditures, can be sufficient to cause some NEV lawsuits that are noncredible absent divisibility to become credible. Bebchuk's analysis also indicates that greater divisibility can only bolster a lawsuit's credibility.⁷⁶

Bebchuk's analysis, however, does not allow for learning or uncertainty in the course of litigation and does not provide a contextual reason for the existence of cost divisibility at any particular point in the litigation process. In contrast, our model expressly allows for a learning option with a subsequent abandonment or continuation option as a function of information disclosure at the point of cost divisibility. Our model is thus naturally interpreted as creating divisibility with a concomitant abandonment option arising when events induce information revelation, as occurs with rulings on questions of law or discovery of third-party information. Bebchuk's pure divisibility model can therefore be viewed as a special case of our model in which information disclosed during litigation has no payoff-relevant value because no litigant changes his action in response to such disclosure.⁷⁷

Cornell describes litigation as a real option process that involves information revelation at discrete stages where a plaintiff has an option to abandon his claim if it appears that further litigation is unprofitable.⁷⁸ Cornell's analysis is, in many respects, similar to ours in that it "accounts for the sequential nature of decision making without introducing asymmetric

N.Y.U. L. REV. 1943 (1998) (providing a real options analysis of risk multipliers for attorneys' fees in public interest litigation); Frederick C. Dunbar et al., *Shareholder Litigation: Deterrent Value, Merits and Litigants' Options* 26-30 (John M. Olin Sch. of Bus., Washington Univ., Working Paper No. 95-07-a, 1995) (on file with authors) (presenting an options approach to nuisance suits, plaintiffs' attorneys' behavior under contingent fee arrangements in securities litigation, securities litigation reform, and testable hypotheses about observed settlements in shareholder class actions).

74. Bebchuk, *supra* note 31.

75. Cornell, *supra* note 6.

76. Bebchuk, *supra* note 31, at 15.

77. For a formal proof of this observation, see *infra* Appendix, Proposition 5.

78. Cornell, *supra* note 6, at 182, explains that "[t]he option pricing approach highlights the fact that whenever a suit is filed, the defendant is forced to write litigation options that give the plaintiff the right to pursue the case in promising situations and the right to drop the case in unfavorable conditions."

information”⁷⁹ and also finds that “the value of litigation options rises as the uncertainty of the payoff increases,”⁸⁰ even though litigants are risk-neutral. Cornell’s analysis differs substantially from ours, however, in two distinct respects. First, Cornell does not recognize the possibility of bargaining over the allocation of litigation costs that can be avoided by early settlement. Cornell’s analysis is thus limited to a decision-tree approach in which a plaintiff has options to “prune” the set of outcomes whenever it appears that proceeding will be unprofitable when viewed solely from the perspective of a plaintiff’s own expected litigation costs. This approach, however, ignores the fact that a plaintiff’s abandonment decision also allows a defendant to avoid litigation costs and that there is a game-theoretic opportunity for strategic interaction over the allocation of the surplus generated by those avoided costs. Second, Cornell’s analysis is illustrative, rather than formal. It is expressly designed “not to provide precise estimates of the value of litigation options, but to offer general insights into how such options affect the incentive to sue.”⁸¹ In contrast, we provide precise equilibrium estimates of litigation’s option settlement value and also describe how those precise values depend on the model’s variance, the size and temporal incidence of litigation costs, and the parties’ relative bargaining power, among other matters.

Cornell’s analysis can therefore be viewed as a special case of our model in which a defendant either incurs no defense costs, which is an unrealistic assumption, or makes a credible commitment not to share avoided litigation costs with a plaintiff as part of a settlement. Under either scenario, a plaintiff’s abandonment decision then generates no avoided defense costs over which bargaining can take place, and the game-theoretic component of the analysis drops out of the model.

In summary, Bebchuk’s and Cornell’s models both involve divisible litigation costs. Our model includes both Bebchuk’s and Cornell’s models as special cases: If we assume that no valuable information is revealed during the litigation process, then our model is identical to Bebchuk’s. If we assume that there is no bargaining over avoided litigation costs, then our model is identical to Cornell’s. By presenting a model that contains both Bebchuk’s and Cornell’s analyses as special cases, we illustrate a link between those works that has not previously been noted in the literature,⁸² and we present a model that is consistent with the recent trend toward models that integrate game theory into real options analysis.⁸³

79. *Id.* at 174.

80. *Id.* at 179.

81. *Id.* at 176.

82. It is valuable to observe that Bebchuk cites neither to Cornell nor to real options analysis as relevant literature.

83. See generally SMIT & TRIGEORGIS, *supra* note 69; GAME CHOICES: THE INTERSECTION OF REAL OPTIONS AND GAME THEORY (Steven R. Grenadier ed., 2000).

III. INTUITION AND EXAMPLES

Although the model is relatively simple to describe, its analysis is complex for two distinct reasons. First, each litigant's optimal strategy depends on the information disclosed during the lawsuit. Second, the lawsuit's settlement value requires application of a reasoning process known as backward induction. However, as is the case in all litigation models with full information and homogeneous expectations, the parties here settle at the outset rather than incur any litigation expenses.⁸⁴ This result is the litigation equivalent of the "no-trade" result in financial markets⁸⁵ that builds upon the no-disagreement result in game theory as initially developed by Robert Aumann, 2005 Nobel Laureate in Economics.⁸⁶ Our model is, however, easily modified so as to allow small differences of opinion over the expected variance of the information to cause the parties to incur Stage 1 litigation costs even though they later settle the lawsuit prior to trial.⁸⁷ This pattern is, as we later explain, a more realistic depiction of observed litigation practice in which litigants most commonly incur some litigation expense before settling prior to trial.⁸⁸ As an introduction to our model, however, we initially address only the situation in which the litigants have homogeneous expectations and settle the dispute at its inception.

To help develop intuition about the model's equilibrium settlement value and to establish a foundation for the model's formal solution, we begin with an example that underscores the importance of learning in the presence of an abandonment option in the context of a positive expected value (PEV) lawsuit. This example illustrates the importance of variance in determining a lawsuit's option settlement value and highlights situations in which the predictions of a real option valuation model diverge from those of DCF or NPV models, as well as from the predictions of Bebchuk's model, which considers only divisibility value in the absence of information revelation. We also use this example to

84. See, e.g., POSNER, *supra* note 25, at 569 ("If the parties agree on the probability that the plaintiff will win in the event of litigation . . . the case will be settled because litigation is more costly than settlement In general, then, litigation will occur only if both parties are optimistic about the outcome of the litigation."). See *infra* Part V.C for a discussion of extensions to this model that allow for litigation to begin and lead to mid-suit settlements, as often occur, or cause the lawsuit to proceed through to judgment.

85. See, e.g., Paul Milgrom & Nancy Stokey, *Information, Trade and Common Knowledge*, 26 J. ECON. THEORY 17 (1982) (proving a no-trade theorem).

86. See Robert J. Aumann, *Agreeing To Disagree*, 4 ANNALS STATS. 1236 (1976); John Allen Paulos, *Knowledge Is Power: The Nobel Prize in Economics, the Stock Market and Subterranean Information Processing*, ABCNEWS.COM, Dec. 4, 2005; see also DREW FUDENBERG & JEAN TIROLE, *GAME THEORY* 548 (1991) ("The first and best-known result obtained with the formal definition of common knowledge is Aumann's proof that rational players cannot 'agree to disagree' about the probability of a given event. The intuition for this is that if a player knows that his opponents' beliefs are different from his own, he should revise his beliefs to take the opponents' information into account.").

87. See *infra* Appendix, Proposition 14.

88. See *supra* note 44 and accompanying text.

introduce an online calculator that automatically computes and graphs a lawsuit's option settlement value for any parameterization of our model, thereby eliminating the need for tedious calculations to determine a specific lawsuit's option settlement value. We then offer a more complex analysis of the settlement value of negative expected value (NEV) lawsuits with a series of examples that are constructed to highlight situations in which the real options perspective generates results that are not otherwise found in the literature. We refer interested readers to Part IV and to the Appendix for a formal treatment of the conditions under which these divergences arise.

A. Positive Expected Value Litigation

In a PEV lawsuit, total litigation costs are less than the value of the expected judgment, or $C_{p1} + C_{p2} < \mu$. Because we initially assume that the parties have equal bargaining power, if the plaintiff's minimum demand to settle a lawsuit is lower than the defendant's maximum offer to resolve the same dispute, the parties will settle by splitting the difference between the minimum demand and maximum offer. Therefore, if a lawsuit that is to be litigated in a single period (i.e., a lawsuit that has no optionality and for which the traditional DCF or NPV decision rule properly applies) has an expected judgment of 100 with litigation costs of 70 to be borne by each litigant, then the plaintiff would be willing to accept any settlement greater than 30 (the expected judgment of 100 less litigation costs of 70) while the defendant would be willing to settle for any amount less than 170 (the expected judgment of 100 plus litigation costs of 70). Splitting the difference between the minimum demand and maximum offer leads the case to settle for 100.

The settlement value of the same lawsuit when viewed in the context of our two-stage real options model can, however, be dramatically different and depends critically on the potential values of the information to be revealed (i.e., the decision as to whether the court selects A or B). Because the lawsuit is prosecuted in two stages, the model is solved through a process of backward induction, "the standard method used by economists for analyzing strategic interactions in which parties make decisions over several time periods."⁸⁹ Backward induction is based on the observation that a party's rational course of action at any stage of a process should be independent of historical actions that reflect sunk costs.⁹⁰

To illustrate the operation of the real options model with a backward induction equilibrium process, assume as before that the expected value of the judgment is 100 and that each party bears total litigation costs of 70, with costs

89. Bebchuk, *supra* note 31, at 6 n.7 (citing FUDENBERG & TIROLE, *supra* note 86, at 96-99; DAVID M. KREPS, A COURSE IN MICROECONOMIC THEORY 399-402 (1990)).

90. Experimental evidence suggests, however, that the backward induction process may not be descriptively realistic. See, e.g., THEODORE C. BERGSTROM & JOHN H. MILLER, EXPERIMENTS WITH ECONOMIC PRINCIPLES 374-76, 394-96 (1997).

divided evenly at 35 per period. Now add the assumption that the information to be disclosed at the end of the first period is a ruling on a question of law that has a value of either $A=400$ or $B=-200$ and that the probability of each outcome is 0.5, as previously described.⁹¹ Given that there is a 50% probability of a payoff of 400 and a 50% probability of a payoff of -200, the lawsuit's expected value remains at 100, and the distribution belongs to family of distributions that are mean-preserving spreads of each other.

If the court picks A, the plaintiff, when viewing the situation from the beginning of the second period before Stage 2 litigation costs are incurred, will gladly pay the additional costs of 35 in order to assure a judgment with an expected value of 400 and will, at that point, accept any settlement with a value of at least 400 less Stage 2 litigation costs of 35 (which could be avoided if the case settles early), or 365. The defendant would then be willing to settle for any value less than the anticipated judgment of 400 plus the Stage 2 litigation costs of 35 (which again could be avoided if the case settles early), or 435. Because of their equal bargaining power, the parties will split the difference between the minimum demand of 365 and the maximum offer of 435 and will settle at that stage, conditional on the selection of A, for 400.

If, however, the court picks B, then the plaintiff will abandon the lawsuit rather than invest 35 only to obtain the adverse result of -200. The selection of B thus renders the plaintiff's claim noncredible. Because the defendant knows that the plaintiff will then not pursue the claim, the defendant offers nothing to settle the action. The lawsuit's settlement value conditional on the selection of B is therefore 0. The plaintiff's option to abandon the lawsuit contingent on the selection of B is, however, quite valuable because it allows the plaintiff to avoid the adverse outcome of -200 as well as the need to spend 35 in pursuit of that adverse outcome.

Now take a step back to calculate the expected value of the settlement that would be reached just prior to the revelation of the information as to whether the court selects A or B. That value is 200, or the expected value of the equally probable settlements of 400 (contingent on the selection of A) and 0 (contingent on the selection of B). Applying the process of backward induction, the plaintiff at the beginning of Stage 1 would then have to incur litigation costs of 35 to reach a settlement with an expected value of 200, and will therefore accept any amount in excess of 200 less Stage 1 litigation costs of 35, or 165, to settle the lawsuit at its inception. The defendant analyzes the same situation and would rationally settle at inception for any amount less than the anticipated later settlement of 200 plus Stage 1 litigation costs of 35, or 235. Because the litigants have equal bargaining power they split the difference between 165 and 235 and settle the action at its inception for 200.

That settlement is, however, twice as large as the settlement value

91. For a discussion of some of the implications of the assumption that B assumes a negative value, see *supra* note 65.

predicted by a standard single period expected value analysis of the same lawsuit. The example therefore illustrates the principle that if the variance of the information to be disclosed is sufficiently large, then the lawsuit's real option settlement value can be significantly greater than the settlement value predicted through traditional single-stage expected value analysis.

However, as explained in greater detail below,⁹² this example of PEV litigation settling for an amount greater than its corresponding single-stage expected value arises only because we have assumed that the variance of the information disclosed is large enough to cause the value of B to be negative. Indeed, because of our assumption that the underlying distribution is binomial and mean preserving, it can be proved that if the value of B is constrained to be nonnegative then this lawsuit would settle for no more than its equivalent single-stage expected value of 100.⁹³ This feature of our model can, however, be shown to be an artifact of our simplifying assumption that the underlying probability distribution is binomial. For example, if we assume that the distribution is lognormal (an assumption that would significantly complicate our analysis), then negative returns to the plaintiff are not necessary for the option value of a two-stage PEV settlement to diverge from its equivalent single-stage expected value.⁹⁴ Put another way, the underlying lesson of this example is that for any given PEV lawsuit, if the variance of the information is sufficiently large, the lawsuit's real option settlement value will exceed its single-stage expected settlement value.

If, however, a PEV lawsuit's variance is sufficiently small, then there may be no difference between its option settlement value and its expected value as calculated through traditional techniques. To illustrate, consider the option settlement value of the same lawsuit when $A=100$ and $B=100$, i.e., the case in which the revealed information has no economic value because it will not change the litigants' behavior. In Stage 2, regardless of whether the court picks A or B, the parties will settle for 100, splitting the difference between the plaintiff's minimum demand of 65 and the defendant's maximum offer of 135. Working backward to the beginning of Stage 1, the plaintiff would again be willing to spend 35 in Stage 1 litigation costs to reach a Stage 2 settlement of 100, and would therefore accept any amount in excess of 65. The defendant would likewise be willing to pay any amount less than 135. Splitting the difference leads to an option settlement value of 100.

This example demonstrates that if variance is sufficiently low, then the revealed information has no value and a lawsuit's option settlement value can equal the expected value of the judgment as calculated through traditional DCF or NPV techniques. This example also illustrates a condition under which a lawsuit's option settlement value equals its "divisibility value"—the value for

92. See *infra* Appendix, Proposition 7.

93. See *id.*

94. See Grundfest, Huang & Wu, *supra* note 65.

which the lawsuit would settle if the plaintiff simply has the ability to incur litigation expenses in stages and to abandon the lawsuit at each stage, even if no new information is revealed at each stage.

At intermediate levels of variance, however, this lawsuit's option settlement value displays a discontinuity that does not arise in traditional analysis. Consider, in particular, the behavior of the lawsuit's options settlement value in the vicinity of $A=165$ and $B=35$. Just below that value, when $A=165-\epsilon$ and $B=35+\epsilon$ (where ϵ represents an arbitrarily small positive number), if the court selects A, then the plaintiff will accept offers in excess of $130-\epsilon$ while the defendant will be willing to pay any amount less than $200-\epsilon$ because each party bears litigation costs of 35. Equal bargaining power would lead the parties to settle for $165-\epsilon$. If the court selects B, then the plaintiff will accept a settlement in excess of ϵ while the defendant will be willing to pay an amount less than $70+\epsilon$. Equal bargaining power would lead the parties to settle for $35+\epsilon$. Because A and B are equally probable, the litigants would settle for 100 just prior to information revelation (the midpoint between $165-\epsilon$ and $35+\epsilon$). Working backward to the beginning of Stage 1, the plaintiff would again be willing to spend 35 in Stage 1 litigation costs to reach a Stage 2 settlement of 100, and would therefore accept any amount in excess of 65. The defendant would be willing to pay any amount less than 135. Splitting the difference leads to an option settlement value of 100.

Thus, as compared with the previous example, even when variance grows to the point where $A=165-\epsilon$ and $B=35+\epsilon$, the lawsuit's option settlement value remains identical to its settlement value as traditionally calculated under DCF or NPV models. This result follows because for all values of A ranging from 100 to $165-\epsilon$, and for all corresponding values of B ranging from 100 to $35+\epsilon$, the plaintiff would not change his behavior as a consequence of the information revealed because the plaintiff would continue to prosecute the action regardless of whether the court selects A or B, and therefore the information has no economic value.

The situation, however, differs dramatically as soon as A increases ever so slightly so that $A=165+\epsilon$ and $B=35-\epsilon$. Now, if the court selects A, the plaintiff will accept a settlement in excess of $130+\epsilon$, while the defendant will be willing to pay an amount less than $200+\epsilon$. Equal bargaining power would lead the parties to settle the suit for $165+\epsilon$. If the court selects B, then the plaintiff will abandon the lawsuit because it makes no sense to spend 35 in pursuit of a judgment that is expected to be only $35-\epsilon$. The defendant is aware of this fact and offers nothing in settlement. The selection of B would therefore cause the lawsuit to lose credibility. Because A and B are equally probable, the litigants would settle for $82.5+\epsilon/2$ (or $50\%*(165+\epsilon)$) just prior to information revelation.

Working backward to the beginning of Stage 1, the plaintiff would again be willing to spend 35 in Stage 1 litigation costs to reach a Stage 2 settlement of $82.5+\epsilon/2$, and would therefore accept any amount in excess of $47.5+\epsilon/2$ ($82.5+\epsilon/2-35$). The defendant would be willing to pay any amount less than

$117.5 + \epsilon/2$ ($82.5 + \epsilon/2 + 35$). Splitting the difference leads to an option settlement value of $82.5 + \epsilon/2$. Thus, when variance increases to the point where A is just above 165 and B drops just below 35, the information suddenly becomes valuable because at that point the plaintiff knows that if the court selects B, then it makes sense to act on that information and not to pursue the claim into Stage 2. The expected value of the lawsuit also drops precipitously at that point because all of the option settlement value that was previously impounded in the possibility that the court would select B suddenly disappears. The settlement value impounded in the possibility that the court selects A, however, increases only slightly at that point and certainly not by an amount large enough to offset the loss in value caused by the sudden noncredibility of outcome B.

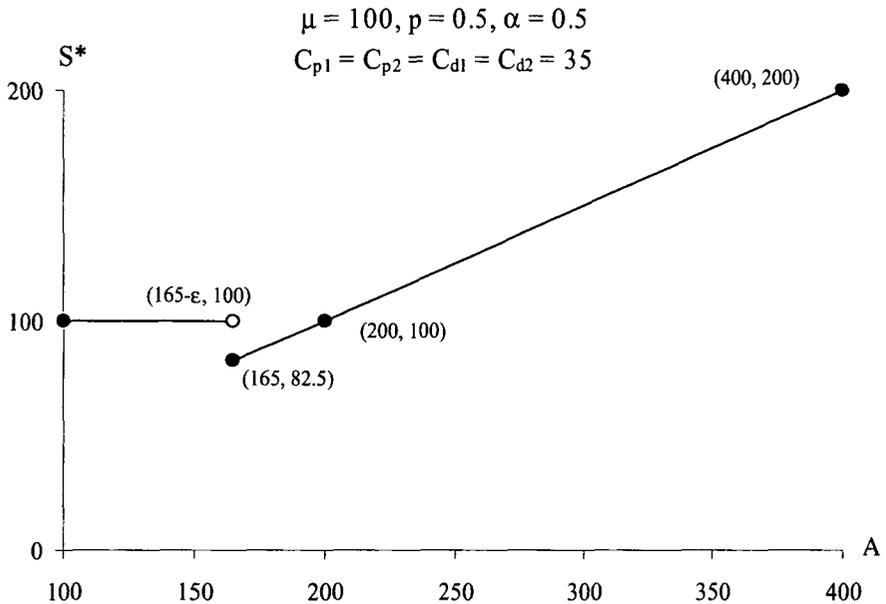
The result is a discontinuity in settlement value at the point where one outcome of the binomial process suddenly loses credibility. Indeed, the amount by which the settlement value suddenly declines at the point of discontinuity, here 17.5, equals half of the defendant's avoided litigation cost of 35. Thus, in a situation in which the variance of the judgment is constrained to have a mean-preserving spread and the parties have equal bargaining power, the sudden loss of credibility contingent on the selection of B implies that the plaintiff suddenly loses the ability to extract half of the defendant's avoided Stage 2 litigation costs.

However, as variance continues to grow and A increases beyond 165 while B declines further below 35, the lawsuit's option settlement value continues monotonically to increase at the rate of $A/2$. The intuition behind this result is also straightforward. At levels of A greater than 165, the lawsuit is never credible if B is selected. All of the lawsuit's option settlement value arises only if A is selected. The probability of selecting A is, however, defined to be 0.5, and it therefore follows that as A increases beyond the point of discontinuity at $A=165$, option settlement value will also increase, but only at the rate of \$1 for every \$2 increase in A.

B. An Online Calculator and Graphing Tool

The option settlement value of any lawsuit described in our model can be represented graphically as a function of the lawsuit's underlying variance. Because of the constraint that the underlying distribution belong to a family of distributions which are mean-preserving spreads of each other, the information's variance can be summarized by the value of A.⁹⁵ Figure 1 illustrates this graphic relationship for the example of PEV litigation just

95. Put another way, once the mean of the expected judgment is defined, the selection of any value of A also determines the value of B because the average must, by construction, generate an expected value equal to the judgment's expected value. A simple example illustrates this point. If a binomial distribution is constrained to have a mean of 100, and if both outcomes are equally probable, then once the value of one outcome is determined to be 150, the value of the second outcome must be 50.

Figure 1: PEV Litigation Example

described and shows that this lawsuit's option settlement value remains fixed at its expected value of 100 until A approaches 165, at which point the lawsuit's option settlement value drops suddenly to $82.5 + \epsilon/2$ and then continues to increase linearly at the rate of $A/2$.

The exercise of calculating a lawsuit's option settlement value in this model and of depicting it as a function of variance can, however, be quite repetitive. To facilitate this exercise, we have constructed an online calculator and graphing tool located at <http://lawreview.stanford.edu/real-options>.⁹⁶ This online calculator and graphing tool allows the user to input the expected value of the judgment, the probability that outcome A will occur, the parties' relative bargaining powers, and the litigants' costs in each stage of the lawsuit—the variables that are necessary and sufficient to define our model—and then generates a table that illustrates the lawsuit's option settlement values as a function of its underlying variance, as well as a graph that depicts that relationship. The calculator also highlights the points at which discontinuities in settlement values arise.

96. Mr. ChenLi Wang, a member of Stanford University's class of 2006, constructed this online calculator and graphing tool. The website contains text explaining the algorithm used to generate the model's solution values and to plot those values as a function of the lawsuit's variance.

C. Negative Expected Value Litigation

As complex as PEV lawsuits can be, NEV lawsuits are even more difficult to analyze for two reasons: first, they can be noncredible if a lawsuit's variance is insufficiently large,⁹⁷ and second, they can contain "dead zones," which are intermediate levels of variance over which the lawsuit is not credible even though it is credible for lower and higher levels of variance.⁹⁸

In an NEV lawsuit, total litigation costs exceed the value of the expected judgment, or, $C_{p1} + C_{p2} > \mu$. Traditional expected value analysis suggests that these cases will never be instituted because they are not credible: it costs the plaintiff more to pursue the lawsuit to completion than he expects to recover, and, because the defendant is aware of that fact, the defendant will offer nothing to settle. Several authors have, however, suggested that NEV litigation can indeed arise because of imperfect information,⁹⁹ asymmetries in the timing of litigation costs between the plaintiff and the defendant,¹⁰⁰ the plaintiff's ability to commit to pay his attorney part of the cost of litigation in advance,¹⁰¹ or a lawyer's reputation for pursuing NEV litigation.¹⁰²

In an important contribution, Bebchuk presents a model in which equally informed identical litigants settle NEV lawsuits for positive amounts simply because the lawsuit can be pursued in stages that allow the plaintiff to subdivide his litigation expenses.¹⁰³ The settlement values generated in Bebchuk's analysis describe a lawsuit's pure "divisibility value," i.e., the amount that the defendant will rationally pay simply because the plaintiff has the ability to subdivide his expenditures over time. Bebchuk's analysis does not, however, contemplate the possibility that information is revealed in the course of the lawsuit, or that the plaintiff's decision to abandon or continue the litigation is animated by new information.¹⁰⁴

To help fix our results within the context of the existing literature and to help focus on the implications of learning options that arise because of information revelation, we begin with a recapitulation of Bebchuk's model and repeat an example offered by Bebchuk to establish a "base case" for the

97. See *infra* Appendix, Proposition 4.

98. See *infra* Appendix, Proposition 9.

99. See Bebchuk, *supra* note 33; Katz, *supra* note 33.

100. See Rosenberg & Shavell, *supra* note 33.

101. See David C. Croson & Robert H. Mnookin, *Scaling the Stonewall: Retaining Lawyers To Bolster Credibility*, 1 HARV. NEGOT. L. REV. 65 (1996).

102. See Amy Farmer & Paul Pecorino, *A Reputation for Being a Nuisance: Frivolous Lawsuits and Fee Shifting in a Repeated Play Game*, 18 INT'L REV. L. & ECON. 147 (1998).

103. See Bebchuk, *supra* note 31.

104. Bebchuk's model is, as we have already suggested, a special case of the model presented in this Article. In particular, the pure divisibility values derived by Bebchuk are identical to the settlement values derived in our model if one assumes that the information disclosed to litigants has no payoff-relevant value in the sense that it does not cause either litigant to change its optimal strategy. See *infra* Appendix, Proposition 5.

analysis of NEV litigation. This base case describes a positive equilibrium value for NEV litigation in the absence of information revelation (i.e., the lawsuit's pure divisibility value). We then offer two examples of how the introduction of a learning option that preserves all the stated parameters of Bebchuk's example causes the NEV lawsuit's real option settlement value to diverge from its pure divisibility value. The first example illustrates a situation in which the introduction of an information option leads to a settlement value that is less than the lawsuit's pure divisibility value. The second example is more complex, and illustrates the existence of dead zones in some NEV lawsuits. These examples are of particular interest because they reveal patterns of settlement value that do not otherwise arise in the literature.

1. *Recapitulating Bebchuk's example: The pure divisibility value of NEV litigation*

To recapitulate Bebchuk's example, consider a lawsuit in which "the expected judgment (the probability of the plaintiff prevailing, times the magnitude of the judgment that he will get if he prevails) is 100. If the parties proceed all the way to judgment, each party will incur litigation costs of 140."¹⁰⁵ The expected value of this litigation is -40. Single-stage expected value analysis suggests that the plaintiff will not file this action and that, if filed, the defendant will pay nothing to settle the complaint because the lawsuit does not present a credible threat.

Bebchuk's model divides the litigation into two stages. During each stage each party must spend 70, for a total of 140. The plaintiff, however, can abandon the lawsuit at the end of the first stage after having spent 70 without any obligation to spend the remaining 70 required to pursue the lawsuit's second stage. Applying backward induction to this two-stage process suggests that the credibility of the plaintiff's threat should first be assessed as of the breakpoint between Stages 1 and 2. If the plaintiff does not then abandon the lawsuit, he can spend 70 in Stage 2 to obtain a payment of 100. The plaintiff will rationally accept any settlement in excess of 30 at that point. The defendant will rationally offer no more than 170 to settle the claim at that stage. Again, because the litigants have equal bargaining power in Bebchuk's model, they split the difference and settle for 100.

Having determined that the lawsuit would rationally settle at the beginning of Stage 2 for 100, the plaintiff understands that for the investment of 70 in Stage 1, he can force the defendant to the beginning of Stage 2 where the defendant will rationally pay 100 to settle the lawsuit. The plaintiff will therefore settle at inception for any amount in excess of 30 (accounting for Stage 1 costs of 70). The defendant similarly realizes that he can be forced to pay 70 in Stage 1 litigation costs to reach a situation at the beginning of Stage 2

105. Bebchuk, *supra* note 33, at 5.

in which he would rationally pay 100 to settle. The defendant will therefore settle at inception for any amount less than 170. Again, because of equal bargaining power, the parties split the difference and settle for 100.

This example illustrates that simple divisibility in litigation expenditures, which can be analogized to the presence of an abandonment option in the absence of a learning option, can be sufficient to cause NEV lawsuits that are not credible in a single-stage expected value model to become credible when viewed as a multistage process. We now introduce information revelation into this process and demonstrate that an NEV lawsuit's real option settlement value can differ dramatically from its simple divisibility value precisely because of the presence of a learning option.

2. An example of a learning option that reduces settlement value

As an initial matter, consider a situation in which the expected value of the judgment is fixed at 100 and where $A=100$ and $B=100$. In this situation, there is no economically useful information to be revealed in the course of the lawsuit, and the results of our model would be identical to the results of Bebchuk's analysis. This simple example demonstrates that Bebchuk's model is a special case of ours in which the information disclosed has zero variance.

Now assume that, all other parameters of Bebchuk's model remaining fixed, the information disclosed in the course of the lawsuit is such that $A=180$ and $B=20$. These values preserve the lawsuit's mean of 100. Thus, if the court picks A, the plaintiff will rationally invest an additional 70 to obtain an outcome of 180 at the end of Stage 2 and will accept any settlement with a value of at least 110. The defendant will pay any value less than 250. Conditional on the selection of A, the parties will split the difference and settle for 180. If, however, the court selects B, then the plaintiff will abandon the litigation rather than invest 70 to obtain 20. Outcome B, in other words, means that the plaintiff has no credible threat in Stage 2. The expected value of these two equally likely outcomes, 180 and 0, is thus 90. Viewed as of Stage 1, the plaintiff has to pay Stage 1 litigation expenses of 70 to obtain a settlement with an expected value of 90. The plaintiff's minimum demand at inception is therefore 20, while the defendant's maximum offer is 160. Equal bargaining power leads the litigants to split the difference and settle for 90, or 10 less than the lawsuit's pure divisibility value.

This example again illustrates that introducing a learning option into an environment where an abandonment option is already present does not invariably increase a lawsuit's settlement value, particularly if variance is not sufficiently large. The example also helps establish the intuition that information can cause a lawsuit to become contingently noncredible—i.e., a lawsuit will pay off for a plaintiff only if some information pans out in favor of the plaintiff—and that the existence of such a contingent noncredibility can reduce the lawsuit's real option settlement value.

3. *An example of a real option with a dead zone*

NEV litigation differs from PEV litigation in several respects. As we later demonstrate, while every PEV lawsuit is credible at every level of variance, some NEV lawsuits are credible only at levels of variance that are sufficiently large.¹⁰⁶ In addition, some NEV lawsuits exhibit an intriguing pattern in which they are credible for sufficiently low levels of variance, lose credibility over intermediate levels of variance, and then regain credibility over sufficiently high levels of variance. Indeed, once these lawsuits regain credibility in our model, their option settlement value becomes a continuously increasing function of the lawsuit's variance. Put another way, NEV lawsuits can exhibit dead zones over which the plaintiff's claim is not credible. For variances below the lower bound of this transition phase, we demonstrate that the lawsuit is credible and has a settlement value equal to its pure divisibility value. For variances greater than the upper bound of this transition phase, the lawsuit initially has a real option settlement value less than its pure divisibility value, but its real option settlement value then continues to increase as variance increases and can far exceed the pure divisibility value.

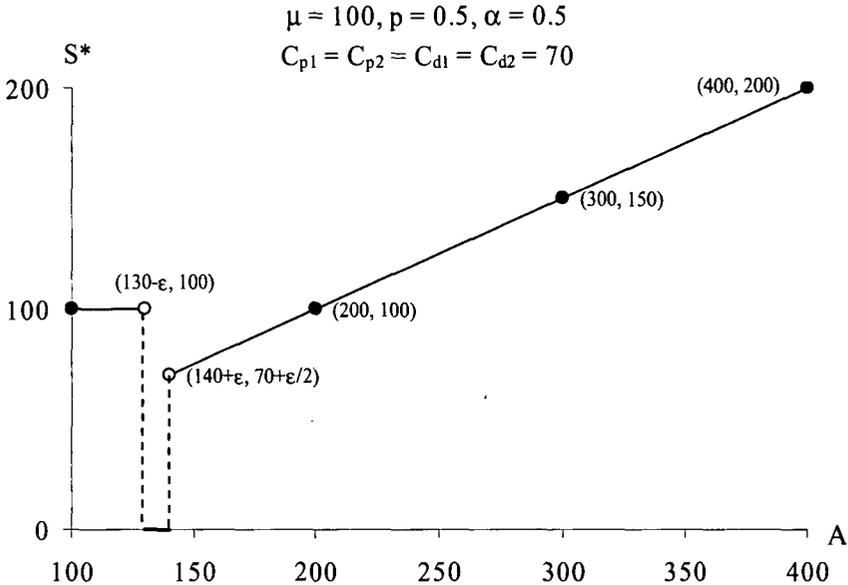
In particular, we now demonstrate that for Bebchuk's parameterization of his model, where the initial expected value of the verdict is 100 and each party incurs litigation costs of 70 per stage, the real option settlement value of the lawsuit will be 100 for all values of A lower than 130. However, over the interval $A=130$ through $A=140$, the lawsuit loses all credibility. This is the lawsuit's "transition phase," or dead zone. Then, for values of A greater than 140, the settlement value initially equals 70 and monotonically increases as variance increases. Thus, the credibility of Bebchuk's NEV lawsuit depends critically on assumptions about the variance of the information disclosed during litigation. This lawsuit's settlement value described as a function of variance is illustrated in Figure 2, and these observations can be confirmed by running the online calculator with the parameterization describing this model.

To illustrate this pattern of settlement values more explicitly, we begin by first examining settlement dynamics when $A=130$ and $B=70$. If the court selects A , then the plaintiff's minimum demand is 60, the defendant's maximum offer is 200, and the case would settle for 130. If the court selects B , the plaintiff will drop the lawsuit because it would cost the plaintiff 70 in litigation expense to obtain a judgment of 70. In that event, viewed from the perspective of Stage 1, the case has a 50% probability of a settlement of 130 and a 50% probability of a settlement of 0, for an expected value of 65. However, it makes no sense for a plaintiff to file the lawsuit because the Stage 1 litigation costs of 70 exceed the lawsuit's expected value of 65. The claim as a whole is therefore not credible.

Observe, however, that if the previous example is changed ever so slightly

106. See *infra* Appendix, Proposition 3.

Figure 2: NEV Litigation with a "Dead Zone"



so that the values are $A=130-\epsilon$ and $B=70+\epsilon$, then the lawsuit would settle for 100 for the following reason: If the court selects A, then the plaintiff will accept a settlement of no less than $60-\epsilon$. The defendant will offer no more than $200-\epsilon$. In that event, the litigation settles at the midpoint, or $130-\epsilon$. If the court selects B, the plaintiff will accept any amount in excess of ϵ , the defendant will pay any amount less than $140+\epsilon$, and the parties settle for $70+\epsilon$. The expected value of these two anticipated settlements is thus 100. Viewed from the beginning of Stage 1, the plaintiff would have to spend 70 to force a settlement of 100, and the defendant would be forced to incur costs of 70 to pay a settlement of 100. This situation induces a settlement at 100 and demonstrates that the discontinuity arises immediately when A reaches 130.

Now consider the settlement value of the lawsuit when $A=140$ and $B=60$. If the court selects A, then the plaintiff will demand at least 70, the defendant will offer no more than 210, and the settlement midpoint is 140. If the court selects B, then the plaintiff has no credible threat because it would be irrational to spend 70 in pursuit of a 60 judgment. Thus, at the beginning of Stage 2, the lawsuit has an expected value of 70. Viewed from the perspective of the beginning of Stage 1, however, the lawsuit lacks credibility because it would not be rational for the plaintiff to spend 70 in pursuit of 70.

However, if this example is changed so that the values are $A=140+\epsilon$ and $B=60-\epsilon$, then the lawsuit will settle for $70+\epsilon/2$. If the court selects A, then the plaintiff will accept no less than $70+\epsilon$, the defendant will offer no more than $210+\epsilon$, and the litigation will settle for the midpoint of $140+\epsilon$. However, if the court selects B, the plaintiff's claim lacks credibility because the plaintiff will

not invest 70 in pursuit of $60-\epsilon$. The lawsuit's settlement value prior to the revelation of the information is thus viewed as a 50% probability of a settlement value of $140+\epsilon$, which is $70+\epsilon/2$. Viewed as of the beginning of Stage 1, the plaintiff would demand a minimum of $\epsilon/2$, the defendant would offer nothing more than $140+\epsilon/2$, and the case settles for the midpoint of $70+\epsilon/2$. It also follows that all values of A equal to or greater than 130 and equal to or less than 140 will generate a settlement value of 0.

This example demonstrates that when learning is possible, equilibrium settlement values are not necessarily smooth functions of variance. The intuition behind this finding is again that the presence of staged, lumpy litigation costs combined with the sudden revelation of information can cause discontinuities in equilibrium settlement values because the lumpiness in litigation costs combined with the revelation of information can induce a sudden loss of credibility. In the case of NEV litigation, however, when one branch of the binomial distribution loses credibility, the remaining branch does not necessarily have a value large enough to support the plaintiff's decision to continue the litigation.¹⁰⁷ A dead zone then begins and continues until the lawsuit's variance becomes large enough that the remaining branch promises an outcome larger than Stage 2 litigation costs, at which point the lawsuit regains credibility. Beyond that level of variance, the NEV lawsuit continues to be credible and its option settlement value again increases monotonically as A increases.

4. *NEV litigation with a point discontinuity*

A particularly interesting situation arises when the dead zone consists of a single point. For example, assume that the expected judgment is 100, the probability of outcome A is 0.5, the litigants have equal bargaining power, and Stage 1 litigation costs are 75 for each party while Stage 2 litigation costs are 50. In this situation, the dead zone will constitute a single point where $A=150$. Without working through the mechanics of the calculations, it can be shown, and the online calculator demonstrates, that for levels of A less than 150 this lawsuit will settle for 100, and for levels of A just above 150 the lawsuit will settle for slightly more than 75. However, at the precise point where $A=150$, the lawsuit is not credible. Intuitively, this result occurs because when $A=150$ and $B=50$ the outcome represented by the possibility of B suddenly becomes noncredible, given Stage 2 litigation costs of 50, and the Stage 2 expected settlement value of 75 (or 50% of 150) equals the Stage 1 litigation costs of 75. Thus, the value of the lawsuit is precisely zero, although the very same lawsuit has a positive option settlement value at any level of A higher or lower than 150.

107. Proposition 2 demonstrates that this pattern cannot arise for PEV lawsuits because they are credible for every level of variance.

This point discontinuity is driven by our assumption that when a settlement value is zero, the lawsuit loses credibility. This assumption, which is common in the literature,¹⁰⁸ could be replaced by the assumption that the plaintiff would continue to litigate at this point of indifference because the decision to litigate, which would still be costless to the plaintiff, can induce the defendant to make a settlement payment that reflects a portion of the litigation costs that could be avoided through a settlement. In this specific case, the result would be that the defendant would agree to pay precisely 75 at the point where $A=150$, and the point discontinuity would be eliminated.

These observations about the model's behavior at this point of discontinuity also suggest areas for further research relating to alternative equilibrium concepts in litigation games. These alternative concepts would recognize the possibility of extortionist incentives in plaintiff behavior (i.e., the possibility that a plaintiff can credibly threaten to continue with a lawsuit that has a negative expected payoff because the payoff to the defendant is even more negative, and the plaintiff calculates that the defendant can be induced to make a settlement payment to avoid this more adverse outcome) and the possibility that a plaintiff experiences *schadenfreude* through litigation (i.e., even though the plaintiff experiences a negative payoff from the litigation, the plaintiff gains value from the ability to inflict losses on the defendant). These potential extensions of the model are discussed in Part V.

IV. ANALYTIC RESULTS

We defined our model in Part II, and in Part III we provided a series of examples that illustrate our model's equilibrium concept with particular emphasis on results that do not otherwise appear in the literature. Here, we describe fourteen formal propositions regarding our model's equilibrium characteristics. These propositions address three broad subject areas.

Our first set of propositions, four in number, describes conditions under which a plaintiff's threat to sue is credible. Simply put, a lawsuit is credible in our model only if its option settlement value, S^* , is positive because rational defendants will refuse to pay anything to settle claims that all parties understand have no value. These credibility conditions, presented in Part IV.A, therefore describe necessary and sufficient conditions for the existence of

108. Although much of the literature makes this assumption, some differ as to what to do with the point of indifference. See, e.g., Bebchuk, *supra* note 31, at 12 n.9. Bebchuk adopts the contrary assumption that "in the event of indifference between proceeding and not proceeding, the plaintiff will proceed." *Id.* This assumption, however, raises the question of whether the plaintiff proceeds in the expectation that he will be able to extract a portion of the defendant's avoided litigation costs and of why the defendant would view the threat as credible if there is no gain to the plaintiff but for the defendant's willingness to share a portion of those avoided litigation costs. To avoid those issues, we assume that the plaintiff does not proceed unless he has a threat that is credible independent of the defendant's willingness to share avoided litigation costs.

litigation in our model. These credibility conditions also provide basic formulae that can be used to calculate a lawsuit's settlement value and are therefore fundamental to further understanding our model's operation.

Our second set of propositions, also four in number, compares a lawsuit's option settlement value with its "divisibility settlement value" and with the expected value of the lawsuit's judgment. A lawsuit's divisibility settlement value describes the settlement value that results if (1) a plaintiff simply has an option to abandon a lawsuit between stages and (2) no payoff-relevant information is revealed during the course of litigation. These propositions, defined in Part IV.B, focus on circumstances in which the ability to learn payoff-relevant information, as reflected by a lawsuit's variance and as distinguished from the simple ability to abandon a lawsuit in midstream, influences a lawsuit's value.

Our third set of propositions, six in number, describes a series of comparative statics analyses.¹⁰⁹ These analyses describe how a lawsuit's option settlement value responds to changes in the variance of the uncertainty to be resolved, changes in the parties' relative litigation costs, changes in the allocation of litigation costs over time, and changes in the parties' relative bargaining power. We also present a proposition that demonstrates how, if we abandon our assumption of homogeneous beliefs, a difference in beliefs over a lawsuit's variance is sufficient to trigger litigation and then to settle midstream, even though the litigants agree as to the lawsuit's expected value. These results are presented in Part IV.C.

We describe our propositions in this Part along with the intuition that supports the proof of each proposition. We present both formal statements and mathematical proofs of these propositions in the Appendix.

A. *Credibility Conditions*

We begin by asking a basic question: When will a lawsuit be credible in our model and, if a lawsuit is credible, for how much will it settle? Proposition 1 answers these questions and describes a general condition for credibility of litigation as it applies to both positive expected value (PEV) and negative expected value (NEV) litigation. We define a lawsuit as being credible if its initial settlement value, S^* , is positive, or $S^* > 0$. A lawsuit is credible as defined here if and only if a plaintiff has a credible threat at the start of each stage to continue the litigation. This additional condition is necessary because, if the defendant perceives that the lawsuit is not credible at the beginning of any stage, then the defendant knows that it is irrational for the plaintiff to invest

109. BRIAN BEAVIS & IAN DOBBS, OPTIMIZATION AND STABILITY THEORY FOR ECONOMIC ANALYSIS 98 (1990) (defining comparative statics analysis to be "[t]he determination of the effects of parameter variations on the optimal choice of control variables and the maximum value of the objective function").

anything in the lawsuit at Stage 1 only to have to walk away empty-handed at a later point in the process.

We compute the value of S^* by reasoning backward. If the litigation reaches Stage 2, a plaintiff will demand a settlement at least as large as the amount it expects to receive at judgment net of its Stage 2 litigation costs. A defendant's maximum offer, if Stage 2 is reached, is at most what it expects to pay at judgment plus Stage 2 litigation costs. Because we assume that both litigants have equal bargaining power at each stage, the settlement value at the start of Stage 2, which we denote by S_2 , splits the difference between the plaintiff's minimum settlement demand in Stage 2 and the defendant's maximum settlement offer in Stage 2.

At Stage 1, the plaintiff will demand a settlement at least as large as the amount it expects to receive in settlement just prior to the revelation of information, S_2 , net of its Stage 1 litigation costs. At Stage 1, the defendant will offer a settlement no greater than the amount it expects to pay in settlement at the start of Stage 2, S_2 , plus its Stage 1 litigation costs, if the plaintiff's threat of proceeding to Stage 2 is credible. Again, because of the assumption of equal bargaining power, at the start of Stage 1, before a plaintiff decides whether to pay for Stage 1 litigation costs, this lawsuit has a settlement value, S^* , which splits the difference between the plaintiff's minimum settlement demand in Stage 1 and the defendant's maximum settlement offer in Stage 1. Proposition 1 defines the formula for calculating S^* and thereby establishes a foundation from which it is possible to describe credibility of all PEV and NEV litigation as well as to calculate the settlement value of those claims.

Having derived the definition of S^* and having demonstrated that it is central to determining whether a lawsuit is credible, we next explore the differences in credibility conditions as they relate to PEV and NEV litigation. In particular, we ask whether PEV lawsuits are always credible. As intuition suggests, our model supports the conclusion that PEV lawsuits are always credible and will always lead to payment of some amount in settlement. Proposition 2 proves this result by demonstrating that there is no circumstance in which a PEV lawsuit would fail to be credible. Proposition 2 reasons that if a lawsuit is PEV, then, by definition, the plaintiff's total litigation costs are less than the expected judgment for every level of variance. Proposition 2 also observes that, for any level of a plaintiff's litigation costs and for any level of variance, a lawsuit is least likely to be credible if all litigation costs are incurred in Stage 1. However, because those costs will always be less than the expected value of the judgment, Proposition 2 is able to demonstrate that every PEV lawsuit must be credible for every level of variance.

While every PEV lawsuit is credible for every level of variance, it does not follow that every NEV lawsuit is credible for every level of variance, although every NEV lawsuit can be made credible *with sufficient variance*. Proposition 3 demonstrates the second half of this assertion by proving that if variance is allowed to grow without limit, then every NEV lawsuit can become credible.

The logic behind this finding is rather straightforward. Imagine a call option that is out of the money. As the variance of the underlying instrument increases, the value of the call option also increases, even though it remains out of the money. At some point the increase in variance can become large enough to cause the option's premium value to exceed any exogenously predetermined value, which here represents the plaintiff's litigation costs. When a previously noncredible NEV lawsuit's variance crosses that threshold, the lawsuit becomes credible. This result is a strong proposition regarding the potential credibility of even the weakest of claims as might be measured under traditional expected value criteria and suggests that in the context of NEV litigation uncertainty can be a powerful tool in the hands of plaintiffs seeking to bring claims.

The fact that every NEV lawsuit is credible for a sufficiently high level of variance does not, however, prove that every NEV lawsuit is credible over any level of variance. Indeed, we have already illustrated in Part III conditions under which some NEV lawsuits are credible only over certain ranges of variance. More generally, Proposition 4 demonstrates that if an NEV lawsuit's variance is constrained so as to preclude any negative payoffs to the plaintiff, then there exists a category of NEV lawsuits that will never be credible. The intuition underlying this nonnegativity constraint is that a court's judgment can never go against a plaintiff so badly that a plaintiff must suffer a loss of wealth as a consequence of a court's judgment, as opposed to a loss in wealth generated by having to bear litigation expenses.¹¹⁰

B. *Option Settlement Value, Divisibility Value, and Expected Value*

Having mapped circumstances under which PEV and NEV lawsuits are or are not credible, we next present four propositions that compare and contrast a lawsuit's option settlement value with its divisibility value and its expected value. A lawsuit's divisibility value describes the amount for which a claim would settle in our model if the uncertainty that a court resolves at the end of Stage 1 has no variance or, as explained below, otherwise lacks economic value because it would not change either litigant's behavior. This settlement value is, as previously described, equivalent to the equilibrium settlement value calculated by Bebchuk,¹¹¹ and our analysis demonstrates that Bebchuk's model is a special case of ours in which information has no payoff-relevant value. The difference between a lawsuit's option settlement value and its divisibility value therefore measures the value of the information that is disclosed between our model's two stages, as distinct from value that exists simply because of a plaintiff's ability to abandon litigation midstream. We demonstrate that the value of information, so measured, can be positive or negative and is a function of underlying variance. We also compare and contrast the expected value of a

110. See *supra* note 65.

111. See *supra* Parts III.C.1, III.C.3

lawsuit's judgment with its option settlement value and again demonstrate that this difference can be positive or negative.

When does a lawsuit's option settlement value equal its divisibility value? We present a pair of propositions analyzing that relationship. Proposition 5 demonstrates that if variance is constrained to be zero for an otherwise credible lawsuit, then the lawsuit's option settlement value equals its divisibility settlement value. This demonstrates that Bebchuk's model with divisible litigation costs is a special case of our model in which variance is zero. To say that variance of uncertainty that a court resolves is zero means that a court's ruling reveals no payoff-relevant information but the plaintiff still has an option to abandon the litigation, thus giving him the ability to stage litigation costs.¹¹²

Proposition 6 extends Proposition 5 and describes a broader set of conditions under which a lawsuit's option settlement value equals its divisibility value. Information has no value to litigants if they do not change their behavior because of the information revealed. It follows that a lawsuit's option settlement value will equal its divisibility value if information is worthless to litigants. Proposition 6 defines the circumstances under which information is economically worthless.

It is trivially easy to demonstrate that when variance becomes sufficiently large a lawsuit's option settlement value will exceed its divisibility value. But precisely when does this condition arise? Proposition 7 demonstrates that if variance in our model is constrained to lead only to nonnegative outcomes, and if a defendant's Stage 2 litigation costs are constrained to equal or exceed a plaintiff's Stage 2 litigation costs, then a lawsuit's option settlement value cannot exceed its divisibility value. This finding is significant because it demonstrates, as has already been illustrated, that there are circumstances in which addition of learning and abandonment options can actually reduce a lawsuit's settlement value below its divisibility value.

To this point, we have formally explored the relationship between a lawsuit's option settlement value and its divisibility value. The literature, however, more commonly addresses the relationship between litigation and the expected value of a lawsuit's judgment. Proposition 8 addresses this relationship and offers necessary and sufficient conditions under which the initial expected value of a lawsuit's judgment (as distinguished from the lawsuit's net initial expected value) equals both that lawsuit's divisibility value and its option settlement value. Proposition 8 demonstrates that this equality requires two conditions when litigants have equal bargaining power. First, a plaintiff must be willing to continue with litigation regardless of information disclosed (i.e., the information must have no economic value). Second, litigants must have equal litigation costs. If these conditions are not satisfied, there will be a divergence between the expected value of the judgment, a lawsuit's option

112. We already provided an explanation of the circumstances in which we also generate the Cornell model as a special case in Part II.C.

settlement value, and its divisibility value.

C. Comparative Statics

Our concluding six propositions provide a comparative statics perspective on our model. We examine how a lawsuit's option settlement value varies in response to changes in underlying variance, total litigation costs, allocation of litigation costs across time periods, changes in parties' relative litigation costs, and changes in parties' bargaining power. We also describe how, if we relax our assumption of homogeneous beliefs, our model allows for litigation to commence at Stage 1 simply because the litigants disagree about the variance of the uncertainty to be resolved (although they agree as to the lawsuit's expected value) and then to settle immediately after information disclosure.

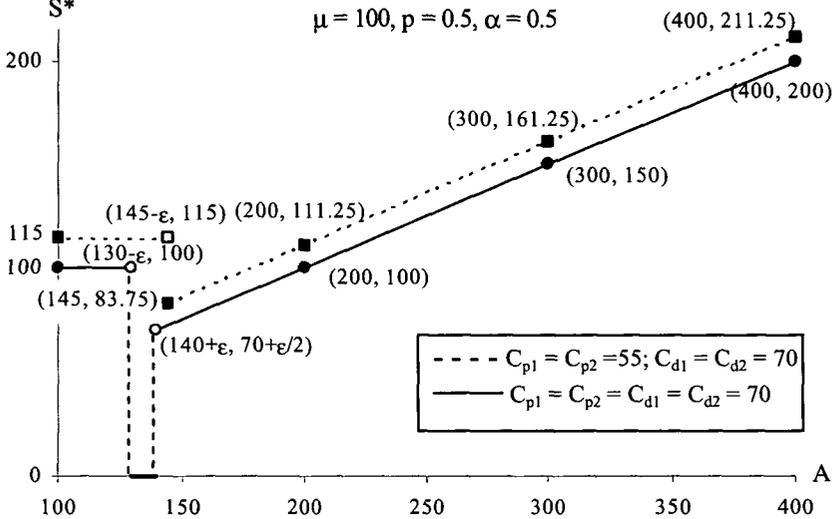
The relationship between a lawsuit's option settlement value and its underlying variance, even in a world of risk-neutral litigants, is a central focus of our analysis. Proposition 9 formally addresses that relationship and demonstrates that it is more complex in our model than is typically the case in modeling standard financial options. More specifically, Proposition 9 emphasizes that a lawsuit's option settlement value becomes a monotonically increasing function of its variance only after its variance becomes sufficiently large. At that point, the relationship between a lawsuit's option value and its underlying variance tracks the standard relationship found in finance, i.e., higher volatility implies higher option valuation.¹¹³ However, if a lawsuit's variance is not sufficiently large, then its option settlement value can be invariant to the underlying volatility (because the information to be revealed has no economic value) or can fall discontinuously. Moreover, for some NEV litigation, a lawsuit that is credible over lower and higher levels of variance can lose credibility over intermediate levels of variance. Figures 1 and 2, previously presented in Part III, illustrate Proposition 9 for PEV and NEV litigation.

The observation that every lawsuit's option settlement value is a strictly increasing function of its underlying variance beyond some critical value also supports a proposition with potentially widespread significance for the analysis of litigation. In particular, as Proposition 10 demonstrates, once variance is sufficiently large that the lawsuit's option settlement value becomes a strictly increasing function of variance, the risk-neutral plaintiff will appear to be risk-seeking because he will demand increasingly large payments to settle increasingly risky cases, while the risk-neutral defendant will appear to be risk-averse because he will offer increasingly large payments to settle increasingly risky cases.

To this point, we have in our examples assumed that plaintiffs' and defendants' litigation costs are equal in both stages. This assumption is clearly unrealistic. There are cases in which plaintiffs have significant leverage over

113. See Rasmusen, *supra* note 63.

Figure 3: Effect of Reduced Plaintiff Litigation Costs in NEV Litigation with a "Dead Zone"

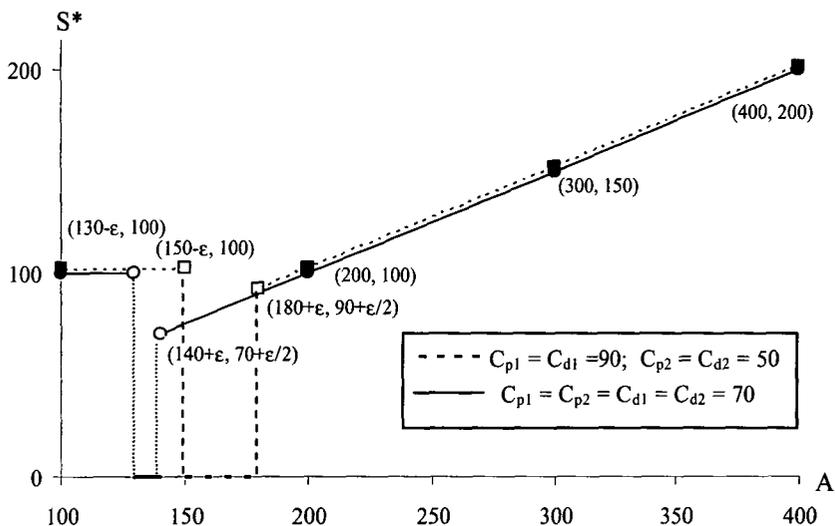


defendants in the sense that the plaintiff's expenditure of a dollar can cause a disproportionately larger expenditure by the defendant. Similarly, there are cases in which defendants have significant leverage over plaintiffs in the sense that the plaintiff can be forced to spend many dollars to prosecute the action for each dollar spent on defense costs. Proposition 11 explores the implications of changes in the plaintiff's litigation expenditures and demonstrates that if a plaintiff's litigation costs decrease (increase) while all other parameters in our model remain fixed, including the defendant's litigation costs, then the lawsuit's option settlement value increases (decreases) as does the size of the discontinuity (if one exists) and its location measured as a function of A. These results indicate that the relationship between the plaintiff's litigation costs and lawsuit valuation are more complex than the simple intuitively plausible assertion that lower plaintiff litigation costs make lawsuits more valuable for plaintiffs because changes in those costs can also influence a lawsuit's credibility and the location and magnitude of discontinuities in its option settlement value.

Figure 3 illustrates Proposition 11. Figure 3 first replicates the relationship between option settlement value and variance that was previously described in Figure 2. That relationship, described by the solid lines in Figure 3, arises when each litigant has costs of 70 in each period for a lawsuit in which the expected value of the judgment is 100, the litigants have equal bargaining power, and the probability of A is fixed at 0.5. The dotted lines in Figure 3 then overlay the lawsuit's option settlement values that arise when the plaintiff's litigation costs are reduced to 55 in each period, a cost level that still causes the lawsuit to be NEV from the plaintiff's perspective. At that level, the dead zone disappears

Figure 4: Stage 1 Costs > Stage 2 Costs

$$\mu = 100, p = 0.5, \alpha = 0.5$$



because the lawsuit is then credible for every level of A , the lawsuit's settlement value increases from 100 to 115 when information has no value, the single point of discontinuity arises at a higher level of A (here $A=145$), and the lawsuit's settlement value beyond its point of discontinuity is uniformly higher than the equivalent settlement value that results when the plaintiff has higher litigation costs. This reduction in litigation costs here causes the lawsuit to become uniformly more valuable to the plaintiff and eliminates the possibility that it will be noncredible over some intermediate levels of variance.

Our model has also, to this point, assumed a fixed distribution of litigation costs across the two stages of litigation and has therefore not considered the implications of procedural rules that cause litigation expenses either to be "front-loaded"—meaning that, all other factors equal, the parties have to spend more earlier in the lawsuit—or "back-loaded"—meaning that expenses are incurred in the later stage of the litigation. Proposition 12 demonstrates that the timing of litigation costs can have a significant effect on a lawsuit's credibility and option settlement value. In particular, all other factors constant, a rule that causes litigation costs to be front-loaded will tend to reduce a lawsuit's option settlement value because a plaintiff must then incur larger expenses before gaining the advantage of the information that is disclosed at the end of Stage 1. Because credibility conditions are also existence conditions, it follows that even if total litigation costs are held constant, rules allocating litigation costs between two stages can alone be sufficient to cause litigants either to institute proceedings or never to file an action.

Figure 4 illustrates Proposition 12 and again replicates the relationship

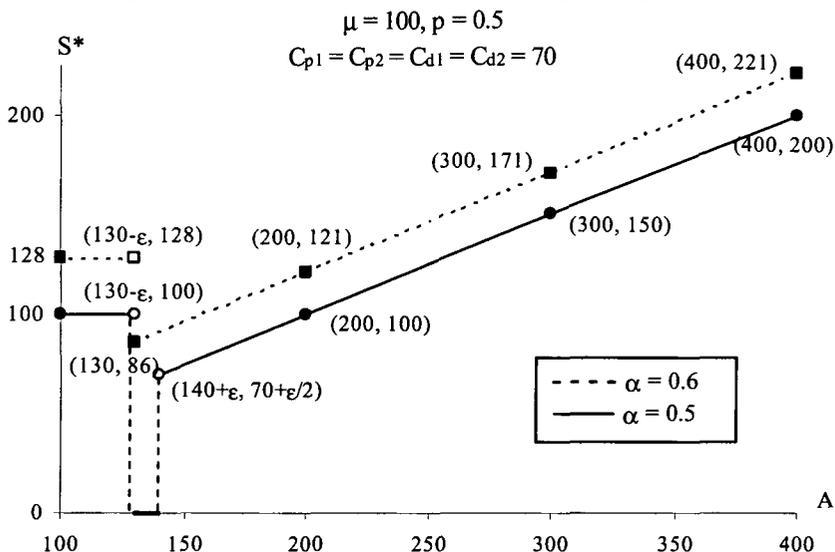
illustrated in Figure 2, but now overlays the lawsuit's option settlement value on the assumption that Stage 1 litigation costs are 90 for each litigant and that Stage 2 litigation costs are 50 for each litigant. This cost front-loading causes the lawsuit's dead zone to shift and expand, moving from the range of $130 \leq A \leq 140$ to $150 \leq A \leq 180$, but it does not cause any change in the lawsuit's divisibility value at levels of variance low enough to make the lawsuit credible or at levels of variance high enough to have passed through the dead zone.

Our model has also assumed that the litigants have equal bargaining power, although plaintiffs or defendants can have disproportionate bargaining power in practice. Proposition 13 shows that changes in litigants' relative bargaining power can cause cases to be brought or to be dropped and can cause significant changes in equilibrium settlement values. More specifically, Proposition 13 shows that as a plaintiff's bargaining power increases (decreases), more (fewer) NEV lawsuits become credible, and option settlement values increase (decrease). Proposition 13 also demonstrates that an increase (decrease) in a plaintiff's bargaining power can have a disproportionate effect in the sense that a 10% increase (decrease) in a plaintiff's bargaining power can lead to a larger than 10% increase (decrease) in a lawsuit's option settlement value, and can create (destroy) a lawsuit's credibility when a lawsuit is NEV or when a plaintiff's litigation costs in Stage 1 are sufficiently large.

Figure 5 illustrates Proposition 13. Furthermore, Figure 5 again replicates the relationship illustrated in Figure 2 but now overlays the lawsuit's option settlement value on the assumption that a plaintiff has more bargaining power than a defendant—in particular, that $\alpha=0.6$. Thus, instead of equally splitting the difference between a plaintiff's offer and a defendant's offer at each stage of their bargaining process, settlement at each stage consists of 60% of the defendant's higher settlement offer and 40% of the plaintiff's lower settlement demand. As illustrated in the overlay on Figure 5, even this small change in bargaining power eliminates the dead zone, causes the lawsuit's option settlement value to increase to 128 for all values of A at which information has no economic value, and causes the lawsuit's settlement value to be uniformly higher for every level of variance beyond the single discontinuity that now arises at $A=130$. Indeed, the increase in option settlement values is, in percentage terms, at every stage greater than the increase in plaintiff's bargaining power.

Finally, we demonstrate that our model can be modified slightly to address the common (but unsatisfying) characteristic of many models of the litigation process that implies that lawsuits settle at inception without the litigants incurring any litigation costs.¹¹⁴ This prediction is obviously unrealistic because a very large number of lawsuits are indeed filed, many billions of dollars are spent on litigation costs, and the large majority of claims settled

114. See *supra* notes 44, 84.

Figure 5: Plaintiff Has Greater Bargaining Power

before going to trial.¹¹⁵ The literature demonstrates, however, that economic models of litigation cannot replicate this pattern unless they assume that the parties have asymmetric information or differential expectations.¹¹⁶ A small modification to our model, however, allows us to generate a pattern in which the plaintiff files suit and both parties incur Stage 1 litigation costs, but the parties then settle before incurring Stage 2 expenses: we simply allow the litigants to have differential expectations over the lawsuit's variance, even though they are constrained to share common expectations as to the judgment's expected value and as to all other parameters of the model. This finding is, we believe, potentially important because it suggests that subtle differences over the second moments of probability distributions can be sufficient to cause litigants rationally to invest substantial sums in pursuing a lawsuit only to settle prior to final judgment. To put the matter more bluntly, our model suggests that even if litigants agree about a lawsuit's expected value, as traditionally defined through DCF or NPV analyses, it can be entirely rational for them to incur substantial litigation costs before settling because they disagree about finer points of the litigation process, such as the potential range of outcomes that can drive the agreed-upon expected value.

To illustrate this result, we modify our model to allow the litigants to have differential expectations only over the lawsuit's variance and introduce the possibility that, after Stage 1 costs have been incurred, the court specifies the range of decisions that it may reach without actually committing to a specific

115. See Silver, *supra* note 44, at 2107-09.

116. See *supra* note 86.

decision within the range. Such an announcement would eliminate the opportunity for differential expectations over the variance of the uncertainty to be resolved without actually resolving that uncertainty. An example of such a situation would be the announcement that a court has accepted or rejected a damage theory that supports a wider range of damage awards without actually deciding a host of other factors that would be necessary to calculate actual damages. Proposition 14 demonstrates that, in this situation, differential expectations as to the lawsuit's variance can be sufficient to cause litigants to initiate a lawsuit and then to settle midstream once that difference of opinion as to variance has been eliminated. The Appendix provides a numerical example that illustrates this equilibrium pattern.

V. DISCUSSION AND EXTENSIONS

The real options model of litigation described and analyzed in this Article, although rudimentary, has material analytic and normative implications for the economic analysis of litigation. From an analytic perspective, the model generates a set of results that is either difficult or impossible to derive from other models of the litigation process. Part V.A describes these results and discusses their significance. Part V.B discusses the model's normative implications for the economic analysis of the litigation process. Part V.C describes a series of potential extensions.

A. Analytic Implications

From an analytic perspective, a real options model of the litigation process elucidates the relationship between a lawsuit's uncertainty and a plaintiff's ability to manage that uncertainty. That relationship is entirely obscured by traditional models that rely on DCF or NPV analyses. In particular, the real options approach suggests that "riskier" lawsuits can be more valuable to risk-neutral plaintiffs than "safer" lawsuits if the plaintiff is able to reduce or eliminate his litigation expenditures sufficiently in the event the lawsuit evolves poorly from the plaintiff's perspective. It also suggests that the relationship between a lawsuit's settlement value and its underlying risk can be quite complex: settlement values can be discontinuous in the lawsuit's underlying variance, and some NEV lawsuits can be credible over lower and higher levels of variance, while being noncredible over intermediate values of variance.

These rather basic insights help cast a new light on several aspects of the litigation process. For example, the credibility of NEV litigation is transformed from a conundrum that requires complex assumptions to explain away,¹¹⁷ to a rather straightforward proposition regarding the value of out-of-the-money call

117. See *supra* note 33 for references to articles seeking to explain the NEV litigation phenomenon.

options. NEV lawsuits are perfectly credible in our model provided that the lawsuit's variance is sufficiently high. Indeed, every NEV lawsuit can be made credible if one assumes a sufficiently large variance,¹¹⁸ just as the value of every out-of-the-money call option can be increased to exceed any fixed premium value if the variance of the underlying instrument is allowed to become sufficiently large. Further, because PEV lawsuits are credible at every level of variance,¹¹⁹ while NEV lawsuits require some minimal level of variance to become credible, the effect of variance on settlement values can be viewed as an alternative characteristic that distinguishes PEV from NEV litigation.

It also follows that, all other factors equal, if the uncertainty of the litigation process increases, then the number of PEV lawsuits that are brought will remain constant because these lawsuits are credible at every level of variance. In contrast, the incidence of NEV litigation will increase or remain stable,¹²⁰ because only those lawsuits become increasingly credible as variance increases. To the extent that some observers view NEV lawsuits as undesirable, increased uncertainty in the litigation process will generate a greater incentive to file more undesirable lawsuits. It bears emphasis that this observation relates only to the number of lawsuits that are initiated. It is not an observation regarding the aggregate option settlement value of the lawsuits that are filed because increased variance can, in theory, increase or decrease the options settlement value of PEV and NEV lawsuits alike.¹²¹ However, once variance becomes sufficiently large, the effect of an increase in variance is an unambiguous increase in a lawsuit's options settlement value.¹²²

Traditional DCF and NPV models cannot generate predictions of this sort because in a world of risk-neutral litigants, DCF and NPV models suggest that changes in variance have no effect on a lawsuit's credibility or settlement value. This point is perhaps best illustrated by the fact that risk-neutral defendants in our model can act as though they are risk-averse, and risk-neutral plaintiffs can act as though they are risk-seeking for reasons that have nothing to do with risk aversion and everything to do with the value of the plaintiff's ability to abandon the lawsuit in the event of information unfavorable to the plaintiff's cause.¹²³ Models that assume that defendants are relatively risk-averse,¹²⁴ therefore, may be making an analytically unnecessary assumption. Moreover, if plaintiffs are in fact relatively risk-seeking while defendants are

118. See *infra* Appendix, Proposition 3.

119. See *infra* Appendix, Proposition 2.

120. As a technical matter, we cannot argue that the number will strictly increase because of the possibility that increased variance will, over some ranges, drive some NEV lawsuits into their dead zones. See *infra* Appendix, Proposition 9.

121. See *id.*

122. See *id.*

123. See *infra* Appendix, Proposition 10.

124. For an example of such a model, see SHAVELL, *supra* note 25, at 406-07.

relatively risk-averse, then our real options model's prediction can be magnified over certain ranges (i.e., risk-adjusted option settlement values would be higher than their risk-neutral equivalents). On the other hand, if plaintiffs are in fact relatively risk-averse and defendants are relatively risk-seeking, then our model's prediction can be tempered (i.e., risk-adjusted option settlement values would be lower than their risk-neutral equivalents).

The model's comparative statics results also suggest that real options models can promote a new style of analysis that integrates procedural and substantive considerations. Changes in procedural rules can increase or decrease the parties' litigation costs; they can change the underlying decision process inherent in a lawsuit by, for example, adding or eliminating the need to make various evidentiary showings; they can cause litigants to incur expenses earlier or later in the litigation process; and they can otherwise influence the litigants' relative bargaining power. Changes in procedural rules can also increase or decrease the uncertainty that arises at various stages of the litigation process. Substantive rules can change the expected value and variance of the judgment awarded at the conclusion of litigation, as well as the variance associated with decisions made in the course of the lawsuit's prosecution. The real options perspective provides a coherent framework through which such changes can be evaluated individually or as part of a larger reform process. Traditional DCF or NPV models, which mask the influence of uncertainty and flexibility in the litigation process, are simply unable to address these concerns in a consistent manner.

Finally, the full-information version of our model shares the common characteristic that litigants tend to settle the lawsuit at its inception rather than actually spend any resources prosecuting the action.¹²⁵ In order for litigation to ensue, it is typically necessary to assume some form of differential expectations or asymmetric information. Our model demonstrates, however, that even subtle forms of disagreement can support significant litigation expenditures before lawsuits settle midstream. In particular, we demonstrate that parties who agree as to the lawsuit's expected value and who differ only as to the lawsuit's variance can rationally incur Stage 1 litigation expenses only to settle once the court or third parties affect the parties' understanding of the variance of the underlying dispute. This finding, which again cannot be derived through a traditional DCF or NPV formulation, suggests that a real option perspective generates insights regarding the operation of the litigation process that are valuable and unique.

B. Normative Implications

A central normative proposition of the economic analysis of law is that litigation induces efficient resource allocation if the substantive rules of

125. See *supra* notes 84-86 and accompanying text.

liability and damages are properly defined. The Hand Formula, for example, describes a rule for the optimal definition of negligence standards.¹²⁶ The "efficient breach hypothesis" maintains that "court-ordered expectations damages (a liability rule) lead parties to maintain or abandon prior agreements efficiently."¹²⁷ Although the efficient breach argument was initially developed in the context of contract law, it has been broadly applied to generate similar "efficiency-based arguments . . . to promote the use of liability rules within the context of tort, property, corporate, and constitutional law."¹²⁸ The Coase Theorem's suggestion that the initial allocation of resources can be irrelevant to their ultimate efficient distribution¹²⁹ similarly relies on a court's ability to set efficient damage awards. In each of these instances, the normative prescription assumes that litigation will, on average and over time, generate damage awards that equal the amounts described by the underlying substantive standards.

It is well understood, however, that litigation is a highly imperfect process. Indeed, "the private incentive to bring suit is fundamentally misaligned with the socially optimal incentive, and the deviation between them could be in either direction."¹³⁰ Plaintiffs are sometimes overstimulated to file private actions that can saddle too many defendants with inefficiently large liabilities. Plaintiffs also sometimes labor under insufficient incentives to litigate against defendants who can inefficiently escape liability. The causes of these divergences are legion, and it is unnecessary to catalogue them in this context.¹³¹

The real options perspective, however, suggests that uncertainty alone can cause private and social incentives to litigate to diverge even in a world of risk-neutral, equally informed, and equally powerful litigants who do not labor under any of the conditions that would otherwise cause such a divergence to arise. It follows that the relationship between uncertainty and litigation's social optimality is more complex than has previously been suggested in the literature. In particular, the assumption that the litigants are risk-neutral is insufficient to eliminate uncertainty's effect on the calculation of a lawsuit's settlement value or on a plaintiff's incentive to sue. Instead, in order to equate private and social incentives to litigate, it appears necessary to assume that the uncertainty involved in a lawsuit is sufficiently small such that it does not cause the lawsuit's option settlement value to diverge from its expected value.

126. See COOTER & ULEN, *supra* note 10, at 333-37.

127. Brooks & Schwartz, *supra* note 14, at 385.

128. *Id.*

129. See generally Ronald H. Coase, *The Problem of Social Cost*, 3 J.L. & ECON. 1 (1960).

130. SHAVELL, *supra* note 25, at 391; see also sources cited *supra* note 51.

131. Commonly cited causes for this divergence include: litigation costs; asymmetric information; the mismatch between the private gain from litigation and the social benefit of the deterrence generated by litigation; social costs of operating a legal system that are not borne by litigants; and the tendency for lawsuits to settle for amounts that are either too large or too small relative to the socially optimal payment from defendant to plaintiff. See SHAVELL, *supra* note 25, at 391-401, 411-15.

But how realistic is this sort of an assumption? Several factors suggest that it may not be realistic at all. Lawsuits are, after all, filled with uncertainty over the facts of the underlying case. How will witnesses testify? Will testimony be credible? Which e-mails will turn up in production? Indeed, all one has to do is look into a jury's eyes to recognize how random the litigation process can be,¹³² and some recent studies suggest that "to the extent that there is a concern about unpredictable damage awards, deliberation [of the sort observed in the jury process] is not likely to alleviate that concern, and is indeed likely to aggravate it."¹³³ Thus, "[u]npredictability is a serious problem for jury verdicts, partly because it ensures that the similarly situated will often not be treated similarly"¹³⁴ Indeed, the category-bound nature of the litigation process ends up creating "predictably incoherent judgments" that further contribute to the uncertainty of the litigation process.¹³⁵

The roots of uncertainty in the litigation process also extend far beyond the jury room. Legislatures have strong political incentives to enact vague or ambiguous statutes that cause confusion and uncertainty when they are implemented by courts.¹³⁶ Judges who practice "minimalist" decisionmaking may well be following a modest and rational style of jurisprudence with much to commend it,¹³⁷ but the narrow scope of minimalist decisionmaking can "inject substantial uncertainty into an area of law."¹³⁸ Rationally ambiguous legislators, minimalist judges, and inconsistent fact-finders thus seem to assure that uncertainty is and will continue to be hardwired into the litigation process, notwithstanding occasional efforts to impose consistency.¹³⁹

132. See, e.g., CONSTANCE E. BAGLEY, *WINNING LEGALLY: HOW MANAGERS CAN USE THE LAW TO CREATE VALUE, MARSHAL RESOURCES, AND MANAGE RISK* 215 (2005) ("Litigation—especially before a jury—can have a lottery quality.").

133. David Schkade et al., *Deliberating About Dollars: The Severity Shift*, 100 COLUM. L. REV. 1139, 1168 (2000).

134. *Id.* Schkade et al. also suggest that uncertainty is troublesome in part because "it may produce over-deterrence in risk-averse defendants," *id.*, but our analysis suggests that the implications of uncertainty are troublesome even in the absence of risk-aversion.

135. See Cass R. Sunstein et al., *Predictably Incoherent Judgments*, 54 STAN. L. REV. 1153 (2002).

136. See, e.g., Joseph A. Grundfest & A.C. Pritchard, *Statutes with Multiple Personality Disorders: The Value of Ambiguity in Statutory Design and Interpretation*, 54 STAN. L. REV. 627 (2002); Victoria F. Nourse & Jane S. Schacter, *The Politics of Legislative Drafting: A Congressional Case Study*, 77 N.Y.U. L. REV. 575 (2002).

137. See CASS R. SUNSTEIN, *ONE CASE AT A TIME: JUDICIAL MINIMALISM ON THE SUPREME COURT* (1999).

138. Debra Livingston, *Police Discretion and the Quality of Life in Public Places: Courts, Communities, and the New Policing*, 97 COLUM. L. REV. 551, 628 (1997) (citing Cass R. Sunstein, *Foreword: Leaving Things Undecided*, 110 HARV. L. REV. 6, 16, 18, 25 (1996)).

139. The most notable effort to impose consistency on the litigation process is reflected in the passage of the Sentencing Reform Act of 1984, which required federal sentencing judges to consider the "the need to avoid unwarranted sentence disparities among defendants with similar records who have been found guilty of similar conduct," 18 U.S.C. §

These observations suggest an “impossibility conjecture” that has potentially significant implications for the normative analysis of the litigation process. If it is true that uncertainty is an essential characteristic of the litigation process, and that uncertainty cannot be reduced to a degree sufficient to equate the private and social incentives to litigate (by causing lawsuits’ option settlement values not to diverge from their expected or terminal values), then the real options perspective suggests that other assumptions about the efficiency or fairness of the private litigation process, no matter how heroic or numerous, will be insufficient to equate private and social incentives to litigate. Put another way, uncertainty alone can be sufficient to throw a monkey wrench into the proposition that private litigation can systematically be relied upon to achieve optimal social objectives even in a risk-neutral world.

This impossibility conjecture can be stated more formally as a combination of three propositions. First, if uncertainty is sufficiently large, then the private incentive to litigate will diverge from the socially optimal incentive even if all parties are risk-neutral and all other conditions necessary to equate private and social incentives are satisfied. Second, while we are aware of no data squarely on point, the uncertainty inherent in the litigation process seems sufficiently large and pervasive that private and public incentives to litigate may be destined to diverge for a large category of lawsuits simply because of the existence of that uncertainty.¹⁴⁰ Third, it may be impossible to reduce litigation

3553(a)(6) (2006), and required judges to follow, in most cases, the Sentencing Guidelines established by the United States Sentencing Commission, *id.* § 3553(b). In January 2005, however, the Supreme Court rejected the Guidelines as unconstitutional because they caused sentences to be increased on the basis of offense characteristics that were not found by a jury beyond reasonable doubt, and held that the Guidelines could not be treated as mandatory. *United States v. Booker*, 543 U.S. 220, 244-46 (2005). Even before the Court’s decision in *Booker*, there was doubt that the Guidelines had in fact overcome the institutional factors that promote disparity in the sentencing process. *See, e.g.*, Frank O. Bowman, III, *The Failure of Federal Sentencing Guidelines: A Structural Analysis*, 105 COLUM. L. REV. 1315, 1326-27 (2005) (“The available evidence suggests that the guidelines have succeeded in reducing judge-to-judge disparity within judicial districts. On the other hand, researchers have found significant disparities between sentences imposed on similarly situated defendants in different districts and different regions of the country, and interdistrict disparities appear to have grown larger in the guidelines era, particularly in drug cases. The question of whether the guidelines reduced or exacerbated racial disparities in federal sentencing remains unresolved.”) (footnotes omitted).

140. Substantial scholarship supports the proposition that uncertainty is rife in the litigation process. *See, e.g.*, Schkade et al., *supra* note 133, at 1145-46 (“[T]he legal system is pervaded by a degree of unpredictability and variance, resulting in apparent arbitrariness, as the similarly situated are treated differently. An extensive study of pain and suffering cases found that as much as 60% of the awards consists of ‘noise,’ unexplained by objective factors. A study of all reported sexual harassment cases was unable to connect either compensatory or punitive awards to any case characteristics that might be thought to explain jury judgments.”) (footnotes omitted). The literature, however, tends not to quantify the magnitude of this uncertainty in a form that would rigorously support the proposition cited in the text. We therefore state our proposition in a modest form that does appear to be supported by the literature.

uncertainty to a point where it becomes irrelevant from a real options perspective because the political and judicial branches operate under institutional incentives that perpetuate litigation uncertainty. Further, juries and other decisionmakers are subject to a wide variety of deliberative imperfections that generate uncertainty, even if they do not cause bias. If these observations are correct, then private and social incentives to litigate cannot be equated for a large number of lawsuits, notwithstanding other litigation reforms that might be adopted. Our inability to prove the second empirical proposition as a formal matter renders this observation no more than a conjecture. However, the pervasive nature of uncertainty in the litigation process suggests that the conjecture may well be highly plausible.

This impossibility conjecture, if correct, calls into question the common assumption that substantive rules of law can be crafted to generate socially optimal deterrence or compensation through litigation.¹⁴¹ Instead, in order to generate socially optimal rules, it appears necessary to consider the procedural environment in which substantive rules are litigated, the ambiguities inherent in the rules' articulation, and the unavoidable uncertainties of the litigation process. If this perspective is correct, then substance cannot be separated from procedure in pursuit of socially optimal rules of law, and the entire normative exercise requires a larger, more general equilibrium framework in which substantive standards are optimized with respect to the procedural environment in which they are enforced and with respect to the uncertainty that they are likely to encounter in application. We do not suggest that this observation is novel.¹⁴² We do, however, suggest that the identification of uncertainty as a sufficient cause for a divergence between private and social incentives to litigate underscores the value of modeling approaches that simultaneously integrate substantive and procedural concerns, such as the real options approach described in this Article.

These observations regarding the normative implications of the real options perspective raise a related pragmatic question about the operation of the litigation process. At one level, the simple binary model presented in this Article is agnostic with regard to the effects of uncertainty on the incentive to litigate because, in theory, uncertainty can increase or decrease the incentive to litigate. However, the model also suggests that if uncertainty becomes sufficiently large, it will unambiguously increase plaintiff's incentive to litigate. The model further suggests that uncertainty can cause NEV litigation to be credible even if the substantive rule of law suggests that plaintiff's recovery

141. For a discussion of this general assumption, see *supra* note 54. Another implication of this observation is that the large literature discussing the conditions under which the Coase Theorem is true may have to be expanded to include an additional requirement that the uncertainty involved in enforcing the litigation contemplated by the Theorem is sufficiently small. Again, if this assumption is not valid, then the Theorem's implication that the initial allocation of rights is irrelevant will also be invalid.

142. See POLINSKY, *supra* note 14, at 145.

should be nonpositive. Both observations suggest—but do not prove—that uncertainty generates a proplaintiff bias in the litigation process that, all other factors equal, provides an incentive for plaintiffs to file a greater-than-optimal number of lawsuits which can generate a greater-than-optimal value of settlements, where optimality is measured relative to the lawsuit's expected or terminal value. We emphasize that this observation, even if correct, is rooted in a partial equilibrium calculus that relies on a set of strong *ceteris paribus* assumptions.

C. Extensions

The binomial two-stage model presented in this Article is the simplest possible real options model of the litigation process that incorporates bargaining behavior. In order to provide greater insights, this model can be extended in several significant directions. In particular, the model can be made more general by substituting a continuous probability distribution for the binomial,¹⁴³ and then by assuming a multiperiod litigation process in which continuous probability distributions describe the information to be revealed at each stage of the litigation.¹⁴⁴ In the limit, the multiperiod model describes a continuous-time litigation process.¹⁴⁵

As presently structured, the model also considers only learning options that are coupled with costless abandonment options. That constraint can be relaxed to allow for costly abandonment, as well as to create options that would allow litigants to increase, reduce, accelerate, or defer litigation expenditures. The model can also be expanded to allow for options that increase or reduce the magnitude of the expected judgment and the volatility inherent in each stage of the process. The underlying stochastic process therefore need not be viewed as stable or as exogenously determined throughout a lawsuit's evolution.

The model's assumption that the plaintiff controls all of a lawsuit's optionality is unrealistic and can be relaxed. In practice, defendants file counterclaims and exercise various other forms of optionality that can be readily incorporated into our model. Our model can also be extended to incorporate assumptions about divergent expectations and asymmetric information,¹⁴⁶ differential risk aversion,¹⁴⁷ and emotional responses to

143. Grundfest, Huang & Wu, *supra* note 65, analyzes uniform and lognormal probability distributions. Alexander Triantis also mentioned extensions of our model to examples involving lognormal and normal probability distributions in his discussion of an earlier version of this Article presented at the John M. Olin Conference on Real Options and the Law, University of Virginia Law School (Oct. 1, 2004).

144. Triantis, *supra* note 143, also discussed extensions of our model to N periods. *See also* Grundfest, Huang & Wu, *supra* note 65 (generalizing this model to multiple periods).

145. Grundfest, Huang & Wu, *supra* note 65 (analyzing a continuous-time model with geometric Brownian motion).

146. For discussions concerning the effect of divergent expectations and asymmetric information in litigation, see Joel Waldfoegel, *Reconciling Asymmetric Information and*

litigation.¹⁴⁸ Extensions that incorporate divergent expectations in real options models explain a common tendency for plaintiffs to initiate lawsuits that settle at particular points during litigation short of trial.¹⁴⁹

Moreover, as previously observed,¹⁵⁰ the precise equilibrium values generated by our model depend on the assumption that the plaintiff's claim loses credibility if the expected value of the plaintiff continuing with litigation is not positive, without giving regard to litigation expenses that would be incurred by the defendant if the plaintiff continues to pursue his claims. An alternative equilibrium concept might view plaintiffs as willing to engage in a form of extortionist conduct. Plaintiffs might credibly threaten to continue with NEV litigation provided that the costs imposed on defendants are greater than the costs that would be borne by plaintiffs. In that event, plaintiffs with sufficient bargaining power could extract settlements that include a portion of the litigation costs that would be avoided by defendants as a consequence of early settlement, even though the claim is not credible absent the threat value.¹⁵¹ Another equilibrium concept might recognize the possibility that some plaintiffs gain pleasure from the simple fact that litigation imposes costs on defendants, even if plaintiffs' costs exceed defendants. This form of litigation *schadenfreude* might arise in divorce actions, child custody cases, and other types of litigation that have high emotional components or that manifest "grudges" held by plaintiffs against others.

As currently constructed, the model assumes that aggregate litigation expenditures, the timing of those expenditures, expected judgments, and anticipated volatilities are exogenously determined. In reality, however, the litigation process can reflect complex strategic interactions as each party's

Divergent Expectations Theories of Litigation, 16 J.L. & ECON. 451, 457-67 (1998) (presenting empirical evidence finding the litigation process is consistent with divergent expectations theories, but not asymmetric information models); Muhamet Yildiz, *Waiting To Persuade*, 119 Q.J. ECON. 223 (2004) (providing a sequential bargaining model involving players having differing optimistic beliefs about their bargaining power). See also Urs Schweizer, *Litigation and Settlement Under Two-Sided Incomplete Information*, 56 REV. ECON. STUD. 163 (1989); David Rosenberg & Steven Shavell, *A Solution to the Problem of Nuisance Suits: The Option To Have the Court Bar Settlement* (Harvard Law & Econ. Discussion Paper No. 489, 2004), available at <http://ssrn.com/abstract=623285> (last visited Feb. 25, 2006).

147. For discussions of differential risk aversion's implications, see W. Kip Viscusi, *Product Liability Litigation with Risk Aversion*, 17 J. LEGAL STUD. 101, 103 (1988); Jianjun Miao & Neng Wang, Risk, Uncertainty, and Option Exercise (2004), available at <http://ssrn.com/abstract=605221> (last visited Feb. 25, 2006).

148. For a discussion of emotional reactions in litigation, see Peter H. Huang & Ho-Mou Wu, *Emotional Responses in Litigation*, 12 INT'L REV. L. & ECON. 31 (1992).

149. See Appendix Proposition 14; see also *supra* note 44.

150. See *supra* Part III.C.4.

151. See, e.g., Huang & Wu, *supra* note 148 (analyzing such emotions as anger and vengeance in litigation); see also William G. Morrison, *Instincts as Reflex Choice: Does Loss of Temper Have Strategic Value?*, 31 J. ECON. BEHAV. & ORG. 335 (1996) (explaining how loss of temper can create such a threat value to bolster credibility of the litigation).

strategy can depend critically on assumptions regarding opposing parties' conduct. A complete model of the litigation process would therefore include a game-theoretic component that incorporates strategic interaction effects throughout the litigation process, including, for example, in the determination of the amount and sequence of litigation expenditures and in the use of strategies that are likely to increase or dampen the volatility and expected value of litigation outcomes.¹⁵²

In addition to rich opportunities for technical extensions of the model, the real options approach is also potentially well suited to the study of specific policy issues related to the operation of the litigation process. The debates over class action litigation and fee shifting are examples of two public policy issues that are particularly susceptible of analysis through the lens of real option theory.

As for the study of class action litigation, Judge Posner's decision in *Rhone-Poulenc*¹⁵³ addresses a situation in which defendants might rationally be willing to try a large number of lawsuits if each is prosecuted on an individual case-by-case basis, but recoil at the prospect of trying the same set of cases if aggregated as a class action claim. In *Rhone-Poulenc*, plaintiff hemophiliacs alleged that they had contracted Human Immunodeficiency Virus (HIV) from negligently manufactured blood clotting factors. Defendants had prevailed in twelve of thirteen individual actions. The question on appeal was whether to grant class certification. The court observed that for the remaining 300 individual actions, given the defendants' record of trial victories, the defendants might lose about 25 individual suits with average damages of \$5 million per defeat, yielding a total liability of \$125 million. However, if a class was certified, Judge Posner projected that the number of claims would then increase to potentially 5000 with a worst-case liability scenario of \$25 billion—more than enough liability to induce bankruptcy risk. As the court observed, the defendants "may not wish to roll these dice. That is putting it mildly. They will be under intense pressure to settle."¹⁵⁴ This observation has spawned the "settlement pressure" hypothesis,¹⁵⁵ which has been cited with approval in some recent decisions as a factor militating against certifying large class actions¹⁵⁶ while being distinguished as irrelevant by other courts certifying

152. For an example of such strategic considerations incorporated into non-options models of the litigation process, see Kathryn E. Spier, *Settlement Bargaining and the Design of Damage Awards*, 10 J.L. ECON. & ORG. 84 (1994). See generally DOUGLAS G. BAIRD ET AL., *GAME THEORY AND THE LAW* (1994) (providing several such examples). For an example of real options models that incorporate strategic interaction effects, see GRENADIER, *supra* note 1.

153. *In re Rhone-Poulenc Rorer, Inc.*, 51 F.3d 1293 (7th Cir. 1995).

154. *Id.* at 1298.

155. See Charles Silver, *We're Scared to Death: Class Certification and Blackmail*, 78 N.Y.U. L. REV. 1357 (2003).

156. See, e.g., *Castano v. Am. Tobacco Co.*, 84 F.3d 734, 746 (5th Cir. 1996) (citing the risk of "all-or-nothing" verdicts).

plaintiff classes.¹⁵⁷ The settlement pressure hypothesis has also generated a split among academic commentators: some express concern over the “legalized blackmail” of low probability class action lawsuits,¹⁵⁸ while others suggest that courts applying the settlement pressure argument have relied on questionable empirical assumptions and have been inconsistent in applying their logic to the evaluation of class certification claims.¹⁵⁹

Real option theory offers a rigorous tool for addressing this debate because it allows for the straightforward comparison of the settlement value of a group of cases if pursued on a case-by-case basis and the settlement value of the same cases if aggregated into a single class claim. The comparison can account for the fact that class certification simultaneously increases the variance of the underlying claim and reduces the average cost of prosecuting and defending each claim, and can eliminate the risk of inconsistent assumptions. Simple examination of the model presented in this Article suggests that the variance-increasing effect of claim aggregation can generate settlement pressure of the form hypothesized in *Rhone-Poulenc* even if the defendants are risk-neutral and not subject to bankruptcy risk. The real options model can also express that pressure in the form of a ratio that describes the real option settlement value of the aggregated class claim as percentage of the real option settlement value of the same cases if pursued as individual claims. Whether the existence or magnitude of such settlement pressure should influence the class certification decision is an entirely distinct question, but real option theory can, we think, help frame this debate with far greater precision.

The fee-shifting debate has also generated a large and contentious literature¹⁶⁰ to which real option theory might be able to make a meaningful contribution. The move from a regime in which each litigant bears his own

157. See, e.g., *In re Visa Check/MasterMoney Antitrust Litig.*, 280 F.3d 124, 145 (2d Cir. 2001) (“While the sheer size of the class . . . may enhance [plaintiffs’ leverage in settlement negotiations], this alone cannot defeat an otherwise proper certification.”).

158. See, e.g., George L. Priest, *Procedural Versus Substantive Controls of Mass Tort Class Actions*, 26 J. LEGAL STUD. 521 (1997) (arguing that preaggregation substantive review is necessary to prevent meritless cases which settle solely due to the presence of a large class); Georgene M. Vairo, *Georgine, the Dalkon Shield Claimants Trust, and the Rhetoric of Mass Tort Claims Resolution*, 31 LOY. L.A. L. REV. 79 (1997) (tracing the history of rhetoric behind the justifications for class aggregation and finding that closer scrutiny to the fairness of aggregation and settlement values is needed).

159. See, e.g., Bruce Hay & David Rosenberg, “Sweetheart” and “Blackmail” Settlements in Class Actions: Reality and Remedy, 75 NOTRE DAME L. REV. 1377, 1379 (2000) (concluding that the “risks of sweetheart and blackmail settlements have been overstated” and that courts should not reduce access to the damage class action); Warren F. Schwartz, *Long Shot Class Actions: Toward a Normative Theory of Legal Uncertainty*, 8 LEGAL THEORY 297, 297-98 (2002) (criticizing the characterization of long shot class actions as “blackmail”); Silver, *supra* note 155, at 1357 (arguing that these “blackmail charges” cannot survive scrutiny).

160. For a discussion of the effects of fee shifting on lawsuits, see SHAVELL, *supra* note 25, at 428-32.

expenses, the “American rule,” to the “British Rule” in which the “loser” (however defined) pays some fraction of the winner’s litigation expenditures, causes a simultaneous change in the variance and in the expected value of the outcome of any lawsuit. Again, by comparing the option settlement values of identical lawsuits with and without fee-shifting rules, it should be possible to describe with precision the implications of changes in the rules governing the allocation of litigation expenditures.

The real options approach also need not be limited to private civil litigation seeking monetary damages. It is readily extended to address the criminal process, as well as the several different forms of civil prosecutorial options held by the Department of Justice, the Internal Revenue Service, the Securities and Exchange Commission, and state enforcement agencies. Extensions to the criminal process are, we believe, of particular interest in light of the extreme penalties often imposed by the Federal Sentencing Guidelines. Those extreme sentences, when viewed through a real options model of the sort presented here, create high variance that can dramatically increase the prosecution’s bargaining leverage, as has proven to be the case.¹⁶¹ At the other end of the dispute resolution spectrum, real option analysis can further be applied to the study of arbitration, mediation, and other alternative dispute resolution techniques, whether those techniques are applied as a prelude to litigation or as stand-alone dispute resolution mechanisms.

At some point, however, it becomes useful to move beyond the construction of abstract models of the litigation process and to apply real option theory to the analysis of actual lawsuits. The challenge in this regard is similar to the challenge observed as real option theory attempts to make the leap from the academic environment to the corporate boardroom. There, practitioners complain that it can be difficult to estimate the variance of the underlying outcomes, that the number of decisions that have to be modeled can be very large, and that the mathematics of solving for options values using formal options methodology, such as the Black-Scholes options pricing model,¹⁶² can be quite daunting.¹⁶³ There are, however, straightforward responses to all of these objections. These responses can be applied to help build real options models of the litigation process and also suggest that constructing real options models of the litigation process can in several respects be simpler than building

161. See, e.g., Stephanos Bibas, *Plea Bargaining Outside the Shadow of Trial*, 117 HARV. L. REV. 2463 (2004) (arguing that plea bargain sentences can be skewed by uncertainty and statutory minimums and maximums for sentencing); Frank O. Bowman, III, *Pour Encourager Les Autres? The Curious History and Distressing Implications of the Criminal Provisions of the Sarbanes-Oxley Act and the Sentencing Guidelines Amendments that Followed*, 1 OHIO ST. J. CRIM. L. 373 (2004) (outlining impacts of increased maximum sentences for economic crimes).

162. Fisher Black & Myron Scholes, *The Pricing of Options and Corporate Liabilities*, 81 J. POL. ECON. 637 (1973).

163. See, e.g., Copeland & Tufano, *supra* note 56 (describing challenges of applying real options theory and giving realistic techniques for responding to these challenges).

real options models of other processes.¹⁶⁴ In particular, litigation is a highly structured process and operates through a well-defined sequence of events. Litigation is, in this respect, better defined than many other investment projects. The likely range of outcomes at each stage of the litigation process is also relatively well defined and is usually bounded in terms of a best and worst possible outcome. Experienced counsel can generally provide reasoned estimates of the distribution of these outcomes at each stage of the process.¹⁶⁵ Indeed, even if counsel lack the experience necessary to generate such estimates, the models can be constructed using the equal ignorance assumption and can be subjected to sensitivity analyses designed to test whether and how various assumptions regarding the model's parameterization influence the lawsuit's potential settlement value. Computationally, because lawsuits typically involve a finite number of key decision points, standard binomial lattice approaches to the valuation of real options will be particularly well suited to the calculation of litigation options settlement values, and there will likely be little reason to resort to more complex computational techniques,¹⁶⁶ such as the Black-Scholes option valuation model.¹⁶⁷

On the other side of the ledger, a lawsuit's settlement value can be influenced by differential expectations, by differential bargaining power (or perceptions of differential bargaining power), and by game-theoretic effects that can be difficult to estimate. As difficult as these considerations are likely to be, they will be no more difficult to address than the game-theoretic considerations that arise in nonlitigation environments.¹⁶⁸ Further, if these considerations are significant, they will have to be addressed in any model of the litigation environment, whether expressed as a real options model or not. From that perspective the problems encountered in implementing a real options model of the litigation process are no easier or more difficult than the problems that would be encountered in the application of other modeling techniques.

164. See, e.g., *id.* (describing realistic techniques for responding to the challenges of applying real options theory). For an application of real option theory to real life valuation, see Don M. Chance et al., *Pricing an Option on a Non-Decreasing Asset Value: An Application to Movie Revenue* (unpublished manuscript, Dec. 16, 2005), available at <http://ssrn.com/abstract=870793>.

165. See Victor, *supra* note 56 (explaining decision tree valuation of litigation).

166. See, e.g., Copeland & Tufano, *supra* note 56 (describing realistic techniques for responding to the challenges of applying real options theory).

167. See Black & Scholes, *supra* note 162.

168. See Grenadier, *supra* note 1 (providing examples of complications in game theory).

APPENDIX: PROPOSITIONS AND PROOFS

PROPOSITION 1

(a) Necessary and sufficient conditions for credibility of litigation at the start of Stage 2, prior to a court's disclosure of information, are: $A > C_{p2}$, or $B > C_{p2}$, or both.

(b) A necessary and sufficient condition for credibility of litigation at the start of Stage 1 is: $S_2 > C_{p1}$, where S_2 is the settlement value at the start of Stage 2.

(c) This lawsuit has an option settlement value measured prior to Stage 1 litigation costs of:

$S^* = \frac{1}{2}\{\max(0, S_2 - C_{p1}) + (S_2 + C_{d1})\text{Inv}[S_2 > C_{p1}]\}$, where $\text{Inv}[S]$ is one if the statement S is true and zero if S is false.

Proof:

At the start of Stage 2, before both parties learn a court's ruling and before a plaintiff decides whether to spend C_{p2} , plaintiff's minimum demand is:

$$\text{Min Demand}_2 = p[\max(0, A - C_{p2})] + (1 - p)[\max(0, B - C_{p2})].$$

Notice that Min Demand_2 involves expressions for payoffs of call options written upon our underlying random variable X , with a strike price of C_{p2} .

Define Inversion bracket, $\text{Inv}[S]$, to have value one if a statement S is true and zero if a statement S is false.

Then, a defendant's maximum offer can be expressed as:

$$\text{Max Offer}_2 = p(A + C_{d2})\text{Inv}[A > C_{p2}] + (1 - p)(B + C_{d2})\text{Inv}[B > C_{p2}].$$

Thus, assuming equal bargaining power, the settlement value at the start of Stage 2 becomes:

$$S_2 = \frac{1}{2}(\text{Min Demand}_2 + \text{Max Offer}_2)$$

At the start of Stage 1, before a plaintiff decides whether to spend C_{p1} , this lawsuit has a settlement value of:

$$S^* = \frac{1}{2}(\text{Min Demand}_1 + \text{Max Offer}_1), \text{ where}$$

$$\text{Min Demand}_1 = \max(0, S_2 - C_{p1});$$

$$\text{Max Offer}_1 = (S_2 + C_{d1})\text{Inv}[S_2 > C_{p1}].$$

Notice that Min Demand_1 is an expression for the payoff of a call option written upon the settlement value at the start of Stage 2, with a strike price of C_{p1} .

Thus, from our above expressions for S_2 and S^* , it is clear that if $A > C_{p2}$, or $B > C_{p2}$, or both, and $S_2 > C_{p1}$, this lawsuit is credible overall for this plaintiff in the sense that $S^* > 0$. Conversely, if $S^* > 0$, then $S_2 > C_{p1}$ and either $A > C_{p2}$, or $B > C_{p2}$, or both.

PROPOSITION 2

All PEV lawsuits are credible for every level of variance, i.e., for any values of A and B .

Proof:

A PEV lawsuit satisfies: $\mu > C_p = C_{p1} + C_{p2} > C_{p2}$.

Suppose that $A < C_{p2}$. Then we argue by contradiction that $B > C_{p2}$ must hold. For if both $A < C_{p2}$ and $B < C_{p2}$, then $pA < pC_{p2}$, $(1-p)B < (1-p)C_{p2}$, and so $\mu = pA + (1-p)B < pC_{p2} + (1-p)C_{p2} = C_{p2}$, which contradicts $\mu > C_{p2}$. Thus, lawsuit credibility constraints at Stage 2 hold (i.e., both legs cannot be noncredible). As for lawsuit credibility constraints at Stage 1 that $S_2 > C_{p1}$, suppose that both $A > C_{p2}$ and $B > C_{p2}$. Then,

$$\begin{aligned} S_2 &= \frac{1}{2}[\text{Min Demand}_2 + \text{Max Offer}_2] \\ &= \frac{1}{2}[p(A - C_{p2}) + (1-p)(B - C_{p2}) + p(A + C_{d2}) + (1-p)(B + C_{d2})] \\ &= \frac{1}{2}[2pA + 2(1-p)B + C_{d2} - C_{p2}] \\ &= \mu + \frac{1}{2}(C_{d2} - C_{p2}) \end{aligned}$$

If $S_2 < C_{p1}$, then $\mu + (\frac{1}{2})(C_{d2} - C_{p2}) < C_{p1}$, so that $\mu + (\frac{1}{2})(C_{d2}) < (\frac{1}{2})C_{p2} + C_{p1}$, and $\mu < \mu + \frac{1}{2}(C_{d2}) < C_{p1} + (\frac{1}{2})C_{p2} < C_{p1} + C_{p2} = C_p$, which contradicts $\mu > C_p$.

Conversely, suppose that $A > C_{p2}$, but $B < C_{p2}$. Then, $S_2 = p[A + \frac{1}{2}(C_{d2} - C_{p2})]$. We argue by contradiction that $S_2 > C_{p1}$ must hold because $S_2 < C_{p1} \Leftrightarrow p[A + \frac{1}{2}(C_{d2} - C_{p2})] < C_{p1} \Leftrightarrow pA < C_{p1} + (p/2)(C_{p2} - C_{d2})$. But now,

$$\begin{aligned} \mu &= pA + (1-p)B \\ &< pA + (1-p)C_{p2}, \text{ because we assume } B < C_{p2} \Leftrightarrow (1-p)B < (1-p)C_{p2} \\ &< C_{p1} + (p/2)(C_{p2} - C_{d2}) + (1-p)C_{p2}, \text{ because we assumed } pA < C_{p1} + \\ &\quad (p/2)(C_{p2} - C_{d2}) \\ &< C_{p1} + (p/2)(C_{p2}) + (1-p)C_{p2}, \text{ because } (p/2)C_{d2} > 0 \\ &< C_{p1} + (\frac{1}{2})(p + 2 - 2p)(C_{p2}) = C_{p1} + (\frac{1}{2})(2-p)(C_{p2}) \\ &< C_{p1} + C_{p2} = C_p, \text{ because } (\frac{1}{2})(2-p) = 1 - (p/2) < 1. \end{aligned}$$

But, $\mu < C_p$ contradicts $\mu > C_p$.

PROPOSITION 3

Every NEV lawsuit is credible for a sufficiently high level of variance.

Proof:

An NEV lawsuit satisfies: $\mu < C_p = C_{p1} + C_{p2}$. In order to be a credible lawsuit, by Proposition 1, at the start of Stage 2, it must be that $A > C_{p2}$, or $B > C_{p2}$, or both. If $A < C_{p2}$, then we can ensure that $B > C_{p2}$ must hold for a sufficiently high level of variance by simply increasing B and simultaneously decreasing A to preserve the value of μ . Thus, the credibility constraints at Stage 2 hold (i.e., both legs cannot be noncredible). As for the credibility constraint at Stage 1 that $S_2 > C_{p1}$, note that as the variance increases, either $A > C_{p2}$ or $B > C_{p2}$ fails to hold. Without any loss of generality, suppose that eventually $A > C_{p2}$, but $B < C_{p2}$. Then, $S_2 = p[A + \frac{1}{2}(C_{d2} - C_{p2})]$. To ensure this expression is greater than C_{p1} , just increase A (and correspondingly, the variance).

PROPOSITION 4

If $A \geq 0$ and $B \geq 0$, then some NEV lawsuits are never credible.

Proof:

Recall that a NEV lawsuit satisfies: $\mu < C_p = C_{p1} + C_{p2}$ and that $\mu = pA + (1 - p)B$. If we assume that $C_{p2} > \mu$, a lawsuit is not credible when $A = B = \mu$ (i.e., when the variance is zero). If both $A \geq 0$ and $B \geq 0$ and p and μ are held fixed, there is a maximum value that A can take on, namely μ/p (equivalently, when $B = 0$). Consider NEV lawsuits with plaintiff's litigation costs in Stage 2 satisfying $C_{p2} > \mu/p$. Because $p < 1$, $\mu/p > \mu$. Therefore, if we assume that $C_{p2} > \mu/p > \mu$, then for such NEV lawsuits, by construction, it is not credible for a plaintiff to proceed with a lawsuit in Stage 2 for all values of A from 0 to μ/p . If both $A \geq 0$ and $B \geq 0$, then only these values are feasible for A . Thus, NEV lawsuits with $C_{p2} > \mu/p$, $A \geq 0$, and $B \geq 0$ are never credible.

PROPOSITION 5

If no variance is associated with the underlying judgment,¹⁶⁹ meaning that $A = B = \mu$, and if a lawsuit is credible, then the option settlement value of a lawsuit equals its divisibility settlement value.¹⁷⁰

Proof:

If $A = B$, then in Stage 2, a plaintiff's minimum demand,

Min Demand₂ = $\max(0, A - C_{p2})$ and the defendant's maximum offer,

Max Offer₂ = $(A + C_{d2})\text{Inv}[A > C_{p2}]$.

Thus, the option settlement value at the start of Stage 2,

$$S_2 = \frac{1}{2}(\text{Min Demand}_2 + \text{Max Offer}_2)$$

$$= \frac{1}{2}[\max(0, A - C_{p2}) + (A + C_{d2})\text{Inv}[A > C_{p2}]]$$

$$= \frac{1}{2}[(A - C_{p2}) + (A + C_{d2})]$$
 because we assumed this lawsuit is credible, meaning that $A > C_{p2}$

$$= \mu + \frac{1}{2}(C_{d2} - C_{p2}),$$
 because $A = B = \mu$.

From Proposition 1, option settlement value of a lawsuit is equal to:

$$S^* = \frac{1}{2}[\max(0, S_2 - C_{p1}) + (S_2 + C_{d1})\text{Inv}[S_2 > C_{p1}]].$$

At Stage 1, by assumption, $S_2 > C_{p1}$ (credibility of lawsuit); so that

$$S^* = \frac{1}{2}[(S_2 - C_{p1}) + (S_2 + C_{d1})]$$

$$= \frac{1}{2}[(2S_2 + C_{d1} - C_{p1})]$$

$$= S_2 + \frac{1}{2}(C_{d1} - C_{p1})$$

$$= \mu + \frac{1}{2}(C_{d2} - C_{p2}) + \frac{1}{2}(C_{d1} - C_{p1})$$

$$= \mu + \frac{1}{2}(C_d - C_p),$$
 the divisibility settlement value.

169. To say variance of uncertainty that a court resolves is zero means a court's ruling reveals no payoff-relevant information.

170. This demonstrates that Bebchuk's model with divisible litigation costs is a special case of our model where variance is zero.

PROPOSITION 6

For a credible lawsuit, if $A > C_{p2}$ and $B > C_{p2}$ (i.e., if the lawsuit is credible in Stage 2 under either court ruling), then the lawsuit's option settlement value equals its divisibility settlement value.

Proof:

If both $A > C_{p2}$ and $B > C_{p2}$, then

$$\begin{aligned} S_2 &= \frac{1}{2}[\text{Min Demand}_2 + \text{Max Offer}_2] \\ &= \frac{1}{2}[p(A - C_{p2}) + (1 - p)(B - C_{p2}) + p(A + C_{d2}) + (1 - p)(B + C_{d2})] \\ &= \mu + \frac{1}{2}(C_{d2} - C_{p2}). \end{aligned}$$

At Stage 1, by assumption, $S_2 > C_{p1}$ (credibility of lawsuit); so that

$$\begin{aligned} S^* &= \frac{1}{2}[(S_2 - C_{p1}) + (S_2 + C_{d1})] \\ &= S_2 + \frac{1}{2}(C_{d1} - C_{p1}) \\ &= \mu + \frac{1}{2}(C_{d2} - C_{p2}) + \frac{1}{2}(C_{d1} - C_{p1}) \\ &= \mu + \frac{1}{2}(C_d - C_p), \text{ the divisibility settlement value.} \end{aligned}$$

PROPOSITION 7

If outcomes A and B are both nonnegative and $C_{d2} \geq C_{p2}$, then a lawsuit's divisibility settlement value is an upper bound for its option settlement value.

Proof:

Suppose that $A > C_{p2}$, but $B < C_{p2}$. Then,

$$\begin{aligned} S_2 &= \frac{1}{2}[\text{Min Demand}_2 + \text{Max Offer}_2] \\ &= \frac{1}{2}[p(A - C_{p2}) + p(A + C_{d2})] \\ &= p[A + \frac{1}{2}(C_{d2} - C_{p2})] \end{aligned}$$

At Stage 1, if $S_2 > C_{p1}$ (credibility of lawsuit), then

$$\begin{aligned} S^* &= \frac{1}{2}[(S_2 - C_{p1}) + (S_2 + C_{d1})] \\ &= \frac{1}{2}(2S_2 + C_{d1} - C_{p1}) \\ &= S_2 + \frac{1}{2}(C_{d1} - C_{p1}) \\ &= pA + (p/2)(C_{d2} - C_{p2}) + \frac{1}{2}(C_{d1} - C_{p1}), \text{ which differs from a lawsuit's} \\ &\text{divisibility settlement value, } \mu + \frac{1}{2}(C_d - C_p), \text{ by } (1 - p)[B + (\frac{1}{2})(C_{d2} - C_{p2})]. \end{aligned}$$

PROPOSITION 8

For a credible lawsuit, if $A > C_{p2}$ and $B > C_{p2}$ and $C_d = C_p$, then μ (the initial expected value of its judgment) equals its divisibility settlement and its option settlement value.

Proof:

A credible lawsuit's divisibility settlement value is $\mu + (\frac{1}{2})(C_d - C_p)$. So, if $C_d = C_p$, then its divisibility settlement value equals μ . If $A > C_{p2}$ and $B > C_{p2}$, then proposition 6 ensures that its divisibility settlement equals its option

settlement value.

Note that if X denotes a random variable that can take on values of either A or B , then $\text{Var}(X) = \mu^2 = E[(X - \mu)^2] = E[X^2 - 2\mu X + \mu^2] = E[X^2] - 2\mu E[X] + E[\mu^2] = E[X^2] - 2\mu^2 + \mu^2 = E[X^2] - \mu^2 = pA^2 + (1 - p)B^2 - \mu^2 = pA^2 - \mu^2 + (\mu - pA)B$, because $(1 - p)B = \mu - pA$ from $\mu = pA + (1 - p)B$. Thus, $\text{Var}(X) = pA^2 - \mu^2 + [(\mu - pA)^2]/(1 - p)$, because $B = (\mu - pA)/(1 - p)$. This demonstrates that $\text{Var}(X) = \sigma^2$ is a function of A (or B because of our mean-preserving spread condition). $\text{Var}(X)$ is a monotonically increasing function of A because the partial derivative of $\text{Var}(X)$ with respect to A is nonnegative. In symbols, $\partial \text{Var}(X)/\partial A = 2pA + [-2p\mu + 2p^2A]/(1 - p) = 2p[A - (\mu - pA)/(1 - p)] = 2p[A(1 - p) - (\mu - pA)]/[(1 - p)] = 2p[A - \mu]/[(1 - p)] \geq 0$ because, by assumption, $A \geq B$, which means that $A \geq \mu$.

PROPOSITION 9

As A increases from μ , where the option settlement value coincides with the divisibility settlement value, there exists a value of A at which the lawsuit's option settlement value differs from its divisibility settlement value. If a lawsuit is not credible at Stage 1, then its option settlement value is constant at zero until A is large enough for the lawsuit to become credible for a plaintiff at Stage 1. Once a lawsuit is credible at Stage 1, its option settlement value is a monotonically increasing affine function of A . This affine function has a value which is initially less than this lawsuit's divisibility settlement value if that divisibility settlement value is positive, but at some value of A , this affine function equals this lawsuit's divisibility settlement value, and for all values of A larger than this critical point, this function exceeds the lawsuit's divisibility settlement value. A discontinuity in this lawsuit's option settlement value occurs when A is sufficiently large.

Proof:

This proposition derives comparative statics for a lawsuit's option settlement value as a function of A (or B or $\text{Var}(X) = \sigma^2$). Graphically, this proposition involves plotting S^* against A . Draw a diagram that has $A = B = \mu$ as its origin with $S^* = \mu + \frac{1}{2}(C_d - C_p)$. As A increases, S^* remains at $\mu + \frac{1}{2}(C_d - C_p)$, until $A = (1/p)[\mu - (1 - p)C_{p2}]$ ($\Leftrightarrow B = C_{p2}$). At which point, if a court selects B , a plaintiff will abandon the lawsuit. If a court selects A , a plaintiff will have a credible threat to proceed at Stage 2 if $A > C_{p2}$ ($\Leftrightarrow \mu > C_{p2}$). If not, a plaintiff would not file a lawsuit because $S_2 = 0$. If a plaintiff has a credible threat to proceed at Stage 2, then $S_2 = p[A + \frac{1}{2}(C_{d2} - C_{p2})]$. A plaintiff at Stage 1 only proceeds if doing so is credible, i.e., $S_2 > C_{p1}$ ($\Leftrightarrow \mu + [(p/2) - 1]C_{p2} + (p/2)C_{d2} > C_{p1}$). If not, a plaintiff would not file the lawsuit because $S^* = 0$. If $S_2 > C_{p1}$, then $S^* = pA + (p/2)(C_{d2} - C_{p2}) + \frac{1}{2}(C_{d1} - C_{p1})$. Thus, S^* drops discontinuously to

$$S^* = [pA + (p/2)(C_{d2} - C_{p2}) + \frac{1}{2}(C_{d1} - C_{p1})] \text{Inv}[A > C_{p2}] \text{Inv}[p[A + \frac{1}{2}(C_{d2} - C_{p2})] > C_{p1}].$$

For large enough values of A , $S_2 = p[A + \frac{1}{2}(C_{d2} - C_{p2})]$ will exceed C_{p1} , so that it will be credible for a plaintiff to proceed at Stage 1.

A discontinuity in S^* occurs at $A = \max\{(1/p)[\mu - (1 - p)C_{p2}], C_{p2}, (1/p)C_p - \frac{1}{2}(C_{d2} - C_{p2})\}$.

PROPOSITION 10

For a range of A values for which a lawsuit's option settlement values are increasing (i.e., over its affine range), plaintiffs will act as if they are risk-seeking and defendants will act as though they are risk-averse, although both are risk-neutral.

Proof:

For values of A which $S_2 = p[A + \frac{1}{2}(C_{d2} - C_{p2})] > C_{p1}$, and $A > C_{p2}$,

$$S^* = [pA + (p/2)(C_{d2} - C_{p2}) + \frac{1}{2}(C_{d1} - C_{p1})].$$

This is an increasing function of A , as are both a plaintiff's minimum demands and defendant's maximum offers at both stages. In this sense, plaintiffs will act as if they are risk-seeking and defendants will act as though they are risk-averse.

PROPOSITION 11

As a plaintiff's litigation costs decrease (increase), *ceteris paribus*, all of the following increase (decrease):

- (a) a lawsuit's option settlement value;
- (b) the difference between a lawsuit's divisibility settlement value and its option settlement value after its point of discontinuity;
- (c) a lawsuit's point of discontinuity of option settlement value as a function of A .

Proof:

A lawsuit's divisibility settlement value is $\mu + \frac{1}{2}(C_d - C_p)$. A lawsuit's option settlement value when it differs from this and is not zero is $S^* = [pA + (p/2)(C_{d2} - C_{p2}) + \frac{1}{2}(C_{d1} - C_{p1})]$.

- (a) This expression increases as a plaintiff's litigation costs decreases, *ceteris paribus*.
- (b) The difference between a lawsuit's divisibility settlement value and a lawsuit's option settlement value after its discontinuity is the absolute value of $(1 - p)B + [(1 - p)/2](C_{d2} - C_{p2})$. This expression also increases as a plaintiff's litigation costs decreases, *ceteris paribus*.
- (c) Finally, the discontinuity in S^* as a function of A occurs at $\max\{(1/p)[\mu - (1 - p)C_{p2}], C_{p2}, (1/p)C_p - \frac{1}{2}(C_{d2} - C_{p2})\}$, which also increases as a plaintiff's litigation cost decreases, *ceteris paribus*.

PROPOSITION 12

As Stage 1 litigation costs increase relative to Stage 2 litigation costs, if total litigation costs and all other variables are held fixed,

- (a) there is a larger interval of A values over which a lawsuit's option settlement value coincides with a lawsuit's divisibility settlement value;
- (b) a plaintiff is more likely to have a credible threat to proceed at Stage 2;
- (c) a plaintiff is less likely to have a credible threat to proceed at Stage 1;
- (d) there is a smaller range of A values over which a lawsuit's option settlement value is a monotonically increasing affine function.

Proof:

As C_{p1} increases, C_{p2} decreases (to keep total plaintiff litigation costs C_p constant), and as C_{d1} increases, C_{d2} decreases (to keep total defendant litigation costs C_d constant). This entails that:

- (a) A reaches the critical point $A = \max\{(1/p)[\mu - (1 - p)C_{p2}], C_{p2}, (1/p)C_p - \frac{1}{2}(C_{d2} - C_{p2})\}$ at higher values;
- (b) Stage 2 credibility constraint $A > C_{p2}$ is more likely to hold;
- (c) Stage 1 credibility constraint $S_2 = p[A + \frac{1}{2}(C_{d2} - C_{p2})] > C_{p1}$ is less likely to hold: C_{d2} decreases as C_{d1} increases and for any increase Δ in C_{p1} , the left-hand term of the inequality will only increase by $\frac{1}{2}p\Delta < \Delta$;
- (d) the minimum value of A for which $S_2 = p[A + \frac{1}{2}(C_{d2} - C_{p2})] > C_{p1}$, namely $A = (1/p)C_{p1} + [C_{p2}/2] - [C_{d2}/2]$ increases because $(1/p) > 1$ as $p < 1$.

Therefore, the increase in C_{p1} trumps the decrease in C_{p2} and the increase in C_{d1} means a decrease in C_{d2} , which is being subtracted.

PROPOSITION 13

As a plaintiff's bargaining power increases, more NEV lawsuits are credible, option settlement values increase, and the effect of the increase in a plaintiff's bargaining power is more than proportional when a lawsuit is NEV or a plaintiff's litigation cost in Stage 1 is sufficiently large.¹⁷¹

Proof:

If parties differ in their bargaining strength, suppose that at each stage, a plaintiff makes a take-it-or-leave-it offer with probability α and a defendant makes the take-it-or-leave-it offer with probability $1 - \alpha$. Because an ability to make a take-it-or-leave-it offer conveys a bargaining advantage, $\alpha > \frac{1}{2}$ means that a plaintiff has greater bargaining power and $\alpha < \frac{1}{2}$ means that a defendant has greater bargaining power (and $\alpha = \frac{1}{2}$ means a plaintiff and defendant have equal bargaining power). When a plaintiff makes a settlement offer, he will offer the highest amount that a defendant will be willing to accept and when a defendant makes the settlement offer, he will offer the lowest amount that a plaintiff will be willing to accept. Thus, at the start of Stage 2,

$$S_2 = \alpha(\text{Max Offer}_2) + (1 - \alpha)(\text{Min Demand}_2), \text{ where}$$

171. An example illustrates what we mean by disproportionality in this context: a 10% increase in a plaintiff's bargaining power can lead to a much larger than 10% increase in a lawsuit's option settlement value because that increase can create lawsuit credibility where there otherwise would be none.

$$\text{Max Offer}_2 = p(A + C_{d2})\text{Inv}[A > C_{p2}] + (1 - p)(B + C_{d2})\text{Inv}[B > C_{p2}]$$

$$\text{Min Demand}_2 = p[\max(0, A - C_{p2})] + (1 - p)[\max(0, B - C_{p2})].$$

Similarly at the start of Stage 1,

$$S^* = \alpha(\text{Max Offer}_1) + (1 - \alpha)(\text{Min Demand}_1), \text{ where}$$

$$\text{Max Offer}_1 = (S_2 + C_{d1})\text{Inv}[S_2 > C_{p1}]$$

$$\text{Min Demand}_1 = \max(0, S_2 - C_{p1})$$

Suppose that both $A > C_{p2}$ and $B > C_{p2}$. Then,

$$S_2 = \alpha(\text{Max Offer}_2) + (1 - \alpha)(\text{Min Demand}_2)$$

$$= \alpha[p(A + C_{d2}) + (1 - p)(B + C_{d2})] + (1 - \alpha)[p(A - C_{p2}) + (1 - p)(B - C_{p2})]$$

$$= \mu + \alpha C_{d2} - (1 - \alpha)C_{p2}.$$

Thus, the Stage 1 credibility condition $S_2 > C_{p1}$ is more likely to be satisfied as α increases.

Suppose that $A > C_{p2}$, but $B < C_{p2}$. Then,

$$S_2 = \alpha(\text{Max Offer}_1) + (1 - \alpha)(\text{Min Demand}_1)$$

$$= \alpha [p(A + C_{d2})] + (1 - \alpha)[p(A - C_{p2})]$$

$$= p[A + \alpha C_{d2} - (1 - \alpha)C_{p2}].$$

Again, the Stage 1 credibility condition $S_2 > C_{p1}$ is more likely to be satisfied as α increases.

If both $A > C_{p2}$ and $B > C_{p2}$, recall from the above that this implies $S_2 = \mu + \alpha C_{d2} - (1 - \alpha)C_{p2}$, and so

$$S^* = \mu + \alpha C_{d2} - (1 - \alpha)C_{p2} + \alpha C_{d1} - (1 - \alpha)C_{p1}$$

$$= \mu + \alpha C_d - (1 - \alpha)C_p.$$

This expression increases as α increases.

If $A > C_{p2}$, but $B < C_{p2}$, recall from the above that this implies $S_2 = p[A + \alpha C_{d2} - (1 - \alpha)C_{p2}]$, and so

$$S^* = p[A + \alpha C_{d2} - (1 - \alpha)C_{p2}] + \alpha C_{d1} - (1 - \alpha)C_{p1}.$$

Again, this expression increases as α increases.

If $A = B = \mu$, by Proposition 6, a lawsuit's option settlement value coincides with its divisibility settlement value, namely $\mu + \alpha C_d - (1 - \alpha)C_p$, an expression that increases as α increases.

Finally, the question of whether the effect of an increase in the plaintiff's bargaining strength on the option settlement value can be more than proportional is equivalent to asking if the elasticity of the option settlement value with respect to the plaintiff's bargaining strength is greater than one, or $(\partial S^*/\partial \alpha)(\alpha/S^*) > 1$.

Notice that if both $A > C_{p2}$ and $B > C_{p2}$ (or $A = B = \mu$), then

$$\partial S^*/\partial \alpha = C_d + C_p, \text{ so that}$$

$$(\partial S^*/\partial \alpha)(\alpha/S^*) = \alpha(C_d + C_p)/S^* = \alpha(C_d + C_p)/[\mu + \alpha C_d - (1 - \alpha)C_p]$$

$$(\partial S^*/\partial \alpha)(\alpha/S^*) > 1 \text{ if } C_p > \mu, \text{ i.e., the lawsuit is NEV.}$$

If $A > C_{p2}$, but $B < C_{p2}$, then

$$\partial S^*/\partial \alpha = p(C_{d2} + C_{p2}) + C_{d1} + C_{p1}, \text{ so that}$$

$$(\partial S^*/\partial \alpha)(\alpha/S^*) = \alpha[p(C_{d2} + C_{p2}) + C_{d1} + C_{p1}] / p[A + \alpha C_{d2} - (1 - \alpha)C_{p2}] +$$

$$\alpha C_{d1} - (1 - \alpha)C_{p1}$$

$$(\partial S^*/\partial \alpha)(\alpha/S^*) > 1 \text{ if } pC_{p2} + C_{p1} > pA.$$

But, as we assumed that $A > C_{p2}$, $pA > pC_{p2}$, so that $pC_{p2} + C_{p1} > pA$ can only hold if C_{p1} is sufficiently large.

PROPOSITION 14

If litigants have heterogeneous beliefs over variance of the judgment, even though they agree over an initial expected value of the judgment, then litigation may not settle immediately, but instead may settle mid-stream.

Proof:

Consider the following parameter values: $p = 1/2$, $C_{p1} = C_{d1} = 10$, $C_{p2} = C_{d2} = 80$, $\mu = 100$; then, $C_p = C_d = 90$. Suppose that a plaintiff believes that $A_p = 260$ (and so believes that $B_p = -60$), and a defendant believes that $A_d = 100$ (and so believes that $B_d = 100$). A plaintiff believes that $S_p^* = S_{p2} = 130$. A defendant believes that $S_d^* = S_{d2} = 100$. Because $S_p^* > S_d^*$, parties do not settle initially. But, a plaintiff initially believes that by spending $C_{p1} = 10$, it will be able to learn a court's announcement of $A = 260$ (and $B = -60$) and receive a settlement of $S_2 = 130$. Similarly, a defendant initially believes that by spending $C_{d1} = 10$, it will be able to learn a court's announcement of $A = 100$ (and $B = 100$) and have only to make a settlement of $S_2 = 100$. So, both parties initially proceed to spend $C_{p1} = C_{d1}$. Once a court announces its variance, both parties know it and proceed to settle for a corresponding value of S_2 . Ex post, one party is wrong and has spent $C_{p1} = C_{d1} = 10$ for naught, because that party ends up with an option settlement value which another party had expected. Ex post, one party is right and even after spending $C_{p1} = C_{d1} = 10$, that party is better off than it would have been had it agreed to settle initially for an option settlement value that another party had expected.